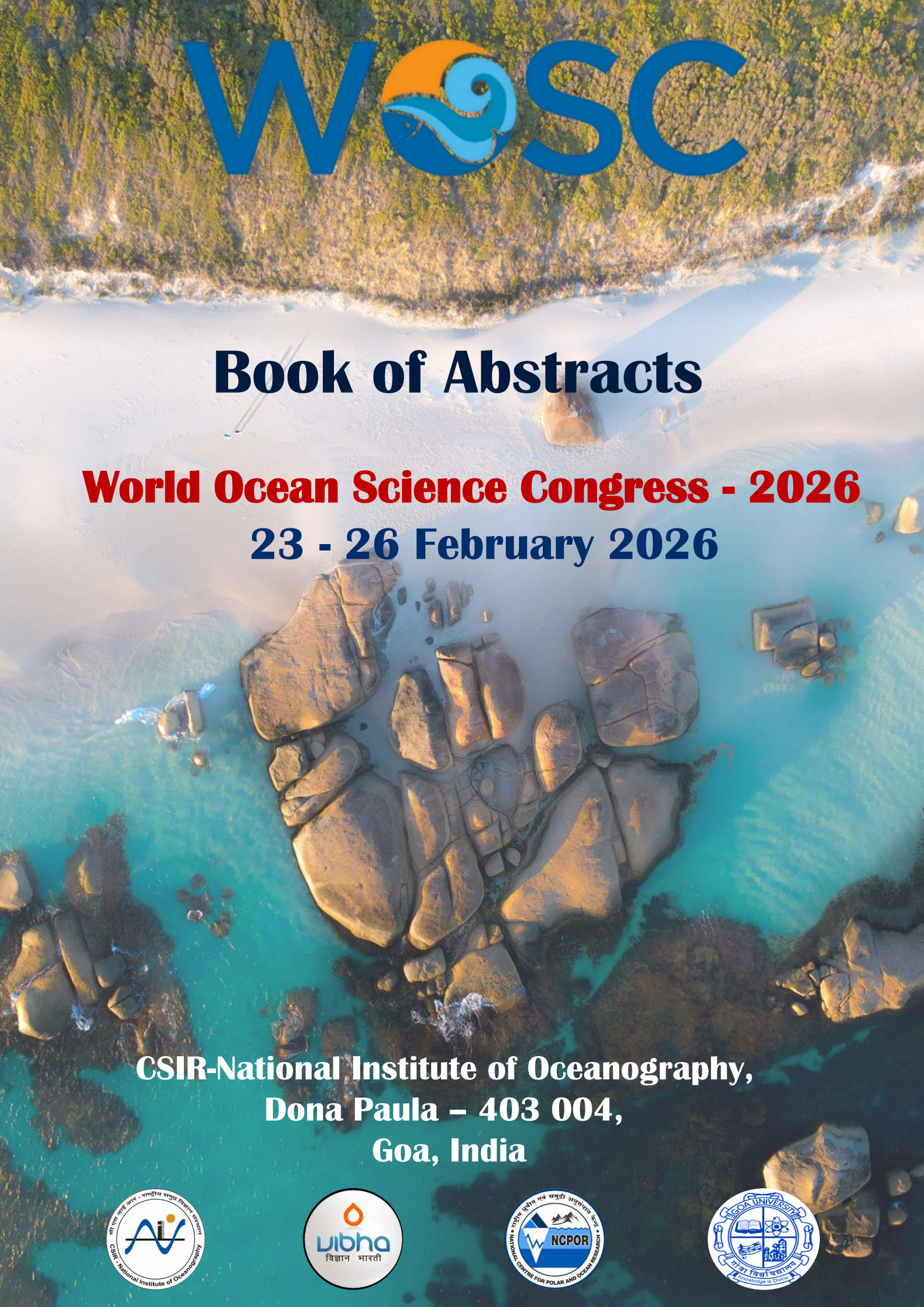

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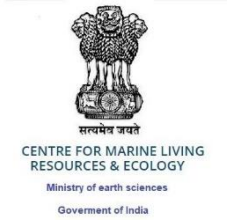
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Validation And Performance Analysis Of Ocm-3 Sensor For Chlorophyll-A Detection In Coastal And Offshore Waters Of Southwest Bay Of Bengal

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ABSTRACT

Accurate estimation of chlorophyll-*a* (Chl-*a*) is essential for monitoring phytoplankton biomass and marine ecosystem health. This study evaluates the performance of the Ocean Colour Monitor-3 (OCM-3) sensor in retrieving Chl-*a* concentrations in coastal and offshore waters of the southwest Bay of Bengal, using in-situ data collected between March and October 2023. Validation included regression analysis, Bland-altman plots, and statistical error metrics. The performance of OCM-3's OC4 algorithm was compared with global algorithms OC5 and OC6. In coastal waters, in-situ Chl-*a* ranged from 0.19 to 3.34 mg/m³, while OCM-3 estimates ranged from 0.50 to 2.88 mg/m³. Offshore values ranged from 0.43 to 1.12 mg/m³ (in-situ) and 0.41 to 0.70 mg/m³ (OCM-3). OCM-3 showed good correlation with in-situ measurements (R^2 = 0.62 coastal, 0.63 offshore), and lower RMSE (0.50 mg/m³ coastal, 0.18 mg/m³ offshore). OC5 and OC6 exhibited higher errors and under-/overestimation trends, particularly in offshore waters. OCM-3 demonstrated reliable performance for Chl-*a* retrieval, but coastal uncertainties highlight the need for region-specific algorithm tuning. Continued validation with expanded in-situ datasets is recommended to enhance accuracy for ecological monitoring in the Bay of Bengal.

Key words: Ocean color, OCM-3, Algorithms, Validation, Bay of Bengal

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Performance Evaluation Of Ocm-3 And Pace Chlorophyll-A In Southern Indian Coastal Waters

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ABSTRACT

Chlorophyll-a (Chl-a) is a primary photosynthetic pigment of oceanic phytoplankton, which plays a crucial role in determining the colour of seawater. Consequently, the estimation of Chl-a is a key indicator for monitoring phytoplankton biomass and the health of marine ecosystems. Effective monitoring of coastal environments requires a clear understanding of biophysical variability. This variability can be captured efficiently and at scale through daily high-resolution satellite observations. High-resolution multispectral data enable the detection of chemical, biological, and physical changes, making remote sensing a crucial tool for assessing marine ecosystem dynamics. This study evaluates the performance of two newly launched satellites, providing a comprehensive validation of Chl-a concentration derived from the Ocean Colour Monitor-3 (OCM-3, 2022) aboard ISRO's EOS-06 satellite and the Ocean Colour Instrument (OCI) aboard NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE, 2024) satellite. In situ Chl-a measurements collected from the southern Indian coastal waters during 3 to 11 November, 2025 on board CRV-Sagar Anveshika were used to validate and assess the accuracy of the satellite-derived chl-a data. OCM-3 exhibited a higher correlation with in situ observation (R^2 = 0.508, N=35) than PACE (R^2 = 0.075, N=35), although PACE-OCI showed a lower RMSE than OCM-3. The satellite-derived Chl-a comparison between the two sensors showed a log bias (0.49), indicating that OCM-3 tended to overestimate low Chl-a concentration, while PACE-OCI values were closer to in situ measurements in the region. This preliminary study assesses OCM-3 performance and highlights the need for a region-specific Chl-a algorithm for southern Indian waters. Future work will involve collecting additional in situ data to enable improved algorithm development and validation.

Keywords: Chlorophyll-a, Ocean health, OCM-3, PACE, validation

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Machine Learning-Based Approach For Estimation Of Chlorophyll-*A* In Bhitarkanika Estuary, India Using Satellite Data

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ABSTRACT

Estuaries are dynamic water bodies that are under continuous pressure from various anthropogenic activities. Thus, constant observation of these waters is essential. The chlorophyll-*a* (chl-*a*) is a critical biological indicator, emphasizing its monitoring in aquatic systems. In estuaries, remote retrieval of near-surface chl-*a* concentration is challenging due to substantial interferences from other constituents, particularly at concentration below 10 µg/L. In this study, a Machine Learning (ML) approach using the Extreme Gradient Boosting (XGB) algorithm was employed to develop an model for chl-*a* estimation based on Senitnel-2 MultiSpectral Instrument in the Bhitarkanika estuary, India. The in-situ chl-*a* concentration were measured within ±2 day of the satellite overpass. The Recursive Feature Elimination with Cross-Validation and Particle Swarm Optimization with Cross-Validation algorithms were used to identify the optimal subset of features and to tune the hyperparameters of the XGB model. The optimized XGB model was highly accurate on the training data (N = 120; R^2 = 0.96; RMSE = 0.29 µg/L) and generalized effectively to an independent validation dataset (N = 40; R^2 = 0.94; RMSE = 0.34 µg/L). The finding of this study highlights the remote estimation of chl-*a* using ML technique. It further provides an effective and robust approach for monitoring chl-*a* in data scarce and environmentally vulnerable regions.

Keywords: Chlorophyll-*a*, Sentinel-2, Extreme gradient boosting, Bhitarkanika.

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Climate-Driven Decline In Northern Indian Ocean Phytoplankton: Insights From Satellite Observations

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ABSTRACT

The Northern Indian Ocean has seen a significant decline in surface chlorophyll-a from 2000 to 2024, with the steepest drops in the Arabian Sea and Somali upwelling zones and moderate decline in the Bay of Bengal, indicating basin-wide weakening of phytoplankton productivity. Trend significance across 34–39% of pixels in major upwelling regions highlights strong spatial coherence and ecosystem sensitivity to environmental change. This decline is linked to weakened upwelling, reduced nutrient entrainment, and deepening thermocline structures that limit nutrient availability in the euphotic zone. Satellite observations reveal that co-occurring ENSO–IOD events exert the strongest and most predictable influence on chlorophyll variability, explaining up to ~80% of variance in the western basins through intensified nonlinear climate interactions affecting winds, thermocline gradients, and nutrient fluxes. In contrast, single-mode ENSO or IOD phases cause weaker, region-specific responses. These results demonstrate a shifting climate driver hierarchy with ENSO emerging as the dominant regulator of marine productivity, underscoring increasing ecosystem vulnerability under amplified coupled climate modes and emphasizing the need for sustained monitoring and improved predictive models for ecosystem and carbon-cycle impacts in a warming ocean.

Keywords: Northern Indian Ocean, chlorophyll-a decline, phytoplankton productivity, ENSO- IOD interaction, upwelling dynamics, nutrient entrainment, thermocline depth, climate variability, satellite observations, ecosystem sensitivity

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Simulation Of Spectral Bioluminescence Water Leaving Radiance In Milky Sea

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ABSTRACT

An improved Monte Carlo-based radiative transfer model for simulating spectral bioluminescence water-leaving radiance (BL_W) in milky sea events has been implemented in this work. A milky sea event off the coast of Java in 2019 is considered for analysis in this study. The model incorporates depth-wise Inherent Optical Properties (IOP) derived using bio-optical models based on chlorophyll depth profiles. Using Gaussian regression fitting, depth profiles of chlorophyll are calculated by using surface chlorophyll from MODIS Aqua sensor, enabling realistic stratification of the water column. Furthermore, multiple isotropic bioluminescent sources are distributed randomly within the water column based on the concentration of bioluminescent organisms. The spatial distribution of the bioluminescent organisms is estimated through a normalized weighted combination of Group for High Resolution Sea Surface Temperature (GHRSST) and MODIS Aqua sensor based chlorophyll data. Validation was conducted by comparing model-generated BL_W with VIIRS Day/Night Band (DNB) radiometrically and lunar-corrected nighttime imagery, assuming bioluminescent organisms as the sole light source. This comparison was achieved using a spectral response function that converts the model's spectral radiance output to broadband radiance. Statistical analysis reveals a correlation coefficient of 0.75, with RMSE of 0.089 and MAE of 0.071. Spatial error analysis of BL_W along latitudinal and longitudinal transects indicates the model captures major radiance variability patterns effectively. Further improvements can be achieved by incorporating vertical bioluminescent organism distribution models linked to chlorophyll depth profiles and underwater currents, along with validation using in-situ UAV-collected data. This framework provides a foundation for predicting bioluminescent events and understanding their optical signatures in coastal and oceanic waters.

Keywords: Bioluminescence, radiative transfer modelling, Monte Carlo, VIIRS DNB, inherent optical properties, milky sea phenomenon.

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Assessment Of Particulate Organic Carbon Dynamics Through Integration Of Multi-Sensor Satellite And In Situ Radiometer Datasets

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ABSTRACT

Particulate Organic Carbon (POC) is a key indicator of marine productivity and carbon cycling, facilitating carbon transfer from surface to deep waters and linking physical–biological processes that regulate global climate, making accurate detection crucial for effective ecosystem monitoring. Traditional field-based POC measurements are resource-intensive and spatially limited, while satellite remote sensing enables efficient large-scale observation. This study evaluates POC retrievals from OCM-3, MODIS-Aqua, and Sentinel-3B sensors using in situ and radiometer derived datasets, including 49 samples collected along Thoothukudi- Calicut transect (03–10 November 2024), to assess sensor performance using Stramski et al. (2008) algorithm and improve understanding of coastal biogeochemical dynamics. In situ Radiometer data were processed with Prosoft software to obtain remote-sensing reflectance (Rrs), while concurrent satellite Rrs of OCM-3, MODIS-Aqua, and Sentinel-3B were acquired from the Bhoonidhi and NASA Ocean Color portals. In situ POC ranged from 49.2-229.7 mg m^{-3}, while satellite retrieved values varied across sensors: OCM-3 (64.8-255.8 mg m^{-3}), MODIS-Aqua (69.0-232.9 mg m^{-3}), and Sentinel-3B (66.9–306.2 mg m^{-3}). Among sensors, Sentinel-3B showed slightly higher correlation ($r = 0.75$; $R^2 = 0.56$) than OCM-3 ($r = 0.72$; $R^2 = 0.52$), but OCM-3 achieved lower RMSE (32.98) and bias (4.25), indicating stronger agreement with in situ POC ($N = 33$). In situ POC validated against radiometer-retrieved POC ($N = 17$; $r = 0.62$; $R^2 = 0.38$) showed good correlation despite limited data, cloud cover, and rough sea conditions. OCM-3 further exhibited a stronger correlation ($R^2 = 0.52$; $N = 17$) with radiometer-retrieved POC, confirming its reliability. Elevated POC concentrations were linked to nutrient inputs from upwelling, river discharge, and runoff, underscoring the need to incorporate regional variability in POC estimation. Overall, OCM-3 exhibited superior accuracy for POC retrieval in southern Indian coastal waters, and supporting future development of region-specific algorithms to improve carbon cycle and ecosystem assessments.

Keywords: Particulate organic carbon (POC), Remote sensing reflectance (Rrs), Oceansat-3 (OCM-3), MODIS-Aqua, Sentinel-3B

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Contrasting Physical And Biogeochemical Controls In A Monsoon-Fed Estuary And The Nearshore Arabian Sea.

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ABSTRACT

Tropical estuaries influenced by the monsoon are highly dynamic systems. The Cochin estuary, one of the major estuaries along the west coast of India, was studied through three years of monthly observations (2023–2025) along a transect spanning the upper estuary (S1), the inlet (S2), and the nearshore open ocean at 10 m depth (S3). This sampling design allowed a clear comparison of estuarine, inlet, and coastal conditions and the dominant physical drivers shaping them. A time-series analysis for each station enabled direct comparison of interannual variability. Rainfall was markedly lower in 2023, resulting in reduced river discharge and distinct differences in hydrodynamic and biogeochemical responses. S1 and S2 were tide-dominated during the pre- monsoon and river-dominated during the monsoon. S1 remained vertically mixed during the pre- and post-monsoon seasons, whereas S2 showed partial stratification during the weak discharge monsoon of 2023. Chlorophyll concentrations were highest in 2023 across all stations, driven by reduced turbidity and greater light availability. At S3, production was influenced by both river input and wind-driven mixing. Although river discharge supplied nutrients to the surface, strong monsoonal stratification in 2024 and 2025 suppressed the mixing of nutrient-rich upwelled waters, reducing surface production and enhancing subsurface chlorophyll. Despite the presence of ambient nutrients, phytoplankton did not immediately flourish within the river plume, likely due to altered environmental conditions and the time required for community adjustment. Overall, turbidity and light availability controlled chlorophyll at S3, while residence time dominated the estuarine stations. Mixing regimes and stratification thus play a central role in regulating the physical and biogeochemical dynamics of this system.

Keywords: Residence time, Stratification, Biogeochemistry, Mixing regimes

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Testing Of OCM-3 Radiometry In A Coastal Lagoon Environment

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ABSTRACT

The performance of the recently launched Ocean Colour Monitor-3 (OCM-3) sensor onboard EOS-06 satellite is evaluated in a complex coastal lagoon environment, with a focus on both water quality retrieval and radiometric accuracy. We test OCM-3 radiometry over Chilika Lagoon (India) from November-2024 to April-2025, retrieving chlorophyll-*a* concentration (Chl-*a*), backscattering coefficient (b_b), colored detrital and dissolved organic matter (CDM) absorption (a_{dg}) and total suspended matter concentration (TSM). The third-generation OCM sensor, with 13 spectral bands, 2-day repitivity and a spatial resolution of 360 m, offers an advanced multi- spectral dataset capable of capturing fine-scale spatial and temporal variations, essential for studying the lagoon's bio-optical properties. Through radiative transfer modelling, forward simulation of remote sensing reflectance (Rrs) was performed using the known IOP combinations for generating a spectral look-up table (LUT) of simulated reflectance. The LUT based spectral matching approach was employed to invert remote Rrs spectra to water constituents. OCM-3 radiometric performance was evaluated by testing Rrs accuracy, spectral band sensitivity to water parameters, and atmospheric correction effectiveness. Preliminary results indicate that OCM-3-derived Rrs agrees with in situ measurements within ~15% error across the visible bands. Retrieved Chl-*a* concentrations ranged from 3 to 20 $mg \cdot m^{-3}$, with highest values in the lagoon's southern sector, consistent with past studies. TSM and a_{dg} exhibited distinct spatial patterns linked to river inflows and salinity gradients. These findings suggest that OCM-3's enhanced radiometric calibration and additional spectral bands provide reliable measurements in optically complex coastal waters. This study highlights OCM-3's potential for routine lagoon water quality monitoring and provides an early benchmark of its radiometric performance in turbid, productive waters.

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Convener: Prof Suneet Dwivedi

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ANN Model For Accurate Gap Filling In Time-Series Datasets: A Case Study On Satellite-Derived Chlorophyll-A Data

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ABSTRACT

Satellite-derived environmental data often suffer from significant data gaps, primarily due to factors such as cloud cover, sensor malfunctions, and other environmental interferences. These gaps hinder analysis, especially when applying spectral tools like Fast Fourier Transform (FFT) and wavelet analysis, which require continuous datasets. Even a single missing data point can render these methods ineffective. Traditional gap-filling techniques, such as linear, cubic, spline interpolation methods, often fail to provide accurate estimates of missing values, particularly in datasets with high spatial and temporal variability. In the present study, we use an Artificial Neural Network (ANN) approach to address the challenge of data gaps, using satellite- derived chlorophyll-a observations, as a case study. Results demonstrate that the ANN method provides a robust solution for data gap filling, making it a promising tool for filling gaps in any time-series data in general. The current 9-input-neuron ANN model demonstrates a remarkable ability to outperform traditional interpolation methods, especially in scenarios where the chlorophyll data exhibits significant variability. This capability highlights the model's effectiveness in capturing complex patterns within the dataset, offering a sophisticated solution to data gap challenges.

Keywords: ANN model, Data gap filling, Interpolation, Chlorophyll

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Ai-Flux: Leveraging Direct Flux Measurements

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ABSTRACT

Recent advances in machine learning offer new opportunities to enhance air–sea flux representations beyond traditional empirical and semi-empirical formulations. In this study, we develop an Artificial Intelligence–based turbulent flux parameterization framework (AI-Flux) for estimating latent heat, sensible heat, and wind stress. A comprehensive dataset of eddy covariance flux measurements from focused ship campaigns across the Bay of Bengal, Arabian Sea, tropical Pacific, and tropical Atlantic Oceans forms the basis for model development. These high-quality fluxes serve as targets, while a suite of meteorological and oceanic variables- including wind speed, humidity, air temperature, sea-surface temperature, stability indices, and radiative fluxes-constitutes the feature space.

The AI-Flux system employs an eXtreme Gradient Boosting (XGBoost) regression model, optimized through systematic hyperparameter tuning, to learn nonlinear and multi-regime relationships between surface forcing parameters and turbulent fluxes. This enables the model to capture variability and interactions that conventional bulk algorithms often miss.

Model performance is evaluated against widely used physical parameterizations, including various bulk flux schemes, using standard statistical metrics (R^2, RMSE, MAE, correlation). On in-sample data, the AI-Flux model markedly outperforms all physical formulations, yielding significantly lower errors and higher predictive skill. Under out-of-sample conditions-covering independent oceanic regimes and unseen ship-based observations-AI-Flux performs on par with the best physics-based parameterizations, demonstrating strong generalization capability.

Overall, AI-Flux provides a more accurate yet computationally lightweight alternative to existing bulk flux schemes, making it suitable for operational and high-resolution ocean–atmosphere modelling systems. This AI-augmented framework highlights the potential of machine learning to deliver next-generation parameterizations that improve the representation of air–sea interactions across diverse marine environments.

Keywords: Artificial Intelligence, Bluk Flux Algorithms, Air-Sea Interaction, XGBoost

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Low-Latency Long-Term Forecasts Of Significant Wave Height Across Different Depths Using Gru

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ABSTRACT

Wave data is crucial for offshore planning, navigation, and the construction of marine structures. Forecasting wave data effectively, especially significant wave height (Hs), becomes critical in early warning systems. Although Artificial Neural Networks (ANNs) demonstrate accuracy metrics comparable to traditional numerical models in predicting Hs, they produce time-lagged predictions relative to the actual values in most cases. In an operational setting, such unreliable forecasts can mislead decision-makers about the occurrence of extreme events.

The current approach uses downloaded wind and wave data ranging from 1985 to 2024. We present a data-driven approach that computes the relation between wind speed (W_S) and H_S along a cross-shore transect covering deep and intermediate water depths using the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis (ERA5) dataset. The variable that represents the relation between W_S and H_S is computed and fed to a Gated Recurrent Unit (GRU) model along with the wind direction (θ_W). The method is tested off Goa's coast at varying depths and exhibits high reliability, described by performance metrics like Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), goodness of fit (R^2), time-lag, Prediction Interval Normalised Average Width (PINAW), Prediction Interval Coverage Probability (PICP), and the Coverage Width-Based Criterion (CWC). The long-term forecasts generated using the present method have low latency, minimum time lag, and high accuracy. The method will be useful in developing early warning systems.

Keywords: Artificial Intelligence, GRU, Early Warning Systems, Significant Wave Height Forecasting, Operational Setting

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Deep Learning-Based Model For Tropical Cyclones Across The Arabian Sea: Comparative Skill Assessment Of Comparative Evaluation Of Pangu-Weather Model And Graphcast Model

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ABSTRACT

The increasing intensity of tropical cyclones poses a significant risk of widespread devastation. Recent advancements in AI-based weather forecasting models, have opened new avenues for improving cyclone prediction. This study evaluates the performance of the Pangu-Weather model and Graphcast Model in forecasting tropical cyclones namely Biparjoy and Nisarga over the Arabian Sea and Remal and Dana over Bay of Bengal. The model outputs were compared against reanalysis datasets and observational records to assess predictive skill. Preliminary results indicate that the both model exhibits good performance in predicting cyclone intensity, track, and associated synoptic fields. However, Graphcast show higher skill in terms of intensity and Pangu shows higher skill in terms of track, particularly for longer forecast. The predictive skill was found to vary depending on the cyclone's trajectory, intensity, and initialization time. The model demonstrated promising potential for forecast up to 72 hours with slight variations in forecast accuracy.

Keyword: Machine learning, Pangu-Weather model, Graphcast Model, Tropical cyclone, Arabian Sea, Bay of Bengal

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Modelling The Western Shore Of Bay Of Bengal During Severe Weather Conditions Using A Deep Learning Framework

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ABSTRACT

The North Indian Ocean exhibits strong monsoonal conditions, high seasonal variability and episodic extreme events such as tropical cyclones. These events strongly modulate the air-sea gas exchange and mixed-layer biogeochemistry in the region. In order to resolve nonlinear interactions across diurnal, seasonal and storm timescales, a deep learning framework such as Deep Operator Network (DeepONet) architecture has been used to learn the complex 3-D spatiotemporal ocean response using ocean observation datasets. DeepONet is made up of two deep neural networks: a branch net for input functions and a trunk net for output locations. It then combines their outputs to learn non-linear operators effectively mapping between different sets of functions. The current study focuses on the Chilika Lake mouth region in the western shore of Bay of Bengal. The model is developed to predict various state variables like temperature and air-sea fluxes. The initial results revealed that the cyclonic events fundamentally altered the sea surface conditions, manifesting as a distinct surface temperature drop, a considerable deepening of the mixed layer and variability in other parameters. This study demonstrates a novel framework blending real-time ocean observations with a physics-based machine learning model. Our current approach will most likely improve the prediction skill for cyclone-driven and seasonal mixed-layer processes in the North Indian Ocean.

Keywords: Tropical cyclones, Deep Operator Networks, mixed-layer biogeochemistry, air-sea gas exchange, non-linear operators

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Reconstructing Temperature Profiles From Surface Observations Using Machine Learning

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ABSTRACT

Understanding the subsurface temperature structure is crucial for various ocean applications, including climate studies, monitoring of marine ecosystems, and ocean state forecasts. However, direct in situ measurements are limited in space and time, especially in remote regions. This leads to gaps and uncertainties in the representation of the ocean state. In this work, a machine learning method is developed to estimate subsurface temperature profiles using Argo observations, along with satellite-derived surface variables, including Sea Surface Height (SSH), Sea Surface Temperature (SST), Surface Winds, and Surface Currents.

The model is trained using paired Argo profiles and surface satellite data, and by learning the relationship between surface features and the vertical temperature structure, the model can then reconstruct temperature profiles at all satellite grid points. The model's capability to infer subsurface states from surface information is also extended to forecasting. By testing the model using predicted surface inputs, our model generates corresponding subsurface temperature forecasts, providing forecasts of the ocean's interior. When validated against independent Argo data, the model's three-day forecast demonstrates competitive performance, achieving skill close to the GLORYS reanalysis and reliably capturing the key features of the subsurface thermal structure.

The reconstructed profiles serve as synthetic observations that can be incorporated into data assimilation techniques in ocean general circulation models during forecasts. Adding these synthetic profiles helps improve both surface and subsurface forecasts, especially in regions where observation coverage is low or highly variable. Improved subsurface fields produce more accurate forecasts by providing more realistic initial conditions for the operational models.

Keywords: subsurface temperature; machine learning; LightGBM; data assimilation

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Enhancing Significant Wave Height Predictions From Cmip6 Forcing Using Multiple Deep Learning Architectures In The Northern Indian Ocean

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ABSTRACT

Accurate prediction of significant wave height (SWH) in the Northern Indian Ocean (0°-30°N, 40°- 100°E) remains challenging due to strong spatial gradients, monsoon-driven variability, and rapidly evolving wind fields. Since ocean wave parameters are not directly available in Coupled Model Intercomparison Project Phase 6 (CMIP6) climate model outputs, this study uses both numerical modeling and deep-learning approaches to generate reliable wave fields for this region. Ten years of 3 hourly WAVEWATCH-III (WW3) simulations at 0.25° resolution (2005-2014), forced with CMIP6 wind fields, are used for training (8 years) and testing (2 years). The deep-learning framework uses zonal and meridional surface winds (u, v) and derived wind magnitude as predictors, with SWH (hs) as the target variable. Multiple architectures are used, including standalone CNN, LSTM, as well as hybrid spatiotemporal models such as CNN-LSTM, ConvLSTM2D, and CNN-BiGRU. Among all tested configurations, the CNN-BiGRU model provides the highest prediction skill, achieving a MAE of 0.1 m and a correlation of 0.97 for the 3h prediction. These results show that deep spatiotemporal learning is well suited for modeling wind-wave interactions in the Northern Indian Ocean and can serve as an efficient alternative to computationally expensive numerical simulations. The study demonstrates that deep-learning approaches can significantly enhance the accuracy and speed of wave-height prediction, supporting future applications in wave-climate analysis and coastal impact assessments.

Keywords: CNN, LSTM, CNN-LSTM, ConvLSTM2D, CNN-BiGRU, significant wave height, WAVEWATCH-III, CMIP6, deep learning, Northern Indian Ocean

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Understanding Ocean-Atmosphere Interaction To Controlling The Indian Summer Monsoon Rainfall Using Machine Learning And Explainable AI Techniques.

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ABSTRACT

Understanding ocean–atmosphere interactions and their influence on Indian summer monsoon rainfall remains a key challenge in climate diagnostics and prediction. This study develops an integrated machine learning (ML) and explainable AI (XAI) framework that uses large-scale oceanic and atmospheric predictors from NCEP reanalysis including SST, OLR, U850/V850 winds, specific humidity (Q850), vertical velocity (ω850), sea-level pressure, and moisture transport fields from the Bay of Bengal (BoB), Arabian Sea (AS), and equatorial Pacific to diagnose and predict monthly rainfall variability over 1948–2024. A lag-augmented predictor matrix was constructed, and two ML models (Random Forest, XGBoost) and a neural network (Multilayer Perceptron (MLP)) were trained and evaluated using an independent post-2000 test period. XGBoost showed the highest predictive skill (CC = 0.9795, RMSE = 0.7552, R^2 = 0.9374), followed by Random Forest (CC = 0.9772, RMSE = 0.8799, R^2 = 0.9150) and MLP (CC = 0.9427, RMSE = 1.0610, R^2 = 0.8764), indicating that nonlinear ML algorithms effectively capture multivariate ocean–atmosphere linkages governing monsoon rainfall. Explainable AI tools, such as SHAP, were used to interpret model behaviour and quantify variable importance. The contribution analysis reveals distinct oceanic controls across the three ML models. For the MLP, BoB (27.48%) and AS (57.71%) dominate, highlighting the strong role of regional moisture supply and monsoon circulation over the adjoining seas. Random Forest shows comparatively weaker but consistent influences from BoB (10.61%), AS (5.64%), and the Pacific (3.21%). XGBoost provides the most physically coherent attribution, with BoB (12.18%) and AS (14.63%) emerging as primary regional drivers, while Pacific SST anomalies contribute 6.22%, reflecting their broader-scale modulation of monsoon variability. The study shows that Arabian Sea and Bay of Bengal conditions directly control monsoon rainfall, while Pacific SSTs influence it indirectly through ENSO, and demonstrates that XGBoost with XAI provides both high predictive accuracy and clear physical insight for monsoon diagnostics and future rainfall prediction.

Keywords: Indian Summer Monsoon, Ocean-Atmosphere Interaction, NCEP, Machine Learning, Explainable AI

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Performance Assessment Of Ocean Reanalysis Systems In Simulating Temperature And Salinity Vertical Structure Over The North Indian Ocean: Need For Advanced Ocean Models

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ABSTRACT

Ocean reanalysis (ORA) systems greatly support the scientific community by producing temperature and salinity estimates in space-time-depth domains over the global and regional oceans. Performance assessment of ORA systems in the North Indian Ocean (NIO) is a research interest due to its intrinsic dynamic behavior resulting from monsoonal variability, Indian Ocean Dipole events, El Nino Southern Oscillation teleconnections, and riverine inputs. The present study evaluates the daily available ORA products, such as ORAS5 (from ECMWF), C- GLORSv7 (from CMCC), and GLORYS2v4 (from Mercator Ocean) against Argo temperature and salinity profiles at standard depth levels, ranging from the surface to 700 m during 2018- 2020. The correlation coefficients suggest that ORA products struggle to capture the variability of temperature and salinity in the Bay of Bengal (BoB) than the Arabian Sea (AS), with the values ~ 0.5 and ~ 0.9, respectively. The magnitude of temperature biases (BoB: RMSE ~ 1 °C, MBE ~ -0.1 °C; AS: RMSE ~ 0.8 °C, MBE ~ -0.05 °C) is comparatively larger in the upper thermocline (50 – 200 m). In contrast, salinity exhibits larger biases (BoB: RMSE ~ 0.4 PSU, MBE ~ +0.03 PSU; AS: RMSE ~ 0.15 PSU, MBE ~ -0.02 PSU) in the upper surface layers (0 - 100 m). The performance of ORA systems is relatively better over AS compared to BoB because of the complex freshwater influence and eddy-induced circulation in the BoB. We show that the limited availability of in situ data for data assimilation, inadequate constraining by governing equations, and poor realistic representation due to various approximations restrict the existing ORA products' ability to capture the dominant oceanic processes and their variability. This critical challenge seeks advanced alternative approaches that significantly reduce the margin of error in simulating the vertical structure of ocean temperature and salinity. The hybrid physics- informed machine learning is a promising state-of-the-art approach that leverages the advantages of both physics-based modeling and data-driven modeling, offering potential pathways to enhance reanalysis accuracy in dynamically complex regions, such as the NIO.

Keywords: Ocean modeling, Ocean reanalysis systems, Argo program, North Indian Ocean, Physics-informed machine learning.

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Smart Seas: An AI-Driven Framework For Predicting And Managing Ocean Deoxygenation And Harmful Algal Blooms

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ABSTRACT

Ocean deoxygenation and harmful algal blooms (HABs) pose a joint threat to the marine ecosystems and the blue economy, often amplifying ecological and socio-economic risks. This approach proposes Smart Seas, an explainable ensemble-based AI framework for forecasting co- occurring hypoxia and HAB events in an Indian ABIS hotspot. It leverages a GAN-synthesized HAB dataset and a curated oceanographic dataset, both developed and publicly released on Mendeley as part of this study, alongside key environmental parameters for robust risk modeling. A stacked ensemble of advanced ML models generates weekly forecasts aligned with coastal decision timelines. A GenAI-powered interpretational layer converts model outputs into human- readable recommendations, offering extensive interpretability beyond traditional SHAP-based methods. As a result, an interactive dashboard visualizes spatio-temporal risk maps, trend dynamics, and adaptive guidance. By cohering ensemble learning with generative explainability, Smart Seas delivers a transparent, operational AI framework to support science-driven coastal governance and a resilient blue economy.

Keywords: Ocean Deoxygenation, Harmful Algal Blooms (HABs), Blue Economy, Explainable Ensemble Learning, Forecasting

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Session Title: Next-gen oceanography: Emerging omics technologies and applications

Session Convener: Dr Sameer Damare

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3.	Effect of Trace Metal Enrichment on Bacterial Diversity and Composition in Waters of the Indian Ocean.
4.	Quantification of Coral Reef Biodiversity Through Passive Acoustic Monitoring and Unsupervised Learning Approaches
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Unraveling Marine Bioresource Complexity Through Proteomics And Metaproteomics

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ABSTRACT

The marine environment is a vast and largely untapped reservoir of biological and chemical diversity, offering considerable potential for bioprospecting in human health, biotechnology, and industrial innovation. Proteomics has become increasingly valuable in marine research because it captures the direct functional output of organisms, linking genotype to phenotype and revealing eco-physiological responses, adaptive mechanisms, and biosynthetic pathways underlying marine natural products and their modes of action. Globally, the Indian Ocean and Bay of Bengal region remain critically underrepresented in high-resolution molecular studies although it is characterized by strong nutrient gradients, dynamic environmental pressures, and exceptional microbial diversity. This region provides an important unexplored resource for understanding functional capabilities and discovering novel biomolecules.

In this study, we applied proteomics and metaproteomics to marine bacterial isolates and community samples collected from the Bay of Bengal and Indian Ocean region. The proteomic datasets were integrated with whole-genome sequencing, public protein repositories, and specific databases to construct a comprehensive functional landscape of marine microbial communities. Our analyses revealed a wide repertoire of proteins, including lipases, hydrolases, proteases, oxidoreductases, transporters, chaperones, and stress-response factors. Pathway-level enrichment indicated active participation in carbon and nitrogen cycling. Several proteins exhibited inherent stability under cold, saline, and high-pressure marine conditions, alongside predicted antimicrobial, catalytic, or bioprocessing-relevant properties.

In summary, these findings provide integrated proteomic and metaproteomic characterizations from the Bay of Bengal and Indian Ocean, addressing regional knowledge gaps. The study underlines the immense bioprospecting potential of these marine ecosystems and highlights promising functional proteins which need further validation.

Keywords: Marine Proteomics, Metaproteomics, Ocean, Bioprospecting, Indian Ocean

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Unravelling The Deep Sea Microbiome Using "Omics"

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Abstract

Life in Oceans has always intrigued humanity, and the quest to explore diversity is increasing. Over the last two and a half decades, new technologies in sequencing and mass spectrometry have emerged, targeting the understanding of life in the Oceans. Here, we discuss four major areas of omic research that are gaining popularity in understanding life in the Oceans. The identification of marine organisms has become more consistent with the help of nuclear and mitochondrial genome studies. The metagenome studies are still evolving and not yet being used widely. Advances in genomic tools and developments in oceanography have led to a deeper understanding of the relationship between marine life and its impact on the ecosystem. Metatranscriptomic analysis helps understand how the microbiome responds to its environment by studying the functional analysis of the genes expressed within it. Metatranscriptome can also help us estimate the taxonomic composition of the microbial population. With the advances in metatranscriptomics, it has become possible to evaluate the impact of changing climatic conditions on marine organisms. Proteomics is the third technique to analyse the functional genome of marine organisms. For the biological processes to be understood, genetic studies should be complemented with proteomics studies. The fourth of the omic technologies is metabolomics. This is the study of low molecular weight metabolites found in the cells. Metabolomics is different from other omic approaches as it responds to stressful and natural conditions. Unlike the genes, transcripts and proteins, the metabolites are compounds with diverse physicochemical properties. Hence, there is no single universal technique available that is capable of measuring all types of metabolites.

Keywords: eDNA, Genes, Illumina, Mass spectrometry, Next-generation sequencing

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Effect Of Trace Metal Enrichment On Bacterial Diversity And Composition In Waters Of The Indian Ocean.

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Abstract

Marine microbial communities play a pivotal role in ocean biogeochemistry, yet their responses to environmental gradients and anthropogenic perturbations, such as trace metal (TM) inputs, remain incompletely understood. In this study, we investigated bacterial community structure and diversity across four locations in the Indian Ocean, spanning coastal and open ocean regions, and assessed the impact of TM enrichment through microcosm experiments. Spatial variability in community composition was strongly influenced by environmental factors including temperature, salinity, nutrient availability, and dissolved oxygen. Bacterial richness was notably higher in the Northern Indian Ocean (NIO) than in the Southern Indian Ocean (SIO), reflecting contrasting nutrient regimes and terrestrial inputs. TM enrichment (10 nM and 100 nM) led to a decline in alpha diversity and a shift in community composition, favoring metal-tolerant and hydrocarbon-degrading taxa such as *Oleibacter*, *Thalassolituus*, and *Marinobacter*. These shifts were more pronounced at NIO sites, likely due to prior exposure to anthropogenic pollutants. Notably, TM addition reduced Cyanobacterial abundance in oligotrophic SIO waters, suggesting potential impacts on primary productivity. Furthermore, the enrichment of *Vibrio* spp. at coastal sites raises ecological and public health concerns. Overall, this study highlights how trace metal inputs, in conjunction with regional oceanographic variability, can substantially reshape marine microbial communities, with implications for ecosystem functioning and environmental management.

Keywords: Aerosol deposition, Indian Ocean, Bacterial Diversity, Trace Metals, Illumina Sequencing.

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Quantification Of Coral Reef Biodiversity Through Passive Acoustic Monitoring And Unsupervised Learning Approaches

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ABSTRACT

Coral reefs, often referred to as the “rain forests of the sea,” are among the most biologically diverse ecosystems on Earth, providing vital ecological benefits. However, their monitoring remains challenging due to limitations in surveying methods. Traditional approaches, which rely heavily on visual observation, are often invasive and constrained by diver accessibility and underwater visibility. Many new age marine robotics solutions are also time and resource-intensive, with limitations in mission duration and energy efficiency. In response to these challenges, our study employs Passive Acoustic Monitoring (PAM) as an alternative method for understanding reef-associated biodiversity and habitat conditions at Malvan, along the coast of Maharashtra. Acoustic signatures were captured using autonomous recorders equipped with hydrophones deployed at three shallow reef sites, two locations at ~ 5m and one location at ~10m . These autonomous recorders captured soundscapes of fixed duration at 15-minute intervals, enabling comparisons between acoustically rich and barren zones. The recorded audio signals were analyzed using Power Spectral Density (PSD) to examine the distribution of acoustic energy across two key frequency domains: a lower band (20–2000 Hz) representing fish sounds, and a higher band (2–20 kHz) dominated by the snapping shrimps sounds. These spectral attributes serve as acoustic indicators of biological presence and habitat complexity. To quantify ecological variations across the three diverse sites, five eco-acoustic indices were calculated: Sound Pressure Level (SPLrms), Acoustic Complexity Index (ACI), Acoustic Evenness Index (AEI), Acoustic Entropy (H), and Acoustic Richness (AR). Cooperatively, these indices provide a quantitative basis for comparing biological activity across different habitats. Unsupervised machine learning techniques were further applied to explore underlying patterns in the dataset. Principal Component Analysis (PCA) was used to reduce dimensionality and highlight major sources of variance, while K-means clustering, DBSCAN, and Hierarchical DBSCAN algorithms were employed to identify natural groupings based on the acoustic indices.

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Proteomic Exploration Of Marine Micro-Organisms For Biotechnological And Industrial Applications

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ABSTRACT

Protein primary sequences carry extensive information on biological function, origin, and degradation mechanisms, and unlike DNA, proteins are often preserved extracellularly in environmental matrices. Advancement in mass spectrometry has enable detection and characterization of proteins which occurs as low-abundant, salt-rich mixtures derived from diverse organisms in marine ecosystem. Hence, marine proteomics holds broad applications, including biodiversity assessment, environmental and pollution monitoring, microbiome and metaproteomic profiling, natural product discovery, aquaculture enhancement, and biotechnological or bioremediation interventions. Worldwide ocean studies has demonstrated these applications, however Bay of Bengal and Indian Ocean region is still less explored.

In this study, marine bacterial isolates collected from the Bay of Bengal and Indian Ocean region has been used for proteomics. The proteomic datasets were analysed with whole-genome sequences, public protein repositories, and specific databases to construct a comprehensive functional landscape of marine microbes and their probable utility. Our analyses revealed a wide repertoire of proteins, including hydrolases, oxidoreductases, transporters, stress-response factors and other industrial important enzymes. Pathway-level enrichment indicated active participation in carbon and nitrogen cycling, photosynthesis, bioremediation, organic matter consumption and nitrification. Several proteins exhibited inherent solvent tolerant, barophilic, halophilic alongside predicted antimicrobial and bioprocessing-relevant properties.

In summary, these findings provides marine bacterial proteomes of the Bay of Bengal and Indian Ocean region and delivers proteomic insights addressing knowledge gap. They also reveal substantial bioprospecting potential in these ecosystems which need to be further addressed.

Keywords: Marine Proteomics, Ocean, Bioprospecting, Indian Ocean, Bay of Bengal

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Exploring Flow Imaging Microscopy For The Detection Of Potential Invasive Phytoplankton Species Linked To Ship Hull Biofouling And Ballast Water Management

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ABSTRACT

Biofouling on ship hulls is considered as primary way for the spread of invasive aquatic species. Dry docking offers a unique opportunity to directly collect and analyse biofouling organisms without interference from seawater. In this study, biofouling samples were collected during the dry dock of ORV Sagar Nidhi at Mumbai port on Oct 2025, to assess phytoplankton species with invasive potential with flow imaging microscopy (FIM; FlowCam 8400). Location, type of fouling, and coverage percentage were documented. Microalgal biofilm community were analysed using both FIM and traditional microscopy. FIM enables accurate and efficient cell counting, identification, and morphological documentation. During the present study, 22 phytoplankton species, including Bacillariophyta (14 Nos.), Chlorophyta (4 Nos.), Pyrrophyta (2 Nos.), and Ochrophyta (2 Nos.) were recorded. FIM results demonstrated higher-quality data for assessing turbid biofouling samples compared to microscopy, because each particle was separated and passed through the flow cell with rapid and high-throughput imaging. *Pseudo- nitzschia sp.*, *Navicula sp.*, *Pleurosigma sp.*, *Melosira sp.*, and *Guinardia flacidae* were found to be prevalent at most of the sampling locations. While calculating total phytoplankton abundance, a positive correlation ($r = 0.72$, $p < 0.05$) was found between FIM and microscopy, indicating FIM's dependability for routine measurement. The automated image recognition feature provided consistent cell counts comparable to microscopy, while also documenting morphological variability. Interestingly, the fouling was not uniform. The lack of antifouling coating in patches where the pillars to hold ships during drydock was the primary cause of the patch fouling. Additionally, this study will help to develop efficient biofouling control solutions for sustainable shipping, improve compliance with international laws, and provide insights to the invasive risks related to ship biofouling.

Keywords: Flow Imaging Microscopy, Biofouling, Invasive Species, Pennate Diatoms, *Pseudo- nitzschia sp.*

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Seasonal Shifts Restructure The Marine Viral Community In The Eastern Arabian Sea.

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ABSTRACT

Marine viruses represent the most abundant and genetically diverse biological entities in the ocean, but their diversity and ecological role in the dynamic Eastern Arabian Sea (EAS) remain poorly explored. This study provides the first baseline virome dataset for the EAS by using metagenomic profiling of surface seawater samples collected from coastal and offshore stations, across the pre-monsoon, monsoon, and post-monsoon seasons. The viral DNA libraries from the samples collected were sequenced using Illumina NovaSeq 6000
The intense Southwest Monsoon, characterised by wind-driven upwelling and nutrient enrichment, stimulate the proliferation of fast-growing heterotrophic bacteria and favoured broad-range lytic phage families. The Autographiviridae—predominantly cyanophages infecting Synechococcus and Prochlorococcus declined sharply during the monsoon, reflecting the reduced cyanobacterial abundance. Their moderate recovery during the pre- and post-monsoon periods corresponds to transitional phases when stratification re-establishes and enabling cyanobacterial resurgence. Monsoon samples also showed elevated contributions from giant virus families such as Mimiviridae, which infect diverse eukaryotic phytoplankton, and Phycodnaviridae, key regulators of algal population dynamics. Additionally, the detection of Lavidaviridae (virophages), which replicate only in the presence of coinfecting Mimiviridae, highlights the complexity of host–virus interactions in these waters. Overall, our findings demonstrate that monsoonal forcing acts as a major ecological driver shaping viral diversity and host–virus dynamics in the Eastern Arabian Sea. We demonstrate that the Southwest Monsoon exerts a strong influence on viral community composition.

Keywords: Marine Virus, Eastern Arabian Sea, Metagenomic Profiling, Southwest Monsoon

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HSP90 Gene Expression As A Potential Biomarker Of Environmental Stress Among Intertidal Barnacles

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ABSTRACT

The intertidal zone represents one of the most dynamic marine habitats, characterised by periodic emersion and immersion, fluctuating salinity, temperature, and light exposure, as well as increasing anthropogenic pressure. These stressors collectively shape the biodiversity, distribution, and physiological adaptation of resident species on diurnal to seasonal scales. InSilico transcriptomics suggest the expression of HSP70, HSP90, CYP450, etc, is pivotal to the adaptation of sessile invertebrates, including barnacles. Acorn barnacles, being sessile and ectothermic crustaceans, are ideal ecological indicators for monitoring the changes in the environment. Their capacity to modulate body temperature and express molecular chaperones such as Heat Shock Protein 90 (HSP90) provides insight into how intertidal organisms cope with thermal and desiccation stress in a fast changing environment. In this study, we examined expression of HSP90 gene in the intertidal barnacles under both controlled laboratory conditions and natural tidal cycles to evaluate its role as a molecular marker of stress. The results revealed significant variation in HSP90 expression between submerged (control) and aerially exposed (treated) conditions, indicating a rapid molecular response to environmental fluctuations. These findings underscore the potential of HSP90 as a sensitive biomarker of environmental and tide-driven stress in the intertidal systems. Further investigations across multi-stressor scenarios will enhance our understanding of adaptive resilience in the organisms inhabiting the coastal ecosystems.

Keywords: Climate change, Intertidal Habitat, Molecular ecology, HSP90 gene expression, stress adaptation

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Decoding The Functional Genomics Of Jellyfish Assemblages Through Shotgun Metagenomic Profiling During A *Pelagia Noctiluca* (Forsskål, 1775) Swarm In The Bay Of Bengal, Indian Ocean

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ABSTRACT

Jellyfish are integral components of marine food webs, influencing nutrient fluxes and trophic interactions; however, their proliferations often trigger ecological and economic disturbances. Despite their ecological prominence, the functional potential and genomic signatures of jellyfish assemblages remain largely unexplored in the Indian Ocean. The present study aims to bridge this gap by investigating the functional landscape of jellyfish diversity during a *Pelagia noctiluca* swarm in the northeastern Bay of Bengal using shotgun metagenomic profiling. Zooplankton samples collected off Visakhapatnam in June 2024 were subjected to metagenomic sequencing on the Illumina HiSeq 4000 platform, followed by taxonomic classification using Kraken2. A total of 1.42 million classified reads were obtained, representing twelve zooplankton phyla, among which *Cnidaria* dominated (84% relative abundance, log-transformed). From Phyla *Cnidaria* and *Ctenophora*, 410,485 jellyfish-associated reads corresponding to 58 species were extracted and assembled into 899 contigs using MEGAHIT. Gene prediction with AUGUSTUS, identified 68 protein-coding genes, of which 64 seed orthologs and **52** functionally annotated proteins (76%) were obtained through eggNOG-mapper. Functional categorization revealed gene associations with amino acid metabolism, transcription, and DNA replication, while a substantial proportion (COG category S) comprised uncharacterized proteins, suggesting potential lineage-specific novel genes in jellyfish. GO and KEGG analyses highlighted pathways linked to energy metabolism, amino acid biosynthesis, signal transduction, oxidative stress response, and detoxification. Pfam and CAZy domain analyses identified RVT_1, DDE_Tnp_4, serine protease-like domains, and glycosyltransferase GT4, indicating active roles in cellular maintenance, environmental adaptation, and organic matter transformation. The present study demonstrates that jellyfish metagenomes encode diverse metabolic and regulatory capabilities, highlighting their biochemical adaptability and ecological significance during swarm events in the Bay of Bengal, Indian Ocean.

Keywords: Functional Annotation, Gene Ontology, Marine genomics, Orthology-Based Classification, Zooplankton.

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Powering Through The Tide: Mitochondrial Oxphos Genes And Environmental Adaptation

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ABSTRACT

The mitochondrial genome, with its conserved structure and maternal inheritance, serves as a powerful tool for exploring evolutionary and ecological adaptations. The Oxidative Phosphorylation (OxPhos) system is the primary engine for cellular energy (ATP) production. It is uniquely constructed from proteins encoded by both nuclear DNA and 13 essential protein- coding genes (PCGs) found in the mitochondrial DNA (mtDNA). This study investigates the mitochondrial DNA of intertidal organisms, focusing on the 13 protein-coding genes of the oxidative phosphorylation (OxPhos) system. Intertidal zones present a uniquely dynamic environment. Organisms here endure fluctuating salinity, temperature extremes, hypoxia, desiccation, and UV exposure due to tidal cycles. These stressors exert selective pressure on cellular energy metabolism, making OxPhos proteins prime candidates for studying molecular responses to environmental variability.

For this *in silico* study, complete mitochondrial genomes of diverse intertidal invertebrates were shortlisted and retrieved from the NCBI database. We analyze sequence divergence, phylogenetic relationships, and potential adaptive signals across intertidal species using comparative genomics and protein-level metrics. This approach allows us to correlate sequence- level changes with known protein functions. By integrating phylogenetic analysis with ecological context, this study highlights how mitochondrial genomes encode adaptive strategies to cope with environmental instability. The conserved yet responsive nature of mtDNA allows us to trace evolutionary trajectories and infer habitat-driven selection. Our findings underscore the role of OxPhos genes not only in energy production but also in mitigating environmental impact, offering insights into how intertidal organisms optimize mitochondrial function for survival in one of Earth's most challenging habitats.

Keywords: OxPhos, mtDNA, PCGs, intertidal stressors, *in-silico*

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Whole-Genome Metagenomics Of Intertidal Microbiomes: Mapping Function, Resilience, And Industrial Promise

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ABSTRACT

Intertidal coastal ecosystems are dynamic interfaces where marine and terrestrial processes converge, acting as both sinks and sources of anthropogenic inputs. The microbial communities inhabiting these environments form vital ecological buffers, driving nutrient cycling, organic matter degradation, and pollutant transformation, yet their functional and genomic potential remains underexplored in tropical coastal waters. This study presents a whole genome metagenomic investigation of seaweed-associated intertidal seawater microbiomes across six ecologically distinct sites spanning Goa. Building upon our earlier targeted amplicon-based study, which identified seawater as the most taxonomically diverse substrate among seaweed-associated habitats, we expand both the spatial and microbial scope to encompass bacteria, archaea, viruses, and eukaryotes. Sequencing was conducted using Nanopore platform, enabling high-resolution insights into microbial composition, functional diversity, and environmental correlations. By integrating taxonomic and functional profiling, this work aims to uncover the structural and functional landscape of intertidal microbiomes under varying environmental stressors. Particular emphasis is placed on identifying functional pathways linked to organic matter transformation, pollutant remediation, and the presence of antibiotic resistance genes, underscoring their implications for ecosystem and public health. Beyond ecological insight, the study highlights the industrial potential of these microbiomes through novel enzymes and pathways involved in polysaccharide degradation, hydrocarbon and xenobiotic metabolism, biomass volarisation. This holds promise for applications spanning bioremediation, biofuel production, pharmaceuticals, and sustainable bioprocessing, aligning with the growing demand for blue biotechnology innovations. This integrative approach highlights intertidal microbiomes as sentinels of coastal ecosystem resilience and reservoirs of industrially relevant resources, providing critical genomic perspectives for monitoring, restoration, and sustainable management of coastal environments of India under intensifying anthropogenic influence.

Keywords: Intertidal, Microbiome, Seaweed, Ecosystem health, Antimicrobial resistance, Nanopore

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Unprecedented Chlorophyll Bloom In The Southeastern Indian Ocean During 2023.

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ABSTRACT

As part of the Polymetallic Sulphide (PMS) exploration programme, it is essential to undertake baseline environmental assessments within the contract area. In this context, the present study examines long-term variability in ocean productivity in the Southern Indian Ocean using satellite-derived observations. Satellite ocean colour data reveal an unprecedented chlorophyll bloom in the southeastern Indian Ocean (SEIO) during the austral spring (September–November) of 2023, with surface chlorophyll concentrations reaching up to 0.78 mg m^{-3}, the highest recorded in the past two decades. The SEIO, particularly the region between 90°E and 110°E and 0° and 10°S, is highly sensitive to Indian Ocean Dipole (IOD) events due to their influence on ocean–atmosphere interactions that modulate nutrient supply and phytoplankton productivity. During the strong positive IOD of 2023, chlorophyll concentrations were ~13% higher than in 2019 (0.6 mg m^{-3}), previously considered the strongest positive IOD year, and around 75% above the climatological mean. Although large-scale atmospheric and surface ocean indicators such as wind anomalies, Walker circulation changes, and sea surface temperature patterns were comparable between 2019 and 2023, the subsurface thermocline structure showed marked differences. In 2023, weaker stratification and enhanced upwelling led to higher phytoplankton biomass, despite relatively warmer surface conditions. A cold-core mesoscale eddy embedded within the upwelling region further shoaled the thermocline, facilitating anomalously high vertical nutrient flux into the euphotic zone. This combination of atmospheric forcing, subsurface thermocline modulation, and mesoscale eddy activity collectively sustained the unusually intense chlorophyll bloom. The findings highlight the critical role of subsurface ocean dynamics in regulating interannual variability in biological productivity during IOD events, with important implications for environmental assessments in the PMS exploration region.

Keywords: Chlorophyll, Indian Ocean Dipole, Thermocline, Southeastern India Ocean, Mesoscale eddy, Upwelling.

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Resolving Submesoscale Oceanographic Features With Glider Observations In The Southern Ocean

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ABSTRACT

In a collaborative effort, National Centre for Polar and Ocean Research (NCPOR) and Indian National Centre for Information Service (INCOIS) deployed a Slocum G3 Glider in Southern ocean during the 44th Indian Scientific Expedition to Antarctica (February - April 2025). Deployment and recovery of the glider were carried out from the Antarctic logistics cargo vessel Vasiliy Golovnin. The glider surveyed approximately 1300 km of the Southern Ocean (25E- IOE, 63S- 65S), sampling the upper 1000m of the water column. The glider was equipped with temperature, conductivity, pressure, PAR, fluorescence, turbidity, dissolved oxygen and backscatter sensors. Even though the glider was not equipped with a thruster, which is typically recommended for southern ocean missions, the glider could traverse ocean eddies, fronts, and high sea states during storms. Observations revealed submesoscale hydrographic structures in the eastern Weddell Gyre and across the Southern Boundary front. The presence of winter water as a subsurface cold layer was detected throughout the track. The observed submesoscale features were closely associated with freshwater layers formed by meltwater input. These results highlight the capability of autonomous gliders to resolve fine-scale processes in extreme polar environments, offering new insights into Southern Ocean dynamics and strengthening future observing strategies.

Keywords: Glider; Southern Ocean; Submesoscale features; Winter water

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Atmospheric Macro And Micro Nutrient Supply To The North Indian Ocean: Sources And Seasonal Variability.

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ABSTRACT

The North Indian Ocean (NIO), mainly constituted of two basins - the Bay of Bengal and Arabian Sea, is vulnerable to the nutrient/toxicant deposition coming via atmospheric pathway from surrounding continental emissions. Several studies have documented on large scale continental outflow (natural and anthropogenic aerosols as well as pollutants e.g. trace gases, acidic species, trace metals) from surrounding arid/semi-arid region, densely populated Indo-Gangetic Plain and South East Asian region. This outflow consists of processed aerosols which are potential supplier of macro and micro nutrients to surface water of both basins and have potential to modulate various biogeochemical processes within the NIO. We measured macro (inorganic nitrogen) and micro (soluble and total trace elements) nutrients along with aeolian dust concentration in aerosols collected over a wide area of the Arabian Sea and Bay of Bengal. Aerosols were collected on-board cruise campaigns during 2015-2020 in different seasons with varying wind patterns. In general, higher trace metal solubility is observed over the Bay of Bengal in contrast to the Arabian Sea, particularly during summer and winter months. However, comparative values were seen during the post-monsoon season. Relatively higher deposition flux was seen for inorganic nitrogen (sum of ammonium and nitrates) in both basins in contrast to those reported from other oceanic basins. Higher nutrient flux was found to associated with the continental outflow which were dominant during the northeast monsoon. These data will provide input to the global biogeochemical models to constrain supply of micronutrients to surface water of the North Indian Ocean. In this talk, I will present new results derived from the NIO.

Keywords: Aerosols, nutrients, trace element, Arabian Sea, Bay of Bengal

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ADCP Derived Backscatter As A Zooplankton Proxy

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ABSTRACT

This study demonstrates the potential of acoustic Doppler current profiler (ADCP) backscatter measurements for generating continuous, high-resolution time series of zooplankton biomass. Data were acquired from ADCP moorings strategically deployed at seven continental slope locations in the eastern Arabian Sea (EAS), off the west coast of India, compiling a robust data set spanning October 2017 to December 2023. The methodology involves the conversion of raw ADCP backscatter signals into zooplankton biomass in two major steps. First, we obtain the backscatter from echo intensity. Second, we convert the backscatter to biomass using a regression relationship between ADCP-derived backscatter and volumetric zooplankton samples collected via net hauls near the mooring sites. This sampling was conducted at all mooring locations over several years during each ADCP servicing cruise. Analysis of data across depths ranging from 24 to 140 m consistently indicated a decline in both backscatter intensity and zooplankton biomass with increasing depth, but the rate of decrease varies along the slope.

A key finding from these ADCP data is the pronounced intraseasonal variability (periods of 30– 90 days) in zooplankton biomass; the variability in this period band is particularly evident during August-November though only for a few years. The range of this high-frequency variability is comparable to, often exceeding, that of the seasonal cycle of the zooplankton biomass and standing stock. Interannual variations are observed with higher intensity in southern EAS. Neither the rapid shifts, nor the longer year-to-year variations can be effectively determined by traditional, intermittent sampling methods. This methodology marks a significant advance for environmental monitoring and assessment, offering insights into marine ecosystem dynamics and as a potent tool for remote sensing primary consumers.

Just as satellite chl-*a* measurements have changed the way we study phytoplankton dynamics, acoustics can change the way we study zooplankton dynamics.

Key words: ADCP, zooplankton, backscatter, Arabian sea, biomass and standing stock

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Decision And Information System For The Coastal Waters Of Oman (DISCO) An Integrative Tool For Managing Coastal Resources Under Changing Climate

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ABSTRACT

The Arabian Sea is one of the fastest changing tropical ecosystems on our planet that has suffered a substantial loss of plankton biodiversity due to the rise of the green *Noctiluca* blooms and their range expansion caused by Eurasian warming, the spread of hypoxia and ocean acidification. *Noctiluca* is a mixoplankton and is able to outcompete other planktonic organisms in a rapidly changing environment. *Noctiluca* is not a preferred food for zooplankton, but instead competes with zooplankton for food. Its emergence therefore, as the dominant bloom forming organism is upending the food web and a fisheries-rich ecosystem that is of great economic and cultural significance in the region. This presentation will provide results from laboratory, field and remote sensing data that are shedding new light on drivers of these seasonal blooms, their range expansion and the threats these blooms pose to regional food, water and national security. We will also show how new knowledge that we are acquiring about green *Noctiluca* is being used for:
1) developing new algorithms for detection of this organism from space, 2) building new ecosystem modeling capabilities and 3) developing of decision support tools for mitigating large socio-economic losses being caused by these blooms.

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Evaluating Surface Current Products In The Southern Indian Ocean: A Comparison Of OSCAR, ORAS5 And GODAS With Drifter-Derived Currents

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ABSTRACT

Understanding surface currents in the southern Indian Ocean (SIO) is a critical requirement of the Polymetallic Sulphide (PMS) exploration Program. To evaluate the regional circulation, we used multiple datasets, including satellite-derived Ocean Surface Current Analysis Real- time (OSCAR) surface currents, reanalysis products from Ocean Reanalysis System 5 (ORAS5) and Global Ocean Data Assimilation System (GODAS), and a newly developed monthly 2.5° × 2.5° gridded current product derived from Global Drifter Program (GDP) observations provided by NOAA-Atlantic Oceanographic and Meteorological Laboratory (AOML). A major challenge in the SIO is the scarcity of in situ observations, which limits the validation of ocean current products in this region. Comparison with the drifter-derived dataset reveals that OSCAR currents perform well within the tropical Indian Ocean, capturing major current features with a high correlation (~0.9). However, their performance declines substantially south of 20°S. ORAS5, a hybrid product combining numerical models and observational constraints, achieves high correlations (~0.8) in the tropics but fails to adequately represent surface currents in the SIO. GODAS exhibits slightly better skill than ORAS5 in some regions but also struggles to capture current variability south of 20°S, further constrained by its coarse spatial resolution. Overall, none of the commonly used products, OSCAR, ORAS5, or GODAS, reliably reproduces surface circulation patterns in the SIO below 20°S. The results underline the need for more comprehensive in situ measurements to refine existing representations in this sparsely observed region.

Keywords: Ocean Currents, Regional Circulation, Polymetallic Sulphide, OSCAR currents, ORAS5, GODAS, Global Drifter Progra

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Multiscale Coastal Circulation Variability Along The Indian Subcontinent: Insights From The Hf Radar Network

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ABSTRACT

Understanding the coastal ocean around the Indian subcontinent is crucial for various applications, including tide monitoring, ecosystem management, navigation, port operations, oil- spill response, fisheries, sediment transport, coastal erosion, and cyclone forecasting. Previous studies relying on altimetry, reanalysis, and coarse-resolution (>25 km) numerical models have largely focused on basin-scale variability, offering limited insight into nearshore circulation. Since 2009, the Indian Coastal Ocean Radar Network (ICORN) has provided continuous High- Frequency (HF) Radar measurements of surface currents at ~6 km spatial and hourly temporal resolutions across the western Bay of Bengal (BoB), western Andaman Sea, Gulf of Khambhat, and northeastern Arabian Sea. This study presents one of the first systematic utilizations of these datasets to examine the coastal ocean circulation and variability at multiple scales.

The results reveal strong seasonality and reversibility of coastal currents along the western BoB, with northward flow during February–April and southward-flowing East India Coastal Current during November–December. Surface current speeds also exhibit clear modulations during positive and negative phases of IOD and ENSO events. Mesoscale and sub-mesoscale dynamics are investigated, including a cyclonic eddy generated by baroclinic instability and intensified through barotropic processes, and lee eddies near the Andaman Islands governed by local winds and vortex stretching. Tidal analyses show dominant M2 tidal currents along the coast, with strong nonlinear distortions and flood asymmetry in the GoKh, where tides account for ~90% of current variance. In contrast, tides contribute only 10–30% of variance along the western BoB. Enhanced M2 amplitudes during the post-monsoon are linked to increased stratification. These findings highlight the need for HF Radar surface currents to resolve fine-scale coastal processes and underscore the need for integrated observations and high-resolution coastal models for improved ocean state forecasting.

Keywords: Northern Indian Ocean, HF Radar, Coastal Currents, Ocean Eddy, Tidal Currents

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Praise: A Sea Ice Observatory For Understanding Air- Ice-Sea Interaction In Prydzbay, East Antarctica

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ABSTRACT

Sea ice cover in Antarctica plays a crucial role in the global climate system by regulating the exchange of heat, freshwater, and momentum between the ocean and the atmosphere. Despite its significance, a detailed understanding of the coupled sea–ice–atmosphere system remains limited due to the sparse and logistically challenging nature of observations in Polar Regions. To bridge this gap, a sea ice observatory consisting of ice-tethered oceanographic mooring system and thermistor chain have proven invaluable for continuously capturing high-resolution measurements of the surface energy balance, the temporal evolution of sea ice and monitor water column properties. Our research, which focuses on the thermal evolution of sea ice prior to breakup, reveals important seasonal dynamics, particularly in Prydzbay, East Antarctica, where available datasets are generally sparse. During winter months, we observed rapid sea- ice growth at approximately 0.32 cm/day under relatively thin snow cover ranging from 10 to 20 cm. This rapid growth is due to the limited insulation provided by snow, which allows for efficient conductive heat loss from the ocean through the ice to the cold atmosphere. Conversely, in spring, growth rates slow to between 0.13 and 0.20 cm/day, concurrent with increasing snow depths reaching up to 54 cm. A pronounced ablation phase commenced in December, resulting in net ice thinning of −8 cm, which coincided with rising air temperatures and a decrease in snow cover. The most rapid deterioration occurred in January, with an observed ice loss of −25.66 cm (−0.83 cm/day). Melted snow percolating into the ice forms a denser snow-ice layer, which further insulates the underlying ice and restricts gas exchange. This alteration in the surface energy balance, caused by the formation of the snow-ice layer, increases the likelihood of surface melt-pond formation.

Keywords: Mooring; Thermistor chain; Air-Ice-Sea interaction; Prydz Bay; Antarctica

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Variability Of Frontal Systems And Zonal Geostrophic Velocity Across 48°E & 57.5°E Meridional Transects In The Indian Sector Of Southern Ocean

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ABSTRACT

In situ hydrographic observations were carried out in the Indian sectors of the Southern Ocean along the two meridional transects (48°E and 57.5°E) during the austral summer of 2009 to investigate the variability of frontal systems and geostrophic currents. The frontal region exhibits strong southward vertical gradients in temperature and salinity isolines from the surface down to 1000 m between station pairs. The major fronts-Agulhas Return Front (ARF), Subtropical Fronts (STF), Subantarctic Fronts (SAF) and the Polar Fronts (PF) were clearly identified along both transects. Along 48°E, the Northern STF (34°-35°S), ARF (39°-40°S), Southern STF (41°-42°S), SAF1 (42°-43°S), SAF2 (43°-44°S) occur north of Crozet Island. South of Crozet Island, the PF is observed on either side of the Conrad (Ob-Lena) Rise, spanning 49°-50°S (PF1) and 55°-56°S (PF2). Along 57.5°E, the Northern STF is displaced northward (33.5°-34.5°S) relative to its position at 48°E, while the ARF (40°-41°S) and Southern STF (43°-44°S) remain distinct. SAF1 (45°-46°S) is separated from the Southern STF by ~1°, and SAF2 occures at 47°- 48°S. PF1 and PF2 are positioned farther south, between 51°-52°S and 59°-60°S, respectively. A clear meridional shift of ~2°–3° toward the south is observed in the southern STF, SAF, and PF when comparing 48°E and 57.5°E transects, along with an increased separation between PF1 and PF2. This southward displacement is attributed to the influence prominent topographic features of the Southwest Indian Ridge. Additionally, a cyclonic cold-core eddy was identified along 48°E between 37°S and 39°S within the isoline structure, consistent with features expected near the ridge system. Geostrophic relative zonal velocity calculations along 48°E further confirm the presence of this cyclonic cold-core eddy.

Keywords: Hydrographic parameters, Fronts, Watermass, Circulation, Geostrophic velocity.

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Chemical Composition Of Aerosols Over The Arabian Sea During The Southwest Monsoon.

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ABSTRACT

Atmospheric aerosols play a significant role in modulating the Earth's climate, influencing atmospheric chemistry, and affecting nutrient deposition, which in turn impacts ocean biogeochemistry. The Arabian Sea, the western part of the North Indian Ocean, receives aeolian dust and anthropogenic aerosols derived from surrounding continental locations and also experiences a reversal of monsoon annually, which causes large variability in the abundance and composition of ambient aerosols. In this context, this present study measured the inorganic chemical composition of atmospheric aerosols and their distribution over the Arabian Sea during the southwest monsoon (SWM) campaign in August 2025 (SSD-094). The results found that the water-soluble ionic concentration (WSIC) is dominated by Na^+ and Cl^- ions, followed by $NO3^-$, Mg^{2+}, Ca^{2+}, and $SO4^{2-}$, with a minor contribution of K^+ and $NH4^+$. Sea salt contribution for the major ions found to be dominant constituents of aerosols, with negligible contribution from anthropogenic species. The pH of the aerosols ranged from 2.82 to 6.10, which is higher than in other seasons. This increase may be attributed to the dilution of acidic species due to higher ambient water content. The Cl^- deficit, primarily resulting from the interaction between sea salt and acidic species, was found to be relatively low (17.16 ± 10.23%) compared to conditions during continental outflow over the Arabian Sea. This indicates a dominance of marine contributions over those from anthropogenic emissions during the SWM months. This study is critical for enhancing our understanding of the connections between aerosols, biogeochemistry, and climate.

Key words: Ionic composition, Aerosol pH, Atmospheric chemistry, Monsoon, North Indian Ocean.

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Investigation Of Black Carbon Mass Concentration Over The Indian Sector Of The Southern Ocean

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ABSTRACT

Black carbon (BC) is emitted from the incomplete combustion of carbonaceous material, fossil fuels and biomass burning. BC absorbs solar radiation and is the second-largest contributor to global warming, after carbon dioxide. The deposition of BC into snow and ice in the Southern Ocean (SO) and Antarctic regions reduces surface albedo, which enhances the absorption of solar radiation. This darkening enhances local warming by triggering a positive feedback mechanism. Although the Antarctic region is not warming as rapidly as the Arctic, it is experiencing significant climate change, with a rapid loss of sea ice in recent years, due to surface darkening caused by impurities such as BC. In recent years, the frequency and intensity of forest fires worldwide have increased significantly, resulting in higher emissions of BC. However, due to the logistical challenges of the SO, BC mass concentrations, sources and their impact in this region remain poorly constrained. In the present study, BC mass concentrations over the South Indian Ocean and the Indian sector of the Southern Ocean were measured using a seven- wavelength aethalometer (AE-33) during the 12th Indian Scientific Expedition to the Southern Ocean (February-March 2025). Median BC mass concentration near the Antarctic coast was found to be in the range of 15 to 35 ng m^{-3}. Along the southward (onward) transect towards the SO, the median BC mass concentration was approximately 150 ng m^{-3}, while, during the return transect, BC levels were considerably lower, with median values of about 50 ng m^{-3} within the same latitude of 30°S to 45°S. The BC present over the sea ice can lead to positive radiative forcing (Warming) and enhance the melting of sea ice.

Keywords: Black Carbon, Southern Ocean, Sea ice, Antarctica

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Polynyas In The Indian Sector Of Southern Ocean – Relevance And Implications

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ABSTRACT

The oceans are the lifeblood of our planet, regulating climate, sustaining biodiversity, and supporting human livelihoods. Continuous observations are therefore essential to understand their complex interactions and responses to climate variability. The Southern Ocean, as part of the greater Indian Ocean system, plays a crucial role in global heat, freshwater, and carbon exchange. Within this region, polynyas—recurring open-water areas within the sea ice cover— serve as critical sites of air–sea exchange, deep-water ventilation, and enhanced primary productivity, thereby influencing both physical and biological processes. These features are also recognized as potential regions for dense water formation, contributing to the renewal of deep and bottom waters that drive the global overturning circulation. However, under a changing climate, increasing ocean stratification may inhibit vertical mixing, leading to fewer or weaker polynya events, with cascading effects on ocean ventilation, biogeochemical cycles, and ecosystem dynamics. Using two decades of satellite-derived sea ice data, we investigated the spatiotemporal variability of open-ocean polynyas in the Indian Sector of the Southern Ocean (20°E–100°E). The polynya events are linked to strong cyclonic wind stress curl, a prolonged positive SAM phase, and anomalously high shortwave radiative fluxes, with a southward shift of the Antarctic Circumpolar Current acting as a preconditioning mechanism. To better understand these processes and their long-term evolution in such remote and harsh environments, an integrated observational approach combining autonomous platforms like Argo floats and gliders with satellite-based measurements is essential.

Keywords: Climate Change, Overturning Solution, Polynya, Sea Ice, Southern

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Theme- Advanced Tools in Oceanography

Session Title: Ocean observations through satellite and autonomous platforms in the realm of global change

Convener: Dr Aneesh Lotlaiker

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2.	Multiscale variability of Euphotic Zone depth in the Arabian Sea: Role of climate drivers
3.	Spatio-Temporal Analysis of Sea Surface Temperature Variability Along the Kerala Coast Using MODIS-Based Remote Sensing and GIS Techniques
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Internal Solitary Waves In The Polar Oceans: Hot-Spots, Structure And Generation Mechanisms From Satellite And In Situ Observations

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ABSTRACT

Here we present results of multi-mission spaceborne synthetic aperture radar (SAR) observations of internal solitary waves (ISWs) in the Arctic and Southern Oceans. Over 10000 SAR images were processed to identify hot-spots and a horizontal structure of ISWs in the Arctic and Southern Oceans. For the Arctic Ocean, the SAR data acquired by Envisat ASAR and Sentinel-1 A/B from June to October in 2007, 2011, 2018 and 2020 were used. For the Southern Ocean, the SAR data acquired by Sentinel-1 A/B from January to March 2020 were used. As a result, over 20000 SAR signatures of ISWs were identified in the data, revealing hot-spots of their generation and detailed picture of their properties in these two polar regions. To analyse ISW generation mechanisms we use state-of-the-art topography, tidal current, ocean climatology and reanalysis data. Analysis of tidal body force (TBF) reveals that high ISW generation potential due to tide-topography interactions is confined to the shelf break and slope regions with rough topography. A large number of ISW trains is detected over shelf regions where Froude number has critical and near-critical values, suggesting the waves are generated by supercritical flows owing to lee wave or resonant generation mechanisms. Generation of ISWs over deep ocean is examined using tidal beam generation mechanism. In situ observations are also used to examine vertical structure of ISWs. The possible implications of ISWs on vertical mixing are also discussed. Processing of Sentinel-1 SAR data and analysis of ISW generation mechanisms was done within Russian Science Foundation grant № 25-17-00309, https://rscf.ru/project/25-17-00309/. The processing of historical Envisat ASAR, as well as data analysis for the Southern Ocean was supported by state assignment № FNNN-2024-0017.

Keywords: internal solitary waves, ocean remote sensing, synthetic aperture radar, Arctic Ocean, Southern Ocean

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Multiscale Variability Of Euphotic Zone Depth In The Arabian Sea: Role Of Climate Drivers

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ABSTRACT

This study presents a detailed examination of the spatial and temporal dynamics of the euphotic zone depth (Zeu) over the Arabian Sea from 1998 to 2023, utilizing satellite-derived observations. The analysis encompasses three key subregions — the Northern Arabian Sea (NAS), South Eastern Arabian Sea (SEAS), and South Western Arabian Sea (SWAS). Results reveal that Zeu exhibits pronounced variability on interannual, intra-annual, and decadal timescales. The basin-wide annual mean Zeu ranges between 6 m and 80 m, indicating marked spatial differences in water transparency. Regionally, Zeu values vary from approximately 10–62 m in the NAS, 10–74 m in the SEAS, and 12–72 m in the SWAS. Empirical Orthogonal Function (EOF) analysis indicates that interannual variations explain 21.57% of the total variance, predominantly influenced by the Indian Ocean Dipole (IOD) and, to a lesser extent, the El Niño–Southern Oscillation (ENSO), particularly within the SEAS and SWAS. In the NAS, Zeu demonstrates a notable lagged relationship, with the first principal component (PC1) lagging the Dipole Mode Index (DMI) and ENSO by roughly 10 and 8 months, respectively. A significant positive trend in Zeu is observed across the Arabian Sea and within each subregion, with the NAS showing the greatest increase. Seasonal trend analysis further reveals consistent increases in Zeu across all seasons, with the most pronounced rise (0.47 m yr^{-1}) occurring in the NAS during the October–November (ON) season. Overall, this study provides the first comprehensive insight into the multi-decadal variability of Zeu across the Arabian Sea based on multi-sensor satellite observations.

Keywords: Euphotic Zone, Arabian Sea, IOD, ENSO, Interannual variability

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Spatio-Temporal Analysis Of Sea Surface Temperature Variability Along The Kerala Coast Using MODIS-Based Remote Sensing And GIS Techniques

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ABSTRACT

Sea Surface Temperature (SST) is a key indicator of coastal environmental change, influencing marine ecosystems, monsoonal behaviour, and fisheries productivity along the Kerala Coast. This study examines long-term SST variability using MODIS Aqua/Terra Level-3 SST products integrated with Remote Sensing and GIS techniques for the period 2005–2025. Monthly and seasonal composites were generated after standard preprocessing steps, including atmospheric correction, reprojection, and pixel-quality filtering to ensure data reliability. Spatial analysis and time-series trend evaluation were conducted to identify warming patterns, anomaly zones, and seasonal fluctuations. The results reveal a consistent rise in SST across the Kerala coastal waters, with higher warming rates observed during the pre-monsoon and post-monsoon seasons compared to the southwest monsoon period. Distinct thermal gradients were recorded near upwelling zones and river mouths, highlighting the influence of oceanographic processes, freshwater inflow, and monsoonal circulation. The increasing SST trend suggests potential impacts on marine biodiversity, fish migration patterns, coral reef health, and coastal ecosystem stability. The study demonstrates the effectiveness of MODIS-based satellite observations combined with GIS-based geospatial analysis for monitoring SST dynamics and provides valuable insights into climate-driven ocean changes along the southwest coast of India.

Keywords: Sea Surface Temperature, Kerala Coast, MODIS, Remote Sensing, GIS

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Interannual Variability Of Upwelling And Biological Productivity: Insights From A Coastal Observatory System

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ABSTRACT

The Arabian Sea hosts one of the world's major monsoon-driven upwelling systems, shaped by large-scale ocean-atmosphere interactions that drive strong interannual variability, particularly along the southeastern Arabian Sea. This study compares the persistence, cyclicity, and intensity of upwelling during the 2022 and 2023 monsoon seasons, evaluating variability in relation to wind-driven Ekman dynamics and climate-modes such as the El Niño-Southern Oscillation and the Indian Ocean Dipole. The 2022 monsoon was marked by highly persistent and coherent upwelling, with continuous surface cooling, elevated salinity, oxygen depletion, and sustained chlorophyll enrichment. These features indicated strong vertical nutrient entrainment and tight physical-biogeochemical coupling. Multiple well defined upwelling cycles occurred, each showing a cooling phase followed by a pronounced biological response. Strengthened alongshore winds, enhanced offshore Ekman transport, and positive Ekman pumping boosted the productivity in the region. In contrast, the 2023 monsoon season displayed a delayed, weaker, and fragmented upwelling response. Cooling events were shorter and frequently disrupted, chlorophyll variability was muted, and stronger stratification suppressed vertical mixing and nutrient supply. Only a few weak cycles were observed. This subdued behavior coincided with weakened wind forcing and basin-scale climate anomalies associated with El Niño and a positive Indian Ocean Dipole. These results demonstrate the sensitivity of coastal upwelling to regional winds and remote climate forcing, highlighting the need for sustained high-resolution observations.

Keywords: Coastal Observations, Ekman Dynamics, Upwelling, Chlorophyll, ENSO, IOD

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Session Title: Use of AI/ML for identification of regions responsible for the extreme

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2.	Decoding And Modelling Cyclone-Driven Coastal Transformations With Machine Learning: Chilika Interface
3.	Seasonal Prediction Of Significant Wave Height Using Long-Term Moored Buoy Data And Wave Model Employing Ai/ Ml Methods
4.	Estimation Of Hydrographic Profiles Using Surface Satellite Observations And In-Situ Measurements Through Deep Learning Approaches .
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Design And Development Of A Machine Learning Based Algorithm To Retrieve Ocean Surface Wind Speed From Swath Altimeter Onboard Surface Water Ocean Topography Mission (Swot)

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ABSTRACT

In this study, we use the Ka-band Radar Interferometer (KaRIn) data from the Surface Water and Ocean Topography (SWOT) mission, to develop a machine learning (ML)-based algorithm for retrieving ocean surface wind speed. SWOT provides high-resolution, wide-swath altimeter data, offering new opportunities to estimate wind speed across vast oceanic regions. However, processing this large and complex dataset requires advanced techniques due to issues like noise and geophysical variability.

The present work involves Level-2 expert mode data products from SWOT over the global oceans for the entire year of 2024. Pre-processing of this data is performed through quality flag filtering and subsequent data cleaning by land/ice decontamination. This ensures that only valid ocean observations are retained. A critical part of the work is the collocation process, where SWOT measurements are paired with ECMWF wind and sea surface temperature (SST) parameters with spatio-temporal windows of 0.125° and ±3 hours, ensuring accurate temporal and spatial alignment. Derived features such as incidence angle and gamma-naught are then computed to normalize the radar backscatter (σ^0), aiding the wind speed retrieval process.

Advanced machine learning models and deep neural networks, are trained to predict wind speed based on σ^0 and other oceanographic features. The performance of these models is evaluated using several metrics, such as RMSE, MAE, and R^2 score, with validation against independent datasets. This work presents a scalable framework for transforming SWOT backscatter data into accurate and reliable wind speed estimates.

Detailed results, including data description, collocation, model performance and evaluation, will be presented during the conference, highlighting the potential of this approach to estimate real-time ocean wind speed product towards better ocean monitoring.

Keywords: Ocean Surface Wind Speed, SWOT, Ka-band Radar Interferometer (KaRIn), Machine Learning (ML), Collocation Process

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Decoding And Modelling Cyclone-Driven Coastal Transformations With Machine Learning: Chilika Interface

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ABSTRACT

The North Bay of Bengal is a climate hotspot with frequent cyclones, which trigger rapid, nonlinear changes in upper-ocean physics and biogeochemistry. Yet traditional ocean models struggle to capture these short-term, sub-grid mixed-layer and biogeochemical responses, especially in dynamic coastal transition zones. This study applies machine learning (ML) techniques like EarthFormer, a transformer-based deep-learning framework which uses video-like attention mechanism to model and predict cyclone-driven surface and subsurface responses at the Chilika Lake mouth. This region is a brackish lagoon–coastal interface on the East Indian coast which is highly sensitive to cyclone-driven storm surges and exhibits sharp physical and biogeochemical shifts. The current study has used data from five major cyclones, namely—Phailin (2013), Hudhud (2014), Titli (2018), Fani (2019), and Amphan (2020), to construct pre-, during-, and post-cyclone composites for various parameters like surface temperature, winds, currents, and freshwater inputs. Anomalies were calculated to distinguish the disturbances caused by the cyclones. Model testing has been done by leave-one-cyclone-out validation strategy, where the model is trained on four cyclones and tested on the remaining one. Preliminary results indicate that during the passage of each cyclone, the region experienced pronounced mixed-layer deepening and sharp sea-surface temperature cooling. Thus, based on our initial results, we can infer that ML frameworks are likely to improve our understanding of cyclone-induced coastal biogeochemical dynamics and also support Blue Intelligence coastal forecasting systems in the future.

Keywords: Cyclone-induced coastal dynamics, transformer-based deep learning, mixed-layer dynamics, biogeochemical responses, lagoon–coastal interface, Chilika Lake mouth

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Seasonal Prediction Of Significant Wave Height Using Long-Term Moored Buoy Data And Wave Model Employing Ai/ Ml Methods

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ABSTRACT

Accurate prediction of Significant Wave Height (SWH) is essential for coastal safety, marine navigation, offshore operations as well as in the structural design. Traditional and deterministic numerical models often struggle to capture the highly nonlinear and dynamic behaviour of ocean waves, especially the monsoon-driven variability. AI/ML techniques provide faster, more accurate, and cost-effective SWH forecasts by learning complex non-linear patterns, outperforming conventional models thereby enabling real-time operational prediction. This study investigates the use of Recurrent Neural Network—specifically a Long Short-Term Memory (LSTM) model—for short-term SWH forecasting using a five-year time series (2015–2019) from the ERA5 wave model and in situ observations at a moored buoy location (13.5°N / 84.0°E) in the central Bay of Bengal deployed by the Ocean Observation Systems Group, NIOT, Chennai. Four years data were used for training LSTM model and 2019 data were used for checking the performance of the model. Pre-processing included outlier removal, robust scaling, and time-feature encoding to improve data quality. Optimal input lag was determined using Partial Autocorrelation (PACF) to capture relevant temporal dependencies. To capture the seasonal variability in the SWH prediction, monthly predictions are performed using each month data to predict 3-day forecast at the end of each month. The LSTM model was trained to predict 24 timesteps at 3-hour intervals and evaluated using 5-fold time-series cross-validation. The model predictive performance for different seasons (monthly) of 2019 was assessed using correlation coefficient (R) and Root Mean Square Error (RMSE). The model showed high predictive accuracy, with R and RMSE ranging between 0.81–0.99 and 0.01–0.15 m respectively. The strongest performance occurred in January, April, July, August, October, and November with $R \approx 0.99$ and $RMSE \leq 0.04$ m, indicating excellent reliability under varying monsoonal conditions. These results confirm that LSTM-based models are effective for univariate SWH forecasting and are suitable for real-time operational use.

Keywords: Significant wave height prediction, moored buoy observations, ERA5, ANN, RNN-LSTM.

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Estimation Of Hydrographic Profiles Using Surface Satellite Observations And In-Situ Measurements Through Deep Learning Approaches .

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ABSTRACT

In this study, we developed a deep learning framework to estimate subsurface ocean profiles by integrating satellite observations with in-situ measurements. Vertical temperature and salinity profiles are essential for understanding ocean thermodynamics, density structure, and climate-related variations. Although satellite sensors provide large-scale coverage of surface parameters such as Sea Surface Temperature (SST), Sea Surface Salinity (SSS), Sea Level Anomaly (SLA), and wind speed, direct subsurface data from systems like Argo floats remain limited in spatial and temporal distribution.

To overcome this, we created a unified database by matching daily satellite data with GTSPP temperature and salinity profiles from the Indian Ocean during 2015–2020. The dataset was carefully processed through temporal and spatial interpolation, removal of outliers, and regridding to a uniform 0.25° × 0.25° resolution. Two models were developed: a Random Forest model and a deep learning model using two stacked LSTM layers to reconstruct vertical temperature and salinity profiles up to 600 meters depth.

The LSTM model used 37,074 profiles for training, 7,269 for testing, and 4,119 for validation, totaling 48,462 profiles, and achieved an RMSE of 2.655 with an accuracy of 0.909. The Random Forest model achieved an RMSE of 0.7662 and an accuracy of 0.95. These results highlight the effectiveness of combining satellite and in-situ measurements to estimate subsurface ocean properties. Detailed findings will be presented during the conference.

Keywords: Subsurface hydrographic profiles; LSTM; Random Forest model; satellite observations; in-situ measurements.

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Detection Of Small-Scale Eddies In The North Indian Ocean Using Satellite Altimetry And Numerical Models: An Ai Approach

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ABSTRACT

In this study, we make use of an Artificial Intelligence (AI) technique - the Vector Geometry (VG) Algorithm - to detect and characterize small-scale (50–150 km) oceanic eddies in the North Indian Ocean using satellite observations. The VG algorithm detects eddy-like structures using the geometric properties of velocity vectors derived from Sea Level Anomaly (SLA) fields, allowing estimation of eddy amplitude, rotational symmetry, and classification into cyclonic and anticyclonic types.

Intitially, the methodology was developed and tested using simulated Sea Level Anomaly (SLA) from a high-resolution numerical ocean model (2 km) for the Arabian Sea. To finalize the detection parameters, different amplitude thresholds (0.02, 0.04 ,0.05 and 0.06m) and diameter ranges (20–50 km or 30–80 km) were systematically tested. Lower amplitude thresholds (0.02 m) and smaller diameter ranges (20–50 km or 30–80 km) resulted in excessive noise, where isolated pixels were incorrectly detected as eddies. Testing broader ranges showed that 50–150 km produced coherent submesoscale eddies, while diameters above 150 km captured mesoscale structures. These experiments established a 0.05 m amplitude threshold and a 50–150 km diameter range as optimal for realistic submesoscale eddy detection.

Later, the VG method was applied to AVISO SSHA (12.5 km resolution) and to the daily swath observations of SLA obtained from the Surface Water and Ocean Topography mission acquired during the Calibration/Validation (Cal/Val) phase from 29 March 2023 to 09 July 2023 using the final amplitude and size threshold.

Detailed results, including spatial distribution, temporal variability, and comparison with model and AVISO data, will be presented during the conference.

Keywords: Eddies; North Indian Ocean; Sea Level Anomaly; Vector Geometry Algorithm; Artificial Intelligence.

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Spatial Modelling Of Multi-Hazard Risk In Coastal Ernakulam: A Maxent-Based Village-Level Assessment

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ABSTRACT

Coastal systems, often exposed to multiple and overlapping natural hazards, have been identified to be at risk. Yet, the spatial distribution of multi-hazard susceptibility and the populations exposed to it are poorly understood. Despite the uncertainties and livelihood challenges, approximately two-thirds of the global human population resides within 400 km of a city due to various socio-cultural and economic reasons. The topographical, geological, and hydrological characteristics of the coast provide the population with sufficient natural resources for livelihood, while also making them susceptible to the impacts of hazards. The objective of this study is to map and understand the patterns of susceptibility to multiple hazards, including storm surge, tidal flooding, fluvial flooding, and coastal erosion, in coastal villages of Ernakulam using MaxEnt modelling and to identify multihazard hotspots. For this we will need i) hazard catalogue of different hazards as point data and ii) environmental covariates that determine the susceptibility to various hazards as continuous or categorical layers under different realms of lithosphere (slope, elevation, soil characteristics, geomorphology, bathymetry), hydrosphere (tidal range, sea level rise, significant wave height, drainage network), biosphere (lulc, coastal defenses) and atmosphere (atmospheric pressure, windspeed). We will then overlay the exposed population at a gridded scale and buildings to find the spatial pattern of exposure in the susceptible areas. The result can thus guide policymakers and stakeholders in better planning and prioritisation.

Keywords: Coast, Exposure, Hazard, MaxEnt, Susceptibility

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Advancing Coastal Productivity Monitoring: FRRf-Based Variable Fluorescence Assessment of Microphytobenthos Across Tidal Gradients on Contrasting Monsoon Shores

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ABSTRACT

Microphytobenthos (MPB) are key contributors to intertidal primary production and coastal biogeochemical functioning, yet their in situ photophysiological assessment is limited by the disturbance sensitivity of sediment surfaces. This study demonstrates the first application of the FastAct Fast Repetition Rate Fluorometer (FRRf)—a benchtop system—for MPB assessment, integrated with a non-invasive petriplate-based sampling approach that preserves natural sediment microstructure for accurate variable fluorescence measurements. Field investigations were conducted on a seasonal basis on two monsoon-influenced tropical beaches (Dias and Miramar) on the central west coast of India—one protected and the other under higher anthropogenic pressure. Measurements from four additional beaches (Polem, Palolem, Galgibagh, and Rajbagh) broadened spatial comparisons.

FastAct-derived metrics—including variable fluorescence (Fv), maximum photochemical efficiency (Fv/Fm), and functional absorption cross-section (σPSII)—revealed strong tidal-height patterns. At the Dias, Miramar, and Rajbagh beaches, the mid-tide zone exhibited the highest fluorescence, followed by low tide, with minimal values at high tide, indicating optimal abiotic conditions and sediment stability at mid-elevations. Palolem showed a decreasing trend from low to high tide, while Galgibagh and Polem displayed no significant tidal variation.

The protected Dias beach and Palolem exhibited higher PSII efficiency (Fv/Fm > 0.35) than others; however, MPB biomass and physiological status varied independently, influenced by multiple drivers, including sediment grain size, hydrodynamic exposure, abiotic gradients, and differing anthropogenic pressures. Coarser, more disturbed beaches showed reduced fluorescence, indicating lower biomass potential and physiological stress. Monsoonal forcing temporarily depressed MPB activity, with rapid post-monsoon recovery.

This pioneering integration of FastAct-based variable fluorescence with non-destructive sampling provides a scalable, high-resolution framework for monitoring MPB photophysiology
in dynamic and human-impacted coastal environments, thereby advancing our understanding of coastal ecosystem functioning under changing environmental pressures.

Keywords: Microphytobenthos, FastAct FRRf, Variable fluorescence, Photosynthetic efficiency, Tidal gradients

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Impact of anthropogenic changes on shallow marine benthic ecosystem: Insights from live and dead bivalve assemblages.

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ABSTRACT

Shallow marine benthic communities are sensitive to environmental changes and respond well to anthropogenic perturbations. These communities can be used to assess the impact of pollution on the shallow marine ecosystems. Present-day ecological surveys can be useful for assessing health, but to track changes over time and establish baselines for these changes, archives are needed. Marine bivalve communities are ideal archives for establishing baselines, as they possess great preservation potential, high abundance, and are sensitive to environmental changes. We present a case study from coastal Mumbai, where British-era land reclamation and recent industrial pollution have significantly altered the shallow marine coastline and ecosystem. Our study attempts to evaluate the impact of anthropogenic changes using Live Assemblage (LA) and compare it the a pre-impact baseline created using Dead Assemblage (DA). We collected samples from various polluted sites in Mumbai and Thane districts and compared them to pristine sites in Raigad district. LA and DA for each site were evaluated on the abundance-based Jaccard- Chao similarity Index and Spearman's rank-order correlation. Our results indicated that pristine sites exhibited higher similarity and a positive correlation between LA and DA. In contrast, polluted sites demonstrated variable responses across both parameters. LA of polluted sites were also dominated by bivalve groups, which are tolerant to low oxygen and degraded environments, compared to pristine sites, which are dominated by sensitive filter feeders. These results indicate a possible negative impact of anthropogenic changes on the shallow marine waters of Mumbai. Understanding additional information on environmental factors, such as nutrient levels, substrate, and water current, is essential for developing an effective strategy for the conservation and preservation of these sensitive tropical marine ecosystems.

Keywords: Shallow Marine Ecosystems, Anthropogenic Impact, Bivalve Assemblages, Live- Dead Analysis, Ecological Baselines.

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Unravelling genetic connectivity in new records of Deep-Sea Corals from Indian Seamounts

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ABSTRACT

Over the past few decades, research on deep-water corals has advanced significantly, from the initial discovery of their presence in the deep ocean to a detailed understanding of their ecological, palaeontological, and biogeographical importance. These corals are widely distributed across the world's oceans and are recognized as key components of vulnerable marine ecosystems. By forming complex three-dimensional habitats, they offer refuge and resources for numerous associated species. However, the genetic structure and connectivity of most deep-sea coral populations remain largely unexplored. This study aimed to investigate the genetic connectivity of corals from deep-sea seamounts in the Indian Ocean, particularly in the Andaman and Arabian Seas. Deep-sea coral specimens collected using an Agassiz trawl were processed for morphological identification using scanning electron microscopy (SEM), complemented by molecular taxonomy. For the first time in Indian waters, mitochondrial genome-based analysis was used to examine genetic connectivity, adaptive traits, and evolutionary lineages of deep-sea corals. Because mitochondrial DNA evolves more rapidly than nuclear DNA, it provides high- resolution data for population-level studies, evolutionary research, and comparative genomics. Notably, three of the examined species, belonging to the genera *Narella sp.*, *Hemicorallium sp.*, *Calyptrophora sp.*, and *Dendrophyllia sp.*, represent new species and new distributional records for Indian waters. These findings establish the first mitogenomic baseline for deep-sea corals in this region and provide a foundation for future studies on population dynamics, with direct implications for the conservation and management of vulnerable marine ecosystems.

Keywords: Cold-water corals, Seamount ecosystems, Mitochondrial genome, Indian Ocean, New distributional records.

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Canopy gaps as diversity hotspots: Sucession of vegetation and crab communities in mangrove canopy gaps of the Andaman Islands.

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ABSTRACT

Disturbances are key factors in shaping species richness and composition in many ecosystems at different scales. Lightning strikes in mangrove forests often result in the formation of small- to medium-sized canopy gaps, characterised by tree deaths in a circular pattern. This small-scale disturbance is crucial for maintaining large-scale demography patterns. We investigated canopy gap attributes, vegetation and crab community composition by assessing 40 canopy gaps under two age categories (New Canopy Gaps: 1 - 6 years old; and Recovering Canopy Gaps: 7 - 15 years old; 20 in each category) from six sites across the Andaman Islands. Each canopy gap was paired with a control plot in the intact forest. The canopy gap size ranged between 270 m² and 2463 m² (mean: 941.37±581 m² SD). We found a higher plant species richness in new canopy gaps than in recovering canopy gaps and intact forest. Both seedling and sapling densities were more than two-fold higher in new canopy gaps compared to recovering canopy gaps and intact forests. *Rhizophora apiculata* was the dominant species across trees, saplings and seedlings. Crab diversity was highest in the intermediate gap recovery stage (Shannon diversity, H' = 0.93), with a moderate canopy cover (average canopy cover = 68%). Crabs of the families *Ocypodidae* and *Varunidae* were positively correlated with canopy openness. *Ocypodidae* crabs were abundant in new canopy gaps, whereas their count declined in recovering canopy gaps and intact forests. Our study highlights a clear correlation of mangrove recovery and crab community dynamics, and it provides baseline information on the vegetation and crab community composition among two different recovering categories of canopy gaps and in intact forests. Further, long-term canopy gap monitoring at varying size classes and fixed year intervals would provide crucial insight into mangrove canopy gap succession.

Keywords: Disturbance ecology, Mangroves, Regeneration, Succession, Brachuran crabs

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Interannual and seasonal variability of microphytobenthos assemblages on a monsoon- influenced tropical tidal flat: Evidence of a decadal community shift

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ABSTRACT

Microphytobenthos (MPB) play a crucial role in sediment stabilisation and primary productivity in intertidal ecosystems, yet their temporal variability in monsoon-influenced tropical regions remains underexplored. This study investigates the interannual and seasonal variability of MPB assemblages—considering both taxonomic composition and morphotype diversity—in surface sediments (0–2 cm) from tidal flats at Dona Paula, Goa. Samples were collected at monthly intervals during April–August 2019 and July 2022–October 2023. The results were compared with earlier data to evaluate potential decadal shifts in MPB communities. Surface sediments exhibited higher MPB species richness and shape diversity compared to surf waters. Assemblages were dominated by simple elongated centric diatoms (Prism-on-Triangle forms) in surf-water, low-tide, and mid-tide zones, whereas simple elongated pennate diatoms (Elliptic Prism forms) prevailed in the high-tide zone. Although marked seasonal and tidal variations were evident, the dominance of these shape categories remained consistent. Monsoonal precipitation strongly influenced seasonal abundance and diversity, while phytoplankton blooms contributed to assemblage restructuring across all tidal zones. Both pennate (*Navicula* spp., *Nitzschia* spp.) and centric diatoms (*Thalassiosira* sp., *Bellerochea malleus*, *Lithodesmium undulatum*) co-dominated the community irrespective of tidal height. Comparison with previous datasets revealed a clear decadal community shift, with several species rare in the 2000s now emerging as dominant. These shifts likely reflect responses to changing monsoonal regimes, sea-level rise, and nutrient enrichment. Such transformations in MPB communities may significantly influence benthic–pelagic coupling and ecosystem functioning in tropical coastal habitats.

Keywords: Microphytobenthos, Intertidal flat, Seasonal variability, Decadal shift, Coastal ecosystem

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Mark and recapture field experiment to test host-parasite interactions

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ABSTRACT

Parasitic trematodes have been known to manipulate the behaviour of their host. To attain their next intermediate host in a multitrophic parasitic transmission, trematodes alter the behaviour, physiology and reproduction of their gastropod host. *Pirenella cingulata*, being their obligatory first intermediate host, serves a comfortable niche to multiply and proliferate on the tropical mudflats. To test the hypothesis that on an estuarine mudflat, trematodes drive gastropods towards a certain region or zones, we carried out a mark-recapture field experiment by releasing 1500 *P. cingulata* infected with trematodes for a month and recovered 62% of specimens. Parasitic component community of dominant species pulled the host more towards the low tidal region compared to less abundant trematode species. Parasitic trematodes have multi-tropic host requirements for successful completion of their life cycle. Strategy to drive the host towards subtidal immersion plausibly aids in their survival success as well as closing the gap to switch to the next potential host, which are most likely estuarine teleosts.

Keywords: Mudflat; Trematode; Parasite; Host; Manipulation

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Linking foraminiferal diversity to environmental gradients along the mumbai coast

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ABSTRACT

Foraminifera, a diverse genus of marine protozoans with calcareous shells, are useful indicators of marine environmental conditions. Their sensitivity to environmental factors including salinity, temperature, substrate type, and nutrient availability makes them efficient tools for measuring coastal ecosystem health. The Mumbai coastline, with its broad sandy shoreline, makes an ideal habitat for studying foraminiferal diversity and distribution. This study looks at the spatial variability in foraminiferal assemblages throughout Mumbai's six beaches, with a focus on the link between species composition and current environmental conditions. We found 72 species, including 68 benthic and four planktonic species. *Ammonia tepida*, *Nonion commune* and *Asterorotalia dentate* were dominated taxa. Salinity was the limiting factor determining species distribution within stations. The distribution of foraminifera was impacted by sediment type, with small particle-sized silt sediments from Gorai and Juhu supported major species. The heavy metal analysis revealed the effect of both natural and anthropogenic heavy metals in the studied region. The tests of foraminifera were observed with shell abnormalities, indicating effects of natural and anthropogenic factors on them . The findings emphasized foraminifera's ecological sensitivity to environmental gradients, as well as its potential application in coastal health monitoring. Understanding these microfaunal responses helps to ensure sustainable coastal management and offers important baseline data for anticipating ecological responses to continuing climate change and human stresses along the Mumbai coast.

Keywords: Foraminifera, Diversity, Anthropogenic factors, Intertidal zone, Mumbai

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Knowledge Synthesis on Trends and Gaps of Mangrove Research in India: A Comprehensive Bibliometric Analysis

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ABSTRACT

The increasing impacts by climate change and anthropogenic activities have heightened the global interest to conserve and manage the direct (fisheries, and timber resources) and indirect (coastal protection, shoreline stabilization) services provided by the mangroves. India, being ranked ninth globally in mangrove cover, has experienced mangrove loss similar to the global average (40% by 2020). Yet, mangroves in India have been extensively studied and reviewed owning to intricate linkages with millions of coastal communities for the sustenance. However, a comprehensive synthesis of research trends and knowledge gaps remains lacking. The present study employs PRISMA methodology to analyse publication trends (1900–2023) through a systematic bibliometric analysis of peer-reviewed articles (PRAs) from Google Scholar and ResearchGate. Boolean criteria and Snowballing method identified 1070 PRAs since 1963, averaging 18 PRAs per year, surging to 41 post-2004 tsunami. A total of 4204 indexed keywords were found across PRAs with *Diversity*, and *RemoteSensing*, emerging as dominant themes. A total of 2426 unique authors contributed in 539 journals with *KandasamyKathiresan* and *KakoliBanerjee* being most prolific investigators, and contributions spanning researchers from 32 countries. Indian mangrove research is unevenly distributed; broadly matching mangrove cover nationally but not at the state level. The east coast (62.4%), west coast (30.3%), and Andaman & Nicobar Islands (7.3%) received attention proportional to their cover (57%, 31%, 12%). In contrast, global patterns often show countries with extensive mangrove cover—often economically less developed—tend to have lesser mangrove-related studies, while research is concentrated in wealthier nations with smaller mangrove areas. These disparities highlight the need for innovative, inclusive, and collaborative research methodologies that bridge geographic and economic gaps. Further, the steady rise in mangrove-related PRAs in the recent decade underscores their regional and global significance. This broad synthesis informs research trends of Indian mangroves and suggests effective decision-making for mangrove conservation.

Keywords: 2004 Indian Ocean Tsunami, Citation Analysis, PRISMA, Publication Trends, Research Networks, Thematic Area

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Coral, invertebrate, and fish assemblages across reef habitats and proximity to fishers in Madagascar's marine biodiversity hotspot, Southwest Madagascar.

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ABSTRACT

Establishing a robust ecological baseline is essential for assessing reef status and guiding adaptive management, especially in the Western Indian Ocean where coastal communities depend on reef productivity. We assessed cross-shelf ecological patterns across 33 reef sites in the Bay of Ranobe MPA, Southwest Madagascar, encompassing Outer, Inner, Patch and fringing reefs. Standardized underwater visual census methods were applied, including line intercept transect (LIT), fish belt and macroinvertebrate belt transects. Live coral cover ranged from 1.4% to 83.4% (mean ± sd, 35.4±20.9%) dominated by Montipora (33.9 ±38.4%), Acropora (31.8

±21.5%), and Porites (19.2 ±22.4%). Patch Reefs exhibited the highest live coral cover (up to 83.5%) and genus richness (39 genera). Macroinvertebrate densities increased from fringing (4 ind./60 m²) to outer reefs (14 ind./60 m²). Fish assemblages comprised 148 species belonging to 71 genera and 29 families with biomass ranging from 24.9 to 840 kg/ha, all below regional sustainability thresholds. Coral morphologies were unrelated to habitat, depth, or distance from shore, whereas fish assemblages were significantly influenced by depth ($p = 0.021$). These findings highlight the ecological importance of Patch Reefs and the need for depth-specific management and conservation strategies. This baseline provides critical guidance for sustaining biodiversity and reef-dependent livelihoods in southwest Madagascar.

Keywords: coral reefs, fish assemblages, macroinvertebrates, fish biomass, management

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Benthic Communities And Habitats Of Northern Mozambique

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ABSTRACT

The study provides an overview of the benthic community of the northern Mozambique. Data were collected on the research vessel Dr. Fridtjof Nansen in 2018 between the Pemba Bay (13° S) and the border with Tanzania (10° 30´S), covering a large part of the Rovuma Basin. Bottom fauna and habitat was mapped in three main areas to cover abroad and a representative set of environments including offshore seamounts, the deep sea, estuaries near MPAs, and areas of special interest for industrial development. The 32 mapping sites covered from tropical reefs at 27 m depth down to the bathyal depth at 2000 meters representing a temperature range of 27ºC. Bathymetry data and oceanographic measurements were conducted at each station and sediment samples and ROV transects for fauna and habitat documentation were provided by the Video-Assisted Multi Sampler (VAMS). In total 37 video transects were analysed from 32 localities. The number of taxa observed is 75 % lower in the deepest localities (1275–1934 m) compared to the very rich tropic coral reef fauna in the upper 50 meters. This represents a gradient in temperature from 29ºC down to 2.6ºC. At upper parts of coral reefs hard corals (Hexactinelidae) and soft corals (Alcyonacea) dominated and algae species contributing to the rich community together with sponge and fish fauna. In lower parts of reefs 65-95 meters, gorgonian corals are common and sponges are more frequent. Below 130 meters the change is drastic, and the number of taxa is less than 50 % of the rich shallow habitats. Corals are still an important contribution, but the relative contribution of crustaceans increases with depth and at larger depths, sea pens and echinoderms contribute more to the diversity.

Keywords: Benthic communities1, habitat mapping2, keyword3, Northern Mozambique4, Dr. Fridtjof Nansen5

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Feeding ecology of major demersal species from the west coast of India Motiram Borkar[1,2]

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ABSTRACT

Unique features of the Indian continental shelf (ICS) give rise to flourishing demersal fisheries which has significantly contributed to socio-economic progress. The predominant species that have demersal life history traits from the ICS are Bombay duck, pink perch, ribbonfish, croakers and pomfret etc. These species are opportunistic omnivores. Their gut content analysis reveals a dietary preference with wide spectrum of species representing pelagic as well as benthic groups. Therefore, it can be inferred that shoals of demersal can move across deep to shallow shelf habitats as well as near surface to epibenthic foraging. Fish larvae, teleost (anchovy), squids, crustaceans like shrimps and crabs form a major portion of demersal species.

The lower size of the prey community includes mesozooplankton while the largest consumed species were 1/10th of their body weight. Results show that Bombay duck is cannibalistic consuming their own juveniles which exerts complex feedback to the fecundity: adult survival ratio. Much of their early larval stages are prey for pelagic forage fishes as these demersal lay positively buoyant telolecithal eggs. Adapting an ‘r’ selected strategy ensures success with high fecundity compensating the pelagic loss of early stages. Omnivory helps demersal species to grow fast enhancing fecundity and therefore it dominance. Flourishing demersal fisheries is a testimony to the characteristic northern ICS with a shallow but large benthic gradient with a supply of re/suspended organic flux due to shelf processes aiding such species.

Keywords: Indian continental shelf, demersal, Bombay duck, Omnivores, Cannibalism.

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Molecular biodiversity of Deep-Sea Sponges from Indian seamounts

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ABSTRACT

Deep-sea sponges are one of the oldest and most adaptable marine organisms belonging to three major classes, Desmospongiae, Hexactinellida and Calcarea, each distinguished by differences in skeletal composition, tissue organisation, such as having a siliceous skeleton with spongin fibres, syncytial tissue with silica skeleton and calcareous skeletal structures, respectively. They also play a role in ecology by providing habitat structure, filtering large volumes of water and supporting deep-sea biodiversity. However, traditional morphological identification is both time- consuming and challenging, especially when their structural characteristics are reduced, damaged or too similar to be visually separated. Because of these limitations, molecular techniques are gradually proving to be a means of distinguishing sponge species. This study aims to apply molecular-based methods in the identification of deep-sea sponges from the Indian seamounts. Primers targeting the mitochondrial COI gene, such as dgLCO/dgHCO, LCO/COXIR1 and for the 28S gene C1/D2, were used for amplification. The sequencing results of these samples were compared against a sponge reference database to confirm species identity. By applying molecular techniques, this study provides accurate species identification and deepens our understanding of deep-sea sponges in the Indian Ocean region. These findings may also pave the way for identifying additional new species and support future conservation efforts.

Keywords: Deep-sea, Sponges, DNA barcoding, PCR amplification, Indian Ocean

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Coralline habitat heterogeneity drives polychaete diversity and trophic dynamics along the Maharashtra coast.

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ABSTRACT

Coral habitats are unique benthic system with intricate biodiversity and ecosystem services. Despite its rapid industrialization and urbanization, Maharashtra harbors patchy coral reefs along its along its 878 km long coastline. However, compared to other significant reef systems in India, the benthic diversity associated with these reefs is still poorly characterized. This pioneering study evaluates the effects of habitat complexity on trophic structure and polychaete diversity in eight recently identified coralline habitats along the Maharashtra coast. Along the 34 study sites extending from Shiroda in the south to Mumbai in the north, four distinct habitats—coralline sediment, macroalgae, seagrass, and sandy sediment—were associated with the patchy coral reefs. Sand with low levels of organic carbon predominated in all 34 study sites. A total of 244 polychaete species were identified and characterized under 8 different feeding guilds. The Onuphid, *Nothria conchylega* (EG II) was the most recurring and dominant polychaete species across all study sites. Polychaete species richness and abundance were higher in southern locations than in northern ones. Comparatively, polychaetes associated with coralline sediments exhibited higher abundance and diversity as compared to other habitat types. n-MDS ordination indicated clear spatial separation between the northern and southern assemblages. Moreover, the distinct clustering of the four habitats in the plot indicated that the polychaete community structure was influenced by the habitat type. Investigation on trophic dynamics indicated that all feeding guilds were represented in the coralline sediments without dominance. This signified the availability of multiple food sources in the coralline sediments. Seaweeds and seagrasses supported similar feeding guilds (majorly herbivores and predators), that were less diverse as compared to the coralline sediments. The most prevalent species were indifferent (EGII) forms, followed by sensitive types (EG1). The absence of first order opportunistic groups (EG V) in this study suggested that the coralline sites had low levels of environmental stress. This study highlights habitat heterogeneity within coralline areas as a major factor shaping the polychaete assemblages by offering a variety of living and feeding niches.

Keywords: Corals, Polychaetes, Habitat heterogeneity, Feeding guild.

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New species and new records of the genus *Grandidierella* (Amphipoda: Aoridae) from India

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ABSTRACT

India has a large coastline of about 7,517 km, comprising 72% (5,423 km) along mainland India and 28% (2,094 km) across the Andaman and Nicobar Islands and Lakshadweep Islands. This coastal expanse encompasses diverse habitats that collectively foster a rich marine biodiversity. India also has rich amphipod diversity, with more than 266 species belonging to 56 families recorded from different marine habitats in the country. This study focuses on the taxonomy of amphipod specimens collected from various coastal sites in Gujarat and Odisha, India. All the specimens were collected using the hand-picking method and later preserved in 70% alcohol for morphological analysis in the laboratory. After being brought to the laboratory, dissection of different body parts was carried out using a stereomicroscope (Metlab PST-901) for species- level identification. After dissection, the body parts were photographed using a camera attached to the stereomicroscope to prepare detailed illustrations. A total of five different species were identified from the collected samples. Among these, two species are described as new to science, one is recorded for the first time from the West Coast of India, and two are newly documented from Gujarat State. *G. geetanjalae* **sp. nov.** and *G. khambhatensis* **sp. nov.** are described as new species in this study. *G. macronyx* is reported for the first time from the West Coast of India, and *G. bonnieroides* and *G. megnae* are reported for the first time from Gujarat. *Grandidierella geetanjalae* **sp. nov.** differs from its close congeners, *G. palama* and *G. pseudosakaensis*, by having a comparatively smaller spine on the posterior margin of carpus of gnathopod 1. *Grandidierella khambhatensis* **sp. nov.** differs from its close congener *G. perlata* by having a hook shaped uropod 3 ramus. With the addition of *G. geetanjalae* **sp. nov.** and *G. khambhatensis* **sp. nov.**, the world species count for the genus is increased to 56, and the number of species found in Indian waters rises to 11.

Keywords: Coastal fauna, Crustacean diversity, Distribution, Morphology, Taxonomy

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Spatial modelling of intertidal Molluscans along the Gujarat coast using oceanographic variables

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ABSTRACT

Molluscs play an essential ecological and economic role along the Gujarat coastline, yet their spatial distribution remains poorly documented. This study investigates the habitat suitability of four dominant intertidal molluscan species—Cerithium caeruleum, Lunella coronata, Peronia verruculata, and Trochus radiatus—using species distribution modelling (SDM) integrated with key oceanographic variables. Field surveys were conducted across major intertidal zones, and species occurrence data were combined with environmental predictors including salinity, chlorophyll-a, and sea surface temperature sourced from Bio-Oracle. Four modelling approaches (MaxEnt, BIOMOD, Bayesian modelling, and Random Forest) were evaluated. MaxEnt outperformed other frameworks, achieving the highest AUC (0.63), indicating moderate predictive ability. Correlation analysis revealed temperature as the strongest positive factor influencing molluscan suitability, while salinity showed a pronounced negative effect; chlorophyll-a contributed moderately to predicted distribution patterns. Moran's I analysis indicated weak spatial autocorrelation, suggesting distributions governed primarily by local environmental conditions. The resulting maps highlight ecologically important hotspots along the Saurashtra coast and the Gulf regions. These findings provide baseline spatial intelligence for conservation planning, environmental monitoring, and potential development of sustainable molluscan aquaculture along the Gujarat coast.

Keywords: molluscs, species distribution modelling, MaxEnt, habitat suitability, Gujarat coast

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A Review And Synthesis Of Benthic Community Structure And Environmental Drivers In The Northern Indian Ocean

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ABSTRACT

Benthos, the diverse assemblage of organisms inhabiting the seafloor, play a central role in organic matter remineralization, nutrient regeneration, and long-term carbon sequestration, forming a critical link between surface productivity and deep-sea ecosystem functioning. Their community structure and productivity are strongly modulated by food availability, oxygen levels, and climatic variability, making them robust indicators of benthic ecosystem health.

This review synthesizes current knowledge on benthic communities and their environmental drivers across the northern Indian Ocean. Benthic faunal productivity is higher in the Indian shelf region of the Arabian Sea (AS; 1.9 g C m^{-2} yr^{-1}) than in the Bay of Bengal (BoB; 1.2 g C m^{-2} yr^{-1}), with further declines in the deep sea (1.3 and 0.75 g C m^{-2} yr^{-1}, respectively). Regionally, shelf productivity off Kerala (3.7 g C m^{-2} yr^{-1}) exceeds that off Gujarat (2.9 g C m^{-2} yr^{-1}). In the deeper AS (~65°E), particulate organic carbon flux decreases by ~6-fold (7.3 to 1 mg m^{-2} d^{-1}) from 20°N to 10°N, reflecting reduced food supply to the seafloor and a corresponding decline in benthic abundance. Spatial contrasts are evident across the margin: macrobenthic densities are higher on the southwest shelf (3398 ± 2109 ind. m^{-2}) than on the southeast shelf (1205 ± 331 ind. m^{-2}), and meiobenthos show a similar pattern. Biomass is considerably greater in the AS (17.6 g m^{-2}) than in the BoB (5.32 g m^{-2}). However, major gaps persist, as the deeper southeast Indian shelf remains virtually unstudied, and microbenthic assessments across the region are sparse. Future work must include focused investigations on seasonal changes in community composition, OMZ-linked communities, molecular-based diversity, and depth-related size-class changes, supported by standardized, shelf-to-deep-sea sampling frameworks.

Keywords: benthic communities, diversity, northern Indian Ocean, organic matter flux, deep-sea ecology.

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CMLRE Referral Centre: Marine biodiversity documentation within the Indian EEZ and the High Seas

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ABSTRACT

Indian marine ecosystems support an estimated 20,000 animal species. Climate change, coupled with anthropogenic disturbances through fishing, mining, tourism and pollution, is known to impair their sustainability and, in some cases, leading to extinction. Previous attempts to document the biodiversity of the Indian Exclusive Economic Zone and the Areas Beyond National Jurisdiction have been patchy in terms of geographic coverage. This necessitated comprehensive surveys to understand discernible changes in biodiversity. In this regard, the Marine Living Resources Programme sponsored by the Ministry of Earth Sciences, Government of India, and executed by the Centre for Marine Living Resources & Ecology, Kochi, has been at the forefront of these efforts. Comprehensive cruises by the CMLRE-owned Fishery Oceanographic Research Vessel *Sagar Sampada* as well as sampling surveys in the Island ecosystems and coastal waters within the EEZ have resulted in moderately large faunal collections deposited in the Referral Centre (Bhavasagara) of the institute. The present study provides an overview of 3389 voucher specimens representing 1259 taxa belonging to nine phyla. A total of 600 stations within the Indian EEZ and 28 stations in the ABNJ were surveyed over two decades. The maximum number of stations (356) was surveyed in the Eastern Arabian Sea (including Laccadive Sea and Gulf of Mannar) due to easier accessibility and relatively favorable bathymetry. A lesser number of sites were surveyed in the Andaman waters (168) and Western Bay of Bengal (76). These surveys have resulted in 48 new species and 95 first zoo-geographical records from these regions. Although these efforts attempted to cover a significant portion of the EEZ, large lacunae in terms of geographical regions (the northeastern Arabian Sea and western Bay of Bengal) as well as ecosystems (abyssal sea floor, seamounts, guyots and mid-ocean ridges) need to be explored to unravel the biodiversity of the region.

Keywords: Indian Ocean, Marine Living Resources, surveys, documentation, repository

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Upwelling-induced hypoxia and transient macrobenthic responses off Mumbai coast

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ABSTRACT

The study examines the influence of seasonally induced hypoxia, associated with coastal upwelling, on the macrobenthic community structure off Mumbai coast in the Eastern Arabian Sea. Sampling was conducted at inner shelf stations located at depths of 20m, 30m, 40m and 50m during several months between 2017 and 2020. The intensity and duration of hypoxia exhibited interannual variability, with pronounced declines in dissolved oxygen (DO) concentrations recorded from the southwest monsoon to the northeast monsoon seasons in multiple years. Hypoxia was consistently more severe at the 40m and 50m stations compared to the shallower sites (20-30m). Sediment texture at all stations remained silty with no notable spatial or temporal variation. Polychaeta was the dominant component of the macrobenthic community under both normoxic and hypoxic conditions. With increasing hypoxia, the opportunistic polychaete family, Spionidae (68%) prevailed at shallower stations, whereas Cossuridae and Oligochaeta were predominant at depths of 40-50m, where DO levels approached near-anoxic levels. The emergence of Oligochaeta as a substantial group in sediments off Mumbai during hypoxic events was further reinforced by a significant negative correlation with DO. A notable presence of Echiura was also observed at the oxygen depleted 50m station during November 2017, indicating their adaptive capacity to low oxygen environments. Non-metric multidimensional scaling (nMDS) analyses showed a distinct peripheral cluster corresponding to the November 2017 hypoxic event, suggesting structurally different macrobenthic assemblages during this period. However, the composition of the benthic communities during other sampling periods remained relatively consistent, indicating overall structural stability despite episodic hypoxic perturbations. In summary, the results indicate that upwelling-driven hypoxia off Mumbai coast was transient, inducing only short-lived shifts in macrobenthic community composition without causing long-term structural disruption.

Keywords: hypoxia; upwelling; off Mumbai; macrobenthic community; polychaetes

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Abundance and Diversity of Meiofauna as Bioindicators of Environmental Health in Coastal Ecosystems of the Bay of Bengal.

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ABSTRACT

Meiofauna are highly responsive benthic organisms that react rapidly to changes in sediment quality, pollution, and habitat alteration, making them valuable bioindicators for assessing environmental health. Their abundance, community structure, and functional composition provide sensitive early-warning signals of ecosystem disturbance compared to traditional macrofaunal indicators. Despite their ecological significance, meiofaunal studies along the Indian coastline remain limited, particularly in ecologically dynamic zones such as the coasts and the mangrove-associated mudflats of the Bay of Bengal.

During preliminary sediment surveys along the Digha coast, Talassari eastuary (sandy intertidal zones) and Bichitrapur mangrove-associated mudflats, several key meiofaunal groups were recorded. These included foraminifera, flatworms, copepods, micromolluscs, juvenile polychaetes, and nematodes. Variations in the presence and relative abundance of these groups between habitats provide early indications of environmental differences related to sediment texture, organic matter, and tidal influence.

The aim of this study is to document meiofaunal diversity in this region and evaluate their potential use in routine ecological assessment. By comparing community patterns and applying basic diversity measures, this work seeks to establish baseline information that can support future coastal monitoring efforts by the Zoological Survey of India under the Deep Ocean

Mission.Overall, meiofauna show strong potential for use in rapid and cost-effective environmental assessment, and their inclusion in routine monitoring can improve our understanding of coastal ecosystem changes in the Bay of Bengal.

Keywords: Meiofauna**,** Bioindicators, Environmental Health, Coastal Ecosystems**,** Bay of Bengal.

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Decoding hidden Marine Biodiversity around Grande Island, Goa, using autonomous reef monitoring structures

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ABSTRACT

Coral reefs host large biodiversity and play an important role in ecosystem services, yet cryptic fauna, which make up two-thirds of the total reef biodiversity, are often overlooked due to their habitats and limited sampling methods. This study was carried out to investigate the cryptic fauna along with the benthic fauna of coral reefs around Grande Island, Goa, using Autonomous Reef Monitoring Structures (ARMS) and underwater video transects across the island. Underwater video transects conducted in ten reef sites across Grande Island revealed an average benthic composition of 21% live coral, 8% macroalgae, 14% coralline algae, and 45% rock with algal assemblages. ARMS retrieved after two years were documented with diverse cryptic fauna representing phylum Arthropoda, Mollusca, Polychaeta, Echinodermata, and Chordata. All the representative specimens were morphologically identified and archived in IndOBIS. This identification was complemented with molecular taxonomy using COI, 18S rRNA, and 28S rRNA gene markers for species-level resolution. In addition to the molecular taxonomy, the overall community composition on the ARMS structures was captured using DNA metabarcoding with short gene fragments of COI and 18S rRNA fragments for the metazoan community and 16S rRNA metagenomics for microbial assemblages associated with the structures. This study provides comprehensive data considering both cryptic and mega benthic biodiversity of the coral reefs of Grande Island, Goa. The data generated from these methods can help identify gaps in conservation and establish surveillance with effective management strategies.

Keywords: Marine Biodiversity, Coral Reefs, Autonomous Reef Monitoring System, Cryptic Fauna, DNA Metabarcoding

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A preliminary study of some marine meiobenthic faunal groups of the Digha and adjacent areas, Bay of Bengal

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ABSTRACT

Meiobenthic fauna represents one of the most important faunal communities for marine ecosystems, as they serve as bioindicators of environmental health, pollution, and climate change. A survey on meiofaunal communities along the Digha coast was conducted with the aim of conducting a preliminary study on the diversity and distribution of meiofaunal groups. In the present study, the diversity and distribution of marine meiofaunal groups are observed in different habitats, including sandy shores, estuaries, and mangrove areas, at Digha and its adjacent coastal areas. Observations on meiofaunal communities were made based on samples collected from intertidal areas between the high-tide and low-tide zones during low tide. The study revealed that free-living marine nematodes are the most abundant group among the meiofaunal communities found along the Digha coastal areas, followed by the protozoan group. Along with the phylum Nematoda, there are some other taxa of the meiofaunal group, viz. Gastrotricha, Polychaeta, Turbellaria, Nemertea, Foraminifera, Copepoda, and some larval forms were observed during the study period. In the present investigation, maximum diversity of meiofaunal communities is found in the estuary area, followed by the mangrove and the sandy beach. Meiofaunal assemblages are documented with the highest density in the surface layer of the sediments and in the high tide level zone than in the deeper sediments and the low tide level zone. From the Champa estuary, nematode genera Sabatieria sp., Daptonema sp., Anoplostoma sp., and Metachromadoroides sp. are more abundant than the least abundant genera Mesacanthion sp., Cobbia sp., Terschellingia sp., and Dorylaimopsis sp. In the sandy beach area, Daptonema sp., Mesacanthion sp., Viscosia sp., Oncholaimellus sp., Cyathoshiva sp., Eleutherolaimus sp. and Ptycholaimellus sp. are more abundant groups. The nematode species Mesacanthion armatum Timm, 1961, is found throughout the Digha coast, and Parasphaerolaimus bengalensis Manna, Balakrishnan & Ansari, 2025, is another nematode species restricted to the Champa estuary area. Some juvenile forms of polychaete species Scoloplos (Scoloplos) sp., Glycera sp., and foraminifera genus Asterorotalia sp. were found. The present investigation aims to document the available meiofaunal groups in the Digha coastal area, although more meiofaunal species remain unidentified. Therefore, further research is needed in this region to better understand the ecology, diversity, and distribution patterns of meiofaunal communities.

Keywords: Meiofauna, Marine, Nematoda, Polychaeta, Diversity

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A new species of free-living marine nematode of the genus *Cyathoshiva* (Chromadorida: Cyatholaimidae) from the Bay of Bengal

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ABSTRACT

Free-living marine nematodes are among the most abundant groups of meiofaunal communities found in sediments throughout marine environments. Nematodes are considered environmental indicator species and play a crucial role in the marine food web. Studies on the taxonomy of free- living marine nematodes are going on worldwide. Globally, more than six thousand species have been described, and six hundred and fifty-six species have been recorded from the Indian coast, according to published literature. In the present study, a new species of free-living marine nematode, Cyathoshiva bifurcum sp. nov., from the Bay of Bengal, Indian coast, is described and illustrated based on its morphological characteristics. The new species was collected from the muddy sediments of the Bichitrapur mangrove sanctuary in Odisha, India, near the Subarnarekha River, which flows into and merges with the Bay of Bengal. The new species Cyathoshiva bifurcum sp. nov., belonging to the order Chromadorida Chitwood, 1933, is characterized by a cylindrical body with a tapered anterior end and a filiform tail, a cuticle with transverse punctations and longitudinal rows of pores, six outer labial sensilla and four cephalic sensilla arranged in one circle, a buccal cavity with one large dorsal tooth and two small ventrosublateral teeth. multispiral amphideal fovea with 4-4.5 turns, cheilostoma with twelve cuticularized rugae, cylindrical muscular pharynx posteriorly widened, male with paired testis situated on both sides of the intestine, arcuate spicules with distal end bifurcated, paired gubernaculum proximally fused, two to three precloacal supplements, female with didelphic-amphidelphic ovaries, tail is filiform. The genus Cyathoshiva Datta, Miljutin, Chakraborty & Mohapatra, 2016 was first described as monotypic, having only one species, namely Cyathoshiva amaleshi Datta, Miljutin, Chakraborty & Mohapatra, 2016, from the coastal areas of West Bengal, India. The new species can be differentiated from the existing species C. amaleshi of the genus Cyathoshiva by the presence of a filiform tail vs. a conical tail in C. amaleshi, spicules with a bifurcate distal end vs. spicules with a pointed distal end in C. amaleshi, and total body length and maximum body width are larger compared to C. amaleshi. This is the second species description under the genus Cyathoshiva from the Bay of Bengal, India.

Keywords: Meiofauna, Morphology, Description, India, *Cyathoshiva bifurcum* sp. nov.

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Characterization of pigments in two photosynthetic sea slugs from Indian mangrove ecosystem

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ABSTRACT

In the animal kingdom, the photosynthetic sea slug (Mollusca, Gastropoda) represents nature's most remarkable symbiotic phenomenon, known as 'kleptoplasty'. Through kleptoplasty, emerald green sea slugs retain functional chloroplasts (kleptoplasts) from herbivorous algal prey and perform photosynthesis to sustain their own metabolism. This article presents the first comprehensive characterization of pigment profiles of two photosynthetic sea slugs, *Elysia bangtawaensis* (Swennen, 1998) and *Ercolania tentaculata* (Eliot, 1917), following starvation from the Indian mangrove habitat. The HPLC pigment analysis of *E. bangtawaensis* kleptoplast demonstrated eleven photosynthetic pigments prevalent of green algae including chlorophyll (Chl.) *a*, *b*, violaxanthin, 9 cis neoxanthin, lutein, and canthaxanthin as well as signature pigments from the brown algae, specifically fucoxanthin and 19' HF. Conversely, eight photosynthetic pigments were observed in *E. tentaculata*: two chlorophylls (Chl. *a* and *b*), four xanthophylls (peridinin, diatoxanthin, lutein, and canthaxanthin), and two carotenes (alpha and beta). In both species, the pigment concentrations substantially declined from fresh (non-starved) slugs towards the end of the starvation period. The significant reduction in the Chl. *b*/*a* ratio reflected a specific depletion of light-harvesting complex II elements, whereas a noteworthy rise in the carotenoids/Chl. *a* ratio suggested an upsurge of photoprotective pigments under nutritional limitation. Overall, the pigment composition of these two photosynthetic sea slugs contributes to unravel the unsolved mysteries of kleptoplasty within the animal kingdom, providing crucial insights into the functional longevity of kleptoplasts and their photoprotective properties.

Keywords: Photosynthetic sea slug; kleptoplasty; photosynthetic pigments; chlorophyll, starvation.

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A revision to the nematode genus *Robustnema*, (Xyalidae, Monhysterida, Nematoda), along with the redescription of *Daptonema fosteri* from the coastal estuarine habitats of South Gujarat.

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ABSTRACT

Nematodes are the most dominant group of organisms among the benthic meiofaunal community. They serve various important roles in the ecosystem and are a vital part of the marine food web. Estuaries are dynamic ecosystems with a constant influx of material from the land and are often one of the most anthropogenically affected habitats. Understanding the faunal composition of estuaries is vital to estimating their resilience to external changes. Xyalidae is one of the most diverse families of marine nematodes, comprising 50 genera and 535 species. This study suggests a revision to the generic status of the genus *Robustnema* and its inclusion within *Daptonema*, along with a redescription of the only described species in the genus from the estuarine habitats in south Gujarat, India. *Daptonema fosteri* is characterised by a stout body, annulated cuticle, a small buccal cavity devoid of any armament, depressed lips forming a dome, cephalic and outer labial setae located in a single ring, circular amphid, 10 pairs of post anal somatic setae, strong male spicule, and vulva located close to the anal opening. The male gonad does not extend beyond the mid-body anteriorly. The female gonads are devoid of developing embryos, as seen in eastern Australia. Both males and females are smaller than *D. fosteri* specimens from Australia. These characters are similar to other species described within the genus Daptonema, such as *Daptonema hirsutum*, *Daptonema longiapophysis* and *D. stagnalis*, and thus the genus status of *Robustnema* cannot be justified. Thus, the species *R. fosteri* should be moved into the genus *Daptonema* as *Daptonema fosteri*.

Keywords: Nematode; Taxonomy; Gujarat; Xyalidae; Estuary

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Benthic-pelagic coupling: Shaping nematode communities along the Central Arabian Sea

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ABSTRACT

Benthic-pelagic coupling plays a pivotal role in shaping deep-sea benthic communities. It is regulated by the production, transformation, and export of particulate organic carbon (POC) from surface waters to the deep ocean. In this study, we investigated the influence of benthic-pelagic coupling on nematode community structure, biomass, and secondary production (based on nematode) along the northern and southern transect in the Central Arabian Sea (64°E longitude). Sediment samples collected for meiofaunal analysis from different stations located in the northern and southern Arabian Sea revealed distinct variations in environmental and biological parameters. Total organic carbon (TOC), total nitrogen (TN) content and particulate organic matter (POC) were higher at the northern station due to high sinking rate of particulate organic carbon (POC) to the seabed, indicating a greater flux of labile organic matter. Correspondingly, nematode abundance and biomass were significantly higher in the northern Arabian sea compared to the southern Arabian sea. Estimated secondary production and Production-Biomass (P/B) ratios suggest a higher energy transfer efficiency in the northern station, reflecting stronger benthic-pelagic coupling driven by enhanced surface productivity. In contrast, the southern station exhibited reduced biomass and production, likely due to limited organic inputs, lower POC and altered sedimentary conditions thus resulting in slow sinking of the organic matter to the seafloor. These results highlight the sensitivity of deep-sea nematode communities to variations in surface derived organic fluxes and show the important role of benthic-pelagic coupling in regulating ecosystem functioning in the abyssal Arabian Sea.

Keywords: Particulate organic matter (POC), Arabian Sea, Secondary production, Benthic, Nematode

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Decadal analyses of macrobenthos of a tropical estuary: spatio-temporal shifts, trends and ecological assessment

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ABSTRACT

A decade-long (2013-2023) study of the tropical Amba estuary revealed remarkable stability in abiotic parameters, with spatial gradients and seasonal monsoonal influence dominating over long-term shifts. 134 taxa were identified, with polychaetes being the most abundant taxa (>65%). Opportunistic polychaetes, particularly, *Paraprionospio cristata*, *Namalycastis senegalensis*, and *Capitella capitata*, dominated post-monsoon communities, reflecting natural cycles of colonization and replacement. The numerically dominant species varied each year indicating robust species turnover, likely influenced by biological processes. Multivariate analyses indicated strong spatial structuring, with salinity as the key driver of benthic distribution, consistent with other tropical estuaries. Although year-to-year shifts in dominating species were noted, the consistent long-term chemistry from 2013 to 2023 clearly led to little temporal differences in species compositions for the majority of years. The estuarine ecological quality status using AZTI Marine Biotic Index (AMBI) was largely similar from 2013 to 2023, while it varied throughout the estuary, indicating spatial variability. This study provides the first long-term ecological analyses for any Indian estuary, emphasizing the role of salinity gradient and anthropogenic stressors in shaping macrobenthic communities. These findings underscore the need for sustained biomonitoring for pertinent conservation and management policies.

Keywords: Macrobenthos, long-term monitoring, tropical estuary, salinity gradient, AMBI.

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Deciphering the bioindicator potential and phenotypic plasticity of eunicidae in coralline reef ecosystems: global patterns to local observations

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ABSTRACT

Eunicidae, a prominent family of polychaetes, function as reliable bioindicators of coral reef ecosystems. Global patterns revealed their consistent dominance across diverse reef systems. Indicators of both healthy and deteriorated reefs, eunicids work in symbiotic relationships with corals and serve as both eroders and builders of coral reefs, encouraging development through aggregation and causing structural loss when bioerosion exceeds natural thresholds. The dominance of Eunicidae was further supported by our observations in the contrasting coralline reefs of the Gulf of Kachchh (GoK) and Gulf of Mannar (GoM) Marine Protected Areas, two of India's four main coral reef ecosystems. *Lysidice unicornis*, abundant in these reef systems, was selected as a model organism to investigate phenotypic plasticity manifested in morphological, behavioural, and life-history traits. The morphological plasticity revealed clear regional variations. Smaller forms were evidently resultant of strong currents, high sedimentation, and localised pressures in GoK, while more robust k-selected morphologies with larger body dimensions, feeding structures, locomotory appendages, and setal features were preferred in the ecologically stable GoM. Behavioural traits such as motility, feeding modes, living habitat, and sediment position also displayed plasticity, while life-history traits remained largely conserved. Specific environmental parameters were linked to trait expression in Eunicidae, with total organic carbon and silt being the most important factors in GoK and GoM, respectively. These results demonstrate how different environmental regimes and ecological stresses shape the phenotypic plasticity of *Lysidice unicornis*. Their dominance in both reef systems indicated robust conditions, probably due to the protection accorded by the MPA status.

Keywords: Eunicidae, Coral Reef, Phenotypic Plasticity, *Lysidice unicornis*, Marine Protected

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Shelters of the deep: Benthic fauna within Sponges of the Andaman Seamounts

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ABSTRACT

Seamount ecosystems are major contributors to deep-sea biodiversity, where sponge grounds represent a dominant feature of the benthic environment. These extensive biogenic habitats significantly increase local species richness, acting as 'living hotels' for a wide range of invertebrates, such as ophiuroids, polychaetes, nematodes, molluscs, etc. Critically, the diversity of sponge-associated fauna (SAF) in Indian Ocean seamounts is largely unexplored. Therefore, the current study provides the first comprehensive assessment of SAF from the seamounts of the Andaman Sea. Sponge specimens, were collected using grab and dredge samplers, from the Cratered Seamount (CSM), Seawell Rise Seamount (SRS), and Alcock Rise Seamount (ARS). A total of 8 different hexactinellid sponge species were obtained across these locations and analyzed to characterize their associated benthic communities. The distribution of hexactinellids were varied based on the geomorphological characterictics of the region such as bathymetric gradient and could be its related environmental conditions. The Volume of the sponge was measured using water displacement method and the abundance was later standardize to ind./1000 mL of sponge volume. In total, 330 macrofaunal individuals belonging to 43 families across 16 higher taxa and 2,173 meiofaunal individuals representing 9 major groups were recorded. The assemblages were dominated by Nematoda, Foraminifera, and Copepoda, along with notable contributions from Polychaeta, Ostracoda, and Isopoda. Among macrofaunal assemblages, sponges from the CSM summit exhibited the highest diversity (H'= 2.723), while SRS and ARS displayed lower diversity with higher dominance by a few taxa. For meiofauna, the SRS summit showed the highest diversity and evenness, whereas the CSM summit exhibited the greatest species richness but lower evenness. Additionally, megafaunal individuals such as Ophiuroidea and Nudibranchia were found associated with sponges at the SRS summit. Spatial variations in SAF composition were attributed to differences in sponge morphology, internal canal structure. Overall, the findings highlight that sponges serve as vital biogenic habitats that sustain complex and functionally diverse faunal assemblages, thereby enhancing benthic biodiversity and ecosystem functioning on the seamounts.

Keywords: Sponge-associated fauna (SAF), Hexactinellid, Macrofauna, Meiofauna, Cratered seamount (CSM)

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The distribution ecology and epifaunal assemblages of the cyanobacteria (Symploca hydnoides) are influenced by the abiotic factors of surface water in tropical islands.

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ABSTRACT

Cyanobacteria are unicellular organisms that often form blooms and can also take the form of macroscopic algae such as *Symploca hydnoides*. However, the distribution ecology and faunal assemblages of these macroscopic cyanobacteria are limited in the Indian Ocean. Within this framework, this study aimed to assess the distribution ecology and epifaunal assemblage of S. hydnoides from the intertidal habitats of the Andaman and Nicobar Islands (ANI) in India. We also tested the correlations between physicochemical parameters (salinity, water temperature, and pH) of surface water and the biochemical constituents (ash content, crude fat, carbohydrate, and protein), as well as the epifaunal assemblages of *S. hydnoides*. Significant variation ($p<0.05$) in ash, crude fat, carbohydrate, and protein content was observed in *S. hydnoides* tissues across the six locations. Significant negative correlation ($r=-0.78$, $p< 0.05$) was observed between water temperature and the fibre content, indicating that an increase in temperature reduces fibre content of *S. hydnoides.* Canonical Correlation Analysis indicated that water temperature, salinity, and pH had maximum variational effects (75.6%) on the amphipod and foraminifera assemblages of *S. hydnoides* across the six locations. Nine epifaunal taxa were recorded on *S. hydnoides*, with Amphipoda being the dominant taxon. Across the locations, Marina Park had the highest Margalef's species richness (d; 2.346), Shannon-Weiner diversity (*H';*1.822), and Simpson's Index (1-λ; 0.754), with Kodiyaghat showcasing increased Pielou evenness (*J';*0.815). This study highlights that the distribution ecology of *S. hydnoides* is affected by abiotic factors in surface water, which need to be monitored along the coast of ANI, India, for assessing cyanobacterial blooms.

Keywords: Algal blooms, biochemistry, Andaman and Nicobar, Indian Ocean, Amphipod

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Evaluation of ecosystem-based services of mangrove ecosystem in the gulf of mannar, southeast coast of india

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ABSTRACT

Mangrove ecosystems in the Gulf of Mannar provide vital ecosystem services supporting coastal livelihoods and environmental stability. This study assessed community perception of these services in Chinnapalam, Tamil Nadu, India, through a survey of 126 respondents in which 98 males and 28 females and their mean age 42.0 ± 12.6 years; mean income ₹17,642 ± 3,410/month). We used a five point Likert scale, key services rated highly included storm and cyclone protection (4.48 ± 0.68), flood control (4.38 ± 1.06), livelihood support (4.40 ± 0.91), coastal erosion reduction (4.29 ± 1.00), and water quality maintenance (3.94 ± 1.20). Supporting services such as breeding and nursery grounds (3.92 ± 0.89) and then biodiversity value (3.75 ± 0.94) were also recognized. Restoration participation was reported by 66.7% of respondents, and 100% recommended mangrove conservation prioritization with preference for community management. Ecosystem service perception was consistent across income groups which highlighted an universal reliance on mangroves. Positive correlations between regulating services reflected ecological interdependence. However, only 39.7% perceived government support as adequate therefore this indicates conservation challenges. This study's findings could benefit for the ecological and socioeconomic importance of mangroves in the Gulf of Mannar Biosphere Reserve and support integrated conservation and sustainable resource management efforts.

Keywords: Mangrove ecosystem, ecosystem based services, community perception, Gulf of Mannar, conservation management.

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A novel cryptic gene from Marine bacteria *Cytobacillus oceanisedimis* encoding imipenem specific degrading enzyme: A Potential Threat to Antibiotic Therapy

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ABSTRACT

Marine bacteria possess an inherent ability to survive in harsh, unstable, high salinity and extreme environments, largely due to their highly adaptable and plastic genome. Microbial genomes are often enriched with cryptic or silent genes; however, the role played by these genes in the evolution of antimicrobial resistance remains poorly understood. Although cryptic genes generally lack immediate functional roles, they act as versatile endogenous genetic resources that enable bacterial adaptation and the evolution of new phenotypes under changing environmental conditions. In this study, we demonstrate that cryptic genes can serve as reservoirs or building block for the emergence of novel, next-generation antimicrobial resistance genes capable of conferring resistance to the host bacteria against both current and future antibiotics. Here, we report the identification of a cryptic metallo-β-lactamase gene from the novel marine bacterium *Cytobacillus oceanisediminis*, isolated from the Gulf of Mannar, India. extensive *in silico*, *in vitro*, and *in vivo* analyses revealed that the cryptic gene BMBL282 in *C. oceanisediminis* encodes a protein capable of hydrolyzing imipenem. Remarkably, this gene shows no sequence homology with known imipenem -type metallo-β-lactamase genes but harbors two conserved motifs—HXHXDH and TPGH—typical of metallo-β-lactamases. These findings highlight the importance of systematic exploration of both expressed and cryptic resistance genes to fully understand and combat the growing threat of antimicrobial resistance. To the best of our knowledge, this is the first report of a novel cryptic gene from *C. oceanisediminis* capable of degrading imipenem but not other carbapenem antibiotics.

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Marine fungal bioprospecting: unlocking oleaginous strains for a sustainable future

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ABSTRACT

Marine fungi represent an emerging and underexplored biological resource with significant potential for sustainable biotechnology. Unlike terrestrial fungi, marine-derived species have evolved under fluctuating salinity, nutrient limitation, and intense ecological competition— conditions that often drive the synthesis of unique metabolites, stress-tolerant enzymes, and lipid-rich biomass. While studies on marine fungal oils are still limited, extensive evidence from terrestrial fungi and oleaginous yeasts demonstrates their ability to produce a wide spectrum of lipids, from storage triacylglycerols to structurally diverse polyunsaturated fatty acids. Given the rising global demand for renewable bio-based alternatives, fungal lipids hold strong promise across sectors including biofuels, nutraceuticals, cosmetics, pharmaceuticals, and agriculture.

In this study, we explored marine fungi associated with seaweeds and coastal sediments along the Indian coastline for their lipid bioprospecting potential. Among the isolated and characterized strains, Pichia sp. and Rhodotorula sp. emerged as particularly promising candidates due to their strong lipid accumulation abilities and efficient biomass conversion. Preliminary lipid profiling revealed that Pichia sp. produced ~80–85% total lipid content (w/w), while Rhodotorula sp. yielded ~21% (w/w). The exceptionally high lipid productivity, stress resilience, and fermentation suitability of Pichia sp. position it as an excellent candidate for scalable microbial lipid production.

This work highlights the substantial yet largely untapped biotechnological value of marine fungi and underscores their potential to contribute to future sustainable lipid-based industries.

Keywords: Marine fungi, Oleaginous yeasts, Lipid-rich biomass, Fungi oil, Bioprospecting

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Ocean To The Clinic: Marine Bioresources, Neuro-Immune Modulation And Emerging Possibilities For Liver Therapeutics.

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ABSTRACT

The ocean is perhaps the most generous biological system on the planet, yet its potential in liver medicine is only beginning to be explored. At a time when chronic liver diseases—fatty liver, cholestatic injury, fibrosis and eventually cancer—are growing at an alarming rate, particularly in countries like India where MASH (Metabolic dysfunction-Associated Steatohepatitis) is emerging as a major public health burden, our therapeutic toolbox remains limited. Lifestyle-driven metabolic disease, urbanization, dietary transitions and rising obesity are pushing India toward a silent liver epidemic. Present treatments can slow progression, but rarely reverse fibrosis or regenerate lost hepatic tissue. Transplantation remains the final option, yet access is uneven and donor numbers cannot match demand. This compels us to search beyond conventional pharmacology—to look outward, and often downward, toward the ocean.

Our experimental work in a liver-specific sympathetic denervation model (6-OHDA) combined with bile duct ligation indicates that neural tone plays a decisive role in how the liver responds to injury. Preliminary proteomics suggest major shifts in oxidative stress handling, extracellular matrix remodeling, and adrenergic immune regulation. These insights reinforce the idea that the nervous system is not only a background actor, but a regulator capable of steering fibrosis either toward progression or resolution.

Marine bioresources align strikingly well with these mechanistic observations. Fucoidan, phlorotannins, laminarin and omega-3–derived pro-resolving mediators exhibit anti-oxidative, anti-steatotic and anti-fibrotic effects—properties essential for combating MASH-driven inflammation and metabolic stress. Likewise, marine collagen, alginate and chitosan-based scaffolds may support regeneration or organoid modelling to evaluate therapeutic interventions for metabolically injured livers. By merging ocean-derived molecules with neuro-immune mechanistic understanding, we open a practical and sustainable pathway for liver health in India and beyond—one that aspires not only to slow disease, but to restore what the liver loses.

Keywords: MASH (Metabolic dysfunction-Associated Steatohepatitis); Liver-specific sympathetic denervation ; Animal model, Fucoidan; Phlorotannins; Laminarin'; Omega-3–derived pro-resolving mediators; Marine Collagen, Alginate; Chitosan-based scaffolds; MASH-driven inflammation; Metabolic stress.

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Jellyfish Collagen: Enhanced Nutraceutical And Wound Healing Application

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ABSTRACT

Jellyfish blooms have been a constant menace to fishermen community with climate change and ocean pollution contributing to their increasing bloom occurrences, causing both economical and practical difficulties. An innovative approach to utilise this biomass, otherwise left to rot on the beach, is by extracting collagen which possess both nutraceutical and pharmaceutical applications. The bioactivity studies of jellyfish collagen showed superior potential in comparison to currently considered bovine and porcine collagen. Additional advantages of jellyfish collagen is negligible immunogenicity in the human system, free from risk of transfer of zoonotic diseases and free of religious and cultural constrains. The amino acid study revealed the presence of neuroprotective amino acids such as tryptophan and glutamine; cysteine and methionine that is crucial for wound healing; serine with both the above mentioned properties. Elemental composition study revealed jellyfish collagen is free of harmful elements and safe for use in human system. Antioxidant studies showed superior results on comparison with commercially available marine collagen (fish collagen), Ascorbic acid, FeCl2 standard, BHT standard and curcumin. Cytotoxicity study in L929 cells using jellyfish collagen showed 100% cell viability. In-vitro Wound Healing study in untreated (control) L929 cells using jellyfish collagen showed 20% wound closure in the first 24 hours and 30% wound closure in the next 48 hours. The cumulative interpretation of the results confirms its safety and biocompatibility indicating it to be the best alternative source of collagen for nutraceutical and pharmaceutical application. One noteworthy mention is its potential to accelerate wound healing. This technology transforms “waste to wealth” thereby reducing biological waste, present a safer alternative to terrestrial collagen and livelihood to the fishermen community.

Keywords: Jellyfish Collagen, Wound Healing, Bio-Sustainable Collagen, Nutraceutical Application, Pharmaceutical Application

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Optimising Nutrient Dynamics to Enhance Lipid and FAME Profiles in a Halotolerant Marine Microalga for Blue Bioenergy Applications

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ABSTRACT

Marine microalgae serve as powerful sunlight-driven biocatalysts for blue bioenergy production. In this study, a halotolerant microalga isolated from hypersaline salt pans was characterized through light and ultramicroscopy (SEM and TEM) and 18S rRNA sequencing (KR871012), confirming its affiliation to *Halosarcinochlamys*. Extensive nutrient-based optimization was conducted to evaluate the influence of culture media, buffer amendments, and starvation on growth kinetics and lipid biochemistry**.** Four medias (F/2, Walne, Keller's and Antia's) were compared. Antia's medium supported the highest specific growth rate (μ = 1.18 d^{-1}), while F/2 enabled superior total lipid accumulation (54.17 g/100 g) and a biodiesel-favourable FAME profile enriched in SFAs (70%) and MUFAs (24%). Walne medium enhanced carbohydrates and proteins but showed lower lipid quality. These patterns reflected a clear growth–lipid trade-off, a well-known bottleneck in algal biofuel optimisation. Building on these results, F/2 was further improved by buffer supplementation. Tris at 0.5 g/L boosted lipid content (48.43 g/100 g) and lipid productivity, while higher Tris or glycine levels primarily accelerated growth (μ up to 1.72 d^{-1}) with reduced lipid benefits. FAME analysis showed glycine-driven PUFA enrichment and selective shifts in saturation patterns, indicating strong metabolic flexibility. Starvation studies revealed powerful lipid-inducing responses. Nitrogen depletion elevated lipids to 64.69 g/100 g but reduced biomass. Moderate N-limitation balanced both, achieving the highest lipid productivity (126.16 mg L^{-1} d^{-1}). Phosphate starvation, in contrast, maintained steady growth while enhancing MUFA-rich FAMEs, improving fuel quality.

Overall, the integration of nutrient screening, buffer optimisation and targeted starvation demonstrates that this halotolerant microalga possesses remarkable biochemical adaptability and strong biofuel potential, supporting its future deployment in ocean-based biorefineries.

Keywords: microalgal lipids, nutrient optimisation, FAME analysis, kinetic parameters, blue bioenergy

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Unlocking biotechnological potential of deep-sea microbes: Functional metagenomic screening of Arabian Sea seamount Libraries for next-generation biostimulants and biopolymers

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ABSTRACT

Oceans represent unique and dynamic ecosystems whose physiochemical properties sustain diverse marine life, allowing extremophilic microbes to thrive that underpin functional biodiversity. Seamounts are typically regarded as microbiome hotspots that harbor extremozymes and act as oases for screening bioactive compounds towards industrial applications. This study aimed to bio-prospect phosphatase enzymes and biopolymers using functional metagenomics approach by constructing Arabian Sea seamount sediment fosmid metagenomic clone libraries. Marine sediment samples were collected using NIOT Sagar Manjusha ORV (SAMA 10) during November 2022 Arabian Sea expedition from the seamount bottom (Station-5, NIOT-MASM2B, 12.98°N/73.60°E, 850m) and top (Station-6 NIOT-MASM2T, 12.96°N/73.53°E, 280m). Out of 1344 pooled clones, 42 were found to be functionally positive for phosphatase in agar plate screening. Five clones with high phosphatase activity were further characterized, wherein NIOT-F41 showed 41.2 U/mg specific activity and validated by Nanopore sequencing, revealing phosphate-solubilising bacteria *Pseudomonas spp.*, *Bacillus spp.*, harboring phosphatase genes (*phoC*, *phoD*). Plant growth promotion using pot assay showed that potential clones exhibited positive impacts on shoot length (9.1 ± 1.1 cm, $p < 0.05$), root length (2.05 ± 0.05 cm, $p < 0.05$) compared to negative control, indicating their biostimulant applications for Agriculture. Further pooled metagenomics clones were screened for biopolymers (polyhydroxyalkanoates, PHA) using high-throughput-FACS-based screening by BODIPY staining (493/503) and single positive cells with highest fluorescence were sorted for further analysis. Out of 1344 pooled clones, C9 (SAMA10-MASM2B) and E4 (M-ASM2T) showed highest fluorescence 54754AU and 58345AU, which yielded 53% and 60% PHA, respectively. Functional characterization of potential C9 clones by GC-MS revealed fatty acids in comparison with standard and confirmed its functional groups (O-H, N-H, C=O, C=C) by FT-IR analysis. This proof of concept study highlights that functional metagenomics approach could enable the discovery of novel biostimulants and biopolymers from unique seamount sediment microbiome to be conserved as living repositories for developing green innovation and industrial biotechnological applications.

Keywords: Arabian Sea seamounts, bio-resource conservation, functional metagenomics, biopolymers, bio-stimulants, sustainable Agriculture

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Exopolysaccharide Production and Genome Mining of NIOT.M2S2SY3: A Candidate Novel Species from the Arabian Sea Seamounts

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ABSTRACT

The deep ocean conceals a vast spectrum of life, thriving under extreme conditions that inspire scientific innovation. Seamounts, with their distinct hydrography and topography, support rich and varied ecosystems that play a crucial role in maintaining marine biodiversity and advancing human sustainability. In this study, nine sediment samples from a seamount in the Arabian Sea were analysed for bacterial diversity and screened for exopolysaccharide (EPS) production. Out of 238 bacterial isolates obtained, 52 tested positives for EPS, with the actinobacterial strain NIOT.M2S2SY3 exhibiting notably high yield and bioactivity. Initial 16S rRNA gene analysis revealed a phylogenetic relationship to *Microbacterium* spp., whereas whole-genome sequencing and TYGS (Type Strain Genome Server) analysis showed closest similarity to *Microbacterium hydrothermale (99.82%)*. The genome of strain NIOT.M2S2SY3 spans 3.56 Mb and comprises 3,417 coding sequences. However, its Average Nucleotide Identity (82.6%) and Digital DNA-DNA hybridization values (26.4%) with

M. hydrothermale fall below species delineation thresholds, suggesting it represent a potential novel species. Functional annotation using KEGG and COG databases revealed three pivotal genes, that are associated with exopolysaccharide (EPS) biosynthesis, regulation, and export. Notably, Gene_00073 encodes glycosyltransferases homologous to *WcaL*, *AmsK*, and *CpsK*, which are known to initiate EPS assembly by transferring L-fucose and D-rhamnose. AntiSMASH analysis further revealed a highly similar ε-poly-L-lysine (ε-PL) biosynthetic gene cluster, known for its antimicrobial properties. The extracted EPS exhibited potent antibiofilm activity against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli*, and showed high emulsification indices of 95% (coconut oil) and 90% (benzene). These findings highlight the biotechnological promise of this deep- sea actinobacteria, particularly in pharmaceutical and industrial applications. The study highlights the ecological and functional uniqueness of NIOT.M2S2SY3, particularly its novelty and previously unreported EPS production, opening new avenues for the discovery and application of marine microbial metabolites.

Keywords: Actinobacteria, Exopolysaccharide, Antibiofilm, Genome mining.

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Structural characterization and immunostimulatory potential of exopolysaccharides from a coral associated Brachybacterium sp.

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ABSTRACT

Microbial exopolysaccharides (EPS) are gaining traction emerging as eco-friendly biopolymers with a wide range of functional uses, especially as immune boosters. This study aimed to evaluate deals the immunostimulatory property of with the isolation of Brachybacterium strains and assessed the immune-enhancing potential of their EPS using Artemia nauplii as ab in vivo model organism., a well-established in vivo model in aquaculture. Ten bacterial isolates were screened for Artemia toxicity and selected three strains with significantly higher survival rates at 96hrs were screened for EPS production. EPS produced from two isolates (MMRF 2105 and 2049) was then harvested from culture filtrates supernatants using ethanol precipitation and purified. The structural characterization with FTIR spectroscopy confirmed the presence of hydroxyl, carboxyl, and glycosidic bonds in MMRF 2105 and 2049. Artemia nauplii were exposed to different EPS concentrations, then challenged with pathogenic *Escherichia coli*. Survival rates post 24hrs of challenge were assessed and a clear dose-dependent benefits could be observed- higher EPS levels significantly improved Artemia survival after infection. The innate immune parameter Prophenoloxidase also showed significant increase at higher EPS concentration. These results indicate that the EPS enhances stress resilience and possible immunostimulation in Artemia and activates innate immune defenses. Overall, the study highlights that EPS from Brachybacterium species have strong immunostimulatory effects. These results highlight the potential of EPS produced by MMRF 2105 and 2049 as immunostimulatory agent for disease management in aquaculture.

Keywords: Exopolysaccharides (EPS), *Brachybacterium* sp., Immunostimulation, Artemia, Aquaculture

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Investigating Therapeutic Properties of Marine Fish Venom Proteins against Breast Cancer Cell Lines

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ABSTRACT

Breast cancer continues to be a major global health issue, and there's a constant need for new, effective treatment options with less side effects. Marine venomous fishes increasingly recognized as valuable sources of complex bioactive enzymes and peptides rich venoms. They have potent anticancer properties due to their ability to trigger programmed cell death in tumour cells. In this study, we have selected a venomous fish named Star gazer (Uranoscopus sp.) to explore its bioactive molecules with target-specificity to treat the breast cancer cells. This study focuses on isolating venom proteins from Uranoscopus sp. and evaluating their antioxidant properties against breast cancer cell lines Venom proteins from Uranoscopus sp. were extracted using standard homogenization and centrifugation methods, followed by quantification and characterization through FPLC, LC-MS, and NMR. Biochemical assays, including protease activity, L-amino acid oxidase (LAAO) activity, DNase activity, haemolytic activity, and hyaluronidase activity, were performed to evaluate the functional properties of the crude venom.

The antioxidant potential was assessed using the DPPH assay, while cytotoxicity was evaluated through the MTT assay in MCF-7 and MDA-MB-231 breast cancer cell lines. The extracted protein showed an average yield of 1.8–2.4 mg/mL, and the positive results from preliminary biochemical assays indicate a strong cytolytic potential for the venom. The IC_{50} range of 10–24 µg/mL suggests moderate to strong radical scavenging activity, while the cytotoxicity evaluation revealed that approximately 30 µg/mL of venom caused cell lysis in cancer cell lines after 24 hours of treatment.

We believe that the present work will provide insights on venom protein application in the field of marine pharmacology and oncology.

Keywords: Marine fishes, Uranoscopus sp., Venom proteins, Anti-cancer, Apoptosi

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Marine Microalgae: A Sustainable Resource for the Blue Economy

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ABSTRACT

Marine microalgae are emerging as pivotal resources for advancing the blue economy through their contributions to biodiversity conservation, climate change mitigation, resource efficiency, and sustainable economic development. Their photosynthetic efficiency, rapid growth, short life cycle, and ability to thrive in extreme environments make them promising candidates for addressing the rising global demand for food, energy, and bio-based products. Cultivation of microalgae in systems such as photobioreactors, raceway ponds, and floating marine reactors eliminates the dependence on arable land and freshwater, thereby promoting ecological sustainability. Microalgal biomass serves as a versatile feedstock for the extraction of a wide range of value-added bioproducts, including pigments (fucoxanthin, β-carotene, astaxanthin), carbohydrates, proteins, vitamins, sterols, phenolic compounds, minerals, biopolymers [polyhydroxybutyrate (PHB), polylactic acid (PLA)], and essential oils rich in omega-3 fatty acids. These compounds exhibit diverse applications in the nutraceutical, pharmaceutical, cosmetic, and bioenergy industries. The market for microalgae-derived products has been estimated to generate multi-billion-dollar revenues, highlighting their potential to significantly enhance national and global economies. Marine microalgae also play a vital role in human health and therapeutic research. Their bioactive metabolites possess antimicrobial, anti-inflammatory, antioxidant, neuroprotective, and hepatoprotective properties and show potential in managing lifestyle diseases such as diabetes, obesity, cancer, and cardiovascular disorders. Furthermore, residual algal biomass after compound extraction can be utilized for producing biofertilizers, biopolymers, biohydrogen, and biomethane, reinforcing circular bioeconomy principles. However, realizing the full potential of marine microalgae requires the identification of diverse, high-yielding, and cost-effective strains, along with enhanced public awareness, policy incentives, and multidisciplinary collaboration. Strengthening these areas will accelerate the integration of marine microalgae into the global blue economy framework, contributing to sustainable development and climate resilience.

Keywords: Marine Microalgae; Blue Economy; Sustainable development; Bioproducts; Therapeutic potential

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Bioprospecting of Marine Resources for Biofuels, Biopolymers and Neutraceutical Production

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ABSTRACT

West coast of India can be considered as important area for collecting diverse marine microorganisms with biopolymer producing capacity. In this attempt, more than 200 marine microalgal isolates from west coast of India was obtained, out of which one strain Chlorella variabilis was found to be potential for producing microalgal biomass having average biomass productivity of 20-25 g/m2/d with non polar lipid content of 10-12% with respect to dry weight. Further, A sustainable process was developed for production of γ-linolenic acid through biorefinery model wherein ε-polylysine and protein rich powder was produced as by-product using CSIR-CSMCRI's strain CSMCRI's Coelastrella thermophila.
Microalgal cultivation of Coellastrella thermophila using CO2 from flue gases at a scale of 10m3 and 20 m3 raceway ponds wherein 0.2 g/l/d biomass productivity along with CO2 sequestration at a scale of 0.3 g/l/dwas achieved. Average biomass productivity of 30 g/m2/d was achieved. Further, 0.3 g/l/d biomass productivity along with CO2 sequestration at a scale of 0.45 g/l/d was achieved in 1KL Tubular Photobioreactor. Further, in order to make the microalgal biofuel cost effective and sustainable, one of the CSMCRI's marine isolate Bacillus licheniformis PL26 was found to be potential for producing ε-polylysine and polyhydroxyalkanoate simultaneously in same fermentation medium. The PHA produced by Bacillus licheniformiswas found to be poly- 3-hydroxybutyrate (P3HB). Further, in order to improve the ε-polylysine production, the carbon source was replaced with glucose which yielded 1.2 g L-1 ε-polylysine as oxygen transfer rate is very low in the medium containing crude glycerol.

Keywords: Microalgal Biofuel, Biopolymers; Polyhydroxyalkanoates (PHA); γ-Linolenic Acid;*Coellastrella thermophila;* ε-polylysine.

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Genome Mining Identifies Potential Antibacterial Metabolites From Marine Paenibacillus Sp.

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ABSTRACT

Marine ecosystems are unique and dynamic ecosystems with more productivity. Marine ecosystem supports sustainable food supply to the whole world and reduces the emission of greenhouse gases in larger extent. Marine ecosystem remains not fully explored in terms of microbially derived biologically active metabolites. This study aimed to explore the potential of marine bacteria associated with seaweed of south west coast region of India as a source of bioactive compounds. Conventional microbiological techniques coupled with whole genome sequencing and genome mining approach were employed to identify and predict the bioactive metabolites from these bacteria. A total of 300 bacterial isolates were recovered. The 16S rRNA sequencing of bioactive isolates belonged to 5 genera in which *Bacillus* was the most dominant genera. The genome mining for antiSMASH database (antiSMASH version 7.1.0) of *Paenibacillus* sp. showed the presence of 15 biosynthetic gene clusters in the annotated genome. The predicted gene clusters were belonging to NRP, RiPP, saccharide, polyketide. Out of the 15 BCGs, the gene clusters for the putative compounds such as paenibacterin, bacillibactin, polymyxin, and thermoactinoamide A showed 100% gene similarity with reference gene clusters available in MIBiG database. The BAGEL 4.0 analysis for the ribosomally synthesised and post translationally modified peptides (RiPP) and unmodified bacteriocins in the genome detected six area of interest for core peptide sequences with 4 classes, which are lassopepitde, sactipeptides,489.1 PolyA, and Lanthipeptide class 1. This study concludes that genome mining offers a powerful tool for predicting biosynthetic gene clusters and identifying potential bioactive metabolites in marine bacteria.

Keywords: Marine bacteria, bioactivemetabolites, genome mining, paenibacter

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Bioprospecting of coral-associated microbes

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ABSTRACT

Coral-associated microbes are important for the biology of their host and in control of its host-infecting pathogens. Natural products from coral-associated microbes may possess unique traits that have potential applications in biotechnology and biomedical research. Thus, this study investigates the antimicrobial potential of coral-associated beneficial microbial communities (bacteria, fungi and bacteriophages). After a series of preliminary screening, around 5 coral- associated beneficial bacteria and 3 coral-associated fungal species had proven potential antagonistic activity against coral-associated opportunistic pathogens and clinical pathogens. Further, the bioactive secondary metabolites from these active strains were extracted and characterised through Nuclear Magnetic Resonance and LC-MS analysis. The successfully characterised bioactive compounds are reported to exhibit a wide range of biological activities such as antimicrobial, antioxidant, anticancer and insecticidal activities. Hence, our results demonstrate the importance of exploring coral-associated microorganisms for industrial and biotechnological interest.

Keywords: antibacterial, anticancer, coral, bacteria, fungi, pathogens

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Characterisation of biofilm microbial communities associated with chitinous and non- chitinous substrates through microcosm experiments

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ABSTRACT

Chitin is composed of a β-1,4-linked homopolymer of N-acetylglucosamine (GlcNAc), and is the second most abundant biopolymer, which forms the outer skeleton of crustaceans, fungi and other invertebrates. Although billions of tons of chitin is produced in the oceans, only traces are left, due to its rapid degradation by ambient or biofilm-associated chitinolytic bacteria, which utilise chitin using the chitinase enzyme. Thus, chitinolytic bacteria play a significant role in mineralising chitin to carbon and nitrogen, influencing nutrient recycling and marine food web dynamics. While many studies have explored biofilms and chitinolytic bacteria separately, not much is known about the role of chitinolytic bacteria associated with biofilms. In this study, microcosm experiments were conducted by exposing natural chitin flakes, artificial chitin flakes and non-chitinous glass slides to ambient water from the Zuari estuary. The physicochemical parameters (temperature, salinity, pH, nutrients), Chl *a*, Total Viable Count (TVC), Total Bacterial Count (TBC), chitinase activity, and bacterial diversity were assessed.

The results revealed that the biofilm microbial communities associated with natural/artificial chitin were distinctly different from the non-chitinous glass slides. The ambient water was dominated by Firmicutes, and the same was reflected in the biofilms associated with the glass slides. However, Bacteroidetes dominated the biofilms associated with natural chitin flakes and Gammaproteobacteria in artificial chitin flakes; their ambient water communities also differed. The chitinase activity of the ambient water exposed to natural chitin was maximum compared to the other substrates. Overall, the present study demonstrated that the nature of the substrate and environmental conditions influence the bacterial community structure, the total bacterial abundance, and chitinase activity. Chitinous substrates support specialised bacterial communities essential for efficient chitin degradation, highlighting their ecological importance. The findings also suggest that chitin-degrading bacteria could be valuable for biotechnological applications as biocontrol agents and pathogen antagonism in waste management and crop protection.

Keywords: Chitin, N-acetylglucosamine, Biogeochemical cycles, Firmicutes, Bacteroidetes, Gammaproteobacteria, chitinase.

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Evaluation of Proximate Composition in Seaweeds to Elucidate Their Role in Seed Priming and Biostimulant Potential for Commercially important millets and vegetables

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ABSTRACT

Seaweed-derived biomolecules are increasingly recognised for their dual benefits of efficacy and sustainability in both traditional and modern agriculture. This study critically evaluated the biostimulant potential with the proximate biochemical contents of wild seaweeds, along with the cultivated species *Gracilaria salicornia* and *Kappaphycus alvarezii*, collected from the west coast of India. Aqueous seaweed extracts at a concentration of 10% were tested to evaluate their biostimulant efficacy using both monocotyledonous *Sorghum bicolor* (sorghum) and *Cenchrus americanus* (pearl millet) and dicotyledonous crop models, including *Pisum sativum* (green pea), *Cicer arietinum* (chickpea), *Trigonella foenum-graecum* (fenugreek) and *Solanum lycopersicum* (tomato), representing major staple crop plant families. The assessment was based on shoot and root growth as well as seed growth indices. Biochemical profiling of the seaweeds and their aqueous extracts revealed pronounced interspecies variations in biochemical composition, with relatively low levels of reducing sugars in the seaweeds but higher concentrations in their corresponding extracts. All biomolecular constituents, except phenolics, exhibited significant biostimulant activity. The seaweed extracts of *Sargassum cinereum*, *G. corticata*, *G. salicornia*, *Porphyra umbilicalis*, *K. alvarezii*, *Ulva lactuca* and *Ulva intestinalis* exhibited substantial biostimulant activities, with the extent of bioactivity varying depending on the seaweed species used for extract preparation and the plant species employed in bioassays. These findings provide a critical assessment of seaweed-based biostimulants and highlight their crop-specific responses as seed priming applications, underscoring their potential for targeted applications in sustainable agro-biotechnology.

Keywords: Aqueous seaweed extracts, Biochemical composition, Crop enhancement, Sustainable agriculture

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Marine Fish Gut Microbiome: A Source of Industrially Important Enzymes

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ABSTRACT

Across the six marine fish species screened, 253 bacterial isolates were recovered from *Sardinella longiceps* (Oil Sardine), *Loligo duvaucelii*(Squid), *Centropristis striata* (Sea Bass), *Mugil cephalus* (Grey Mullet), *Harpadon nehereus* (Bombay Duck) and *Rastrelliger kanagurta* (Indian Mackerel) and screening of enzymes such as amylase, pectinase, cellulase, lipase and protease. Enzyme screening showed that cellulase was the most common activity, detected in 94 isolates (41.0%), followed by lipase (31.4%), protease (30.1%), amylase (24.9%) and pectinase (17.5%). Although enzyme distribution varied among host species, isolates from *R. kanagurta* and *S. longiceps* consistently displayed higher enzyme-positive frequencies. Selected high- performing strains were quantified for extracellular enzyme production. Amylase activity ranged from 0.42–0.58 U/mL, with IM30 showing the highest levels, followed by GM30 and OS40. Cellulase activity remained lower (0.06–0.09 U/mL) but relatively consistent across strains. Pectinase activity varied more widely, with IM30 reaching 0.92 ± 0.04 U/mL and GM30 showing moderate activity at 0.71 ± 0.06 U/mL. These findings confirm that specific marine gut isolates combine both high prevalence and strong quantitative hydrolytic activities, underscoring their potential relevance for digestion enhancement, biofilm disruption and postbiotic development. From an industrial standpoint, the marine origin of these enzymes adds significant value. Marine-derived enzymes typically show natural tolerance to salinity, broad pH ranges and fluctuating temperatures, enabling them to remain active under conditions where many terrestrial enzymes lose stability. Such resilience positions these amylases, cellulases and pectinases as promising candidates for applications including detergent formulations, industrial starch processing, textile desizing, wastewater treatment and marine biofouling management. Further evaluation of salinity tolerance, surfactant compatibility and thermostability of these enzymes will be essential to determine their suitability for large-scale production.

Keywords: Marine derived enzymes, fish-gut associated bacteria, Enzyme Quantification.

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Intertidal zoantharians and macrofaunal assemblages of Priyadarshini Park, Mumbai: variability, adaptation, and bioprospecting relevance.

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ABSTRACT

Intertidal ecosystems host highly adaptable marine organisms that respond rapidly to environmental stress. The intertidal rocky shore of Priyadarshini Park (18.956583–18.957036 N, 72.794924–72.795255 E) in South Mumbai is still underexplored despite strong urban pressures. A year-round, low-tide survey recorded macrobenthic communities across upper and lower intertidal zones, with special focus on zoantharians because of their taxonomic uncertainty and marked morphological plasticity. Zoanthus sansibaricus was common in the lower zone, forming encrusting, desiccation-tolerant colonies on exposed boulders, while Palythoa mutuki occurred in rock pools across both zones, producing dense mats. Seasonal changes in oral disc diameter, pigmentation, and tentacle number indicated strong phenotypic plasticity influenced by emersion, light, and tidal stress, supporting the need for molecular identification currently underway. In total, 18 taxa were recorded: the upper zone hosted molluscs, arthropods, cnidarians, and crustaceans, whereas the lower zone contained porifers, echinoderms, molluscs, cnidarians, annelids, macroalgae, and gastropod egg masses. These baseline observations highlight zoantharian adaptability and intertidal biodiversity under anthropogenic impact and point to their relevance for marine bioprospecting, as morphologically flexible cnidarians often produce ecologically important and potentially valuable bioactive compounds.

Keywords: Bioprospecting, Intertidal zonation, Morphological variability,Mumbai ,

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Assessment of cellulose content and its structural properties in seaweeds from the coast of Goa

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ABSTRACT

Cellulose is a naturally occurring polymer present in both terrestrial plants and seaweeds, serving as a principal structural component of the cell wall. Although lignocellulosic biomass of terrestrial origin remains the primary source of cellulose, the increasing cultivation of seaweeds to meet global market demands offers a promising additional source. In this study, the water content, cellulose content, and total carbohydrate content were evaluated for 20 seaweed species representing different taxonomic classes from the coast of Goa. Water content ranged from 72.66
± 0.66% to 90.93 ± 0.43% of the total fresh weight, with the highest values observed in green seaweeds and lowest in brown seaweeds. Total carbohydrates ranged from 14.69 ± 0.33 % to
52.76 ± 1.87% of the total dry weight, with the highest content in green seaweeds. Cellulose yield ranged from 1.8 ± 0.63 % to 26.35 ± 3.08 % of the total dry weight, with highest yield in green seaweeds and lowest in red seaweeds. Extracted cellulose was characterized using XRD and FTIR. The degree of crystallinity ranged from 42% to 79%, with green seaweeds exhibiting the highest degree of crystallinity. Based on crystallinity and chemical composition, seaweed cellulose exhibits significant potential for applications in pharmaceuticals, biomaterials, and environmental pollution remediation.

Keywords: Seaweeds, carbohydrate, cellulose yield, XRD and FTIR, sustainable applications

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Chitosan–Phloroglucinol Nanocomposite Toothpaste: A Biomaterial-Based Therapeutic Approach For Enhanced Oral Health

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ABSTRACT

Contemporary oral care demands innovative formulations combining biocompatibility and therapeutic efficacy. This study presents novel toothpaste formulations incorporating marine biopolymers and natural antimicrobial agents: chitosan, phloroglucinol, carrageenan, and ascorbic acid. Five toothpaste formulations (TF-1 to TF-5) were systematically developed and characterized.The optimal formulation (TF-3) comprises chitosan (0.3 g), phloroglucinol (0.05 g), carrageenan (0.15 g), ascorbic acid (0.3 g), calcium carbonate (5 g), glycerol (1 mL), cinnamon oil, and sodium lauryl sulphate (0.1 g). Physicochemical characterization revealed: nanoscale particle size of 112.4 nm enabling superior biofilm penetration; optimal pH of 8.1 for acid neutralization; enhanced foamability of 40 mL; reduced moisture content of 20.1% ensuring extended shelf-life; and spreadability of 3.3 cm/sec for prolonged retention.Spectroscopic analysis confirmed successful ingredient incorporation. UV-Visible spectroscopy showed maximum absorption at 276 nm (0.55 OD). FTIR revealed characteristic peaks at 3398 cm^{-1}, 1641 cm^{-1}, 1428 cm^{-1}, and 1045-1109 cm^{-1}, confirming polyelectrolyte complex formation. Fluorescence spectroscopy exhibited dual-emission with excitation at 281 nm and emissions at 306 nm and 425 nm. The formulation demonstrated excellent stability (4°C to 50°C) with no phase separation over 56 days. The synergistic combination of chitosan's antimicrobial properties, phloroglucinol's anti-inflammatory activities, and ascorbic acid's particle modulation resulted in superior therapeutic performance. This nanoscale, marine biopolymer-based toothpaste represents a significant advancement in oral therapeutics, offering enhanced antimicrobial efficacy, enamel remineralization, biofilm penetration, and mucoadhesive retention for comprehensive oral health management.

Keywords: Chitosan, Phloroglucinol, Toothpaste formulation, Oral care therapeutics, Marine biopolymers.

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Microbiome Manipulation Strategies For Improving The Health Of Marine Organisms

Anas Abdulaziz

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ABSTRACT

In recent years, the scientific community has increasingly recognised the role of microorganisms in orchestrating the overall health and metabolic capacity of various organisms. A comprehensive understanding of microbiomes holds the potential to facilitate targeted interventions aimed at achieving optimal health outcomes, particularly in the context of the One Health perspective. Recent research has indicated that the microbiomes of distinct organisms within close proximity, as well as those of the same species across different marine ecosystems, exhibit considerable variation in composition. Furthermore, studies have demonstrated that manipulating the microbiome of host organisms presents a viable strategy for enhancing human health, improving agricultural productivity, and addressing climate challenges. Such manipulation can be accomplished through the provision of specific molecules that promote the proliferation of beneficial microorganisms or by introducing probiotics with tailored properties. This latter approach necessitates the design and delivery of microorganisms, encompassing several critical steps: validating the non-pathogenicity of selected organisms, ensuring their capacity to colonise the targeted system, and confirming their ability to exhibit the desired properties. Nevertheless, several significant challenges remain in this field. These challenges include an inadequate understanding of the microbiomes associated with numerous marine organisms, the difficulty in distinguishing between probiotic species and prebiotic molecules, the need for effective delivery mechanisms for manipulation, and the necessity of validating the effectiveness of microbiome manipulation strategies. This review synthesises current advances and critical gaps in microbiome manipulation, intending to outline pathways toward microbiome-based interventions that support ocean health within the One Health framework.

Keywords: microbiome manipulation, probiotics, prebiotics, One Health, Sustainable Development Goals

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Integrated Approaches For Exploration Of Marine Seaweeds, Halophytes, And Associaed Microorgnisms For Discovery Of Bioactive Metabolites.

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ABSTRACT

The marine ecosystem represents an immense and largely untapped reservoir of bioactive natural products with diverse biotechnological potential. Among marine resources, seaweeds, halophytic plants, and marine microorganisms have emerged as prolific producers of structurally unique and functionally diverse bioactive metabolites. These metabolites exhibit a wide range of pharmacological and industrial applications, including antioxidant, antimicrobial, antiviral, anticancer, and anti-inflammatory properties.

Seaweeds synthesize a variety of secondary metabolites such as polysaccharides, polyphenols, terpenoids, and alkaloids, often as adaptive responses to environmental stress. Similarly, halophytic plants, thriving in saline and arid coastal habitats, produce distinctive phenolic compounds, flavonoids, and osmolytes with significant therapeutic value. Marine microbes, particularly bacteria and actinomycetes associated with these hosts, serve as vital contributors to metabolite diversity, often producing novel compounds through unique biosynthetic pathways.

This presentation highlights recent advances in the isolation, characterization, and functional evaluation of bioactive metabolites derived from these marine sources. Emphasis is placed on the bioprospecting strategies, metabolomic approaches, and biotechnological potential of these natural compounds in drug discovery, nutraceutical development, and sustainable blue biotechnology. Harnessing the synergistic potential of these marine biota may pave the way for innovative bio-based solutions to address global health and environmental challenges.

Keywords: Seaweeds, Halophytes, Marine Microbes, Metabolites, Bioassay

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Actinomycetes From Andaman Coast Sediments: A Promising Source Of Antimicrobial Agents For Aquaculture

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ABSTRACT

The escalating global crisis of antimicrobial resistance poses a severe threat to both aquaculture and the broader marine environment, necessitating the discovery of novel therapeutic compounds. Marine environments, particularly deep-sea sediments, remain a vast and underexplored frontier for uncovering diverse, biologically active microorganisms. This study investigated the antimicrobial potential of Actinomycetes isolated from sediment samples collected across the Andaman coast. Sediment samples were collected from various Andaman Coast locations, followed by the isolation of Actinomycetes using selective media and morphological characterization. These isolates were then screened for secondary metabolite production against a panel of critical aquatic pathogens: *Streptococcus iniae*, *Edwardsiella tarda*, *Vibrio vulnificus*, and *Vibrio harveyi*. Initial antimicrobial activity screening was performed using the agar well diffusion method. Active isolates proceeded to scaled-up secondary metabolite production using mass production media. Crude extracts of these metabolites were then prepared using various extraction methods and subsequently evaluated for their antimicrobial efficacy. Active extracts underwent further analysis to determine their Minimum Inhibitory Concentration against the tested pathogens. Our results revealed that a substantial proportion of the isolated Actinomycetes exhibited potent antimicrobial activity against most of the tested pathogens (values were 9mm, 10mm, and 8mm), directly attributed to the secondary metabolites they produced. Notably, several isolates displayed strong inhibitory effects, highlighting their significant potential in controlling prevalent aquaculture diseases through these bioactive compounds. These findings underscore the Andaman coast as a promising source for Actinomycetes capable of producing valuable secondary metabolites. Further research is crucial to identify and characterize the specific active secondary metabolites produced by these marine isolates. This work paves the way for developing new antimicrobial agents that can support sustainable aquaculture practices and combat the growing threat of antimicrobial resistance.

Keywords: Antimicrobial agents, Actinomycetes, Bioactive compounds, Andaman Coast

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Marine Prawn gut Origin ILSM3028: A Promising Next Generation Probiotic for Coastal Aquaculture

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ABSTRACT

The gastrointestinal tract of aquatic organisms, harbour a highly diverse and dynamic microbial community that significantly contribute to host nutrition, immune-modulation, and overall physiological homeostasis. ILSM3028 was isolated from the gut of marine prawn Metapenaeus monoceros collected from Chilika lagoon, Odisha and assessed for its probiotic potential through a series of in-vitro & in-vivo assays. ILSM3028 exhibited neither hemolytic nor DNase activity and was also sensitive to the most of the tested antibiotics, indicating its non-pathogenic nature. Identification of the strain was performed through morphological, biochemical and molecular characterization by 16S rRNA sequencing, and genomics analysis by Whole Genome Sequencing (WGS). The strain has demonstrated high tolerance to simulated gastric as well as intestinal juice, indicating its capacity to persist in these harsh conditions. Its auto-aggregation property along with attachment to intestinal epithelial cells, suggest a strong adhesion and colonization potential in the gut. Furthermore, the isolate has demonstrated antagonistic activity against pathogenic Vibrio species, which highlights its potential in pathogen inhibition and disease prevention. Acute toxicity assessment of ILSM3028 in zebrafish models confirmed its safety, showing no adverse effects even at high doses. Genome annotation of ILSM3028 revealed 2635 CDS region and highlighted the presence of genes associated with key probiotic function, Amino acid and vitamin biosynthesis along with some hydrolysing enzymes. Collectively, these results suggest that ILSM3028, exhibits strong potential as a probiotic candidate for sustainable aquaculture. Its application may contribute to improved gut health, enhanced immunomodulatory responses in host organisms, and reduced reliance on conventional antibiotic treatment.

Key Words: Probiotics, gastrointestinal track, Chilika lagoon, acute toxicity, immunomodulation

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Phenotypic and genomic characterization of two novel bacterial species isolated from the gut of Penacus indicus from Chilika Lake

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ABSTRACT

The gut microbiome of marine organisms is a significant source of unexplored microbial diversity with potential ecological and biotechnological significance. In this study, two previously uncharacterized bacterial species were isolated from the gut of *Penaeus indicus* collected from Chilika Lagoon, a highly diverse brackish water ecosystem in Odisha. Both isolates, ILSM3011 and ILSM3012, are gram-positive, rod-shaped, aerobic, and non-haemolytic in nature. Biochemical analysis and sugar fermentation patterns were studied, along with antibiotic sensitivity testing, for both isolates. Physiological characterization revealed its enzymatic activities, and stress-tolerance profiles such as salinity (15% & 10%), pH (6-10), and temperature (25-45°C). Gram's staining and 16s rRNA analyses were performed to determine their morphology and taxonomic identity, respectively. Whole-genome sequencing (WGS), followed by assembly and annotation, enabled genome-based comparisons with closely related taxa. Average Nucleotide Identity (ANI) and digital DNA–DNA hybridization (dDDH) values showed less than 95% and 70% similarity, respectively, with any known species, supporting their recognition as novel taxa. The complete genome length and GC content of ILSM3011 and ILSM3012 are 3307670bp, 42.8%, and 2884430bp, 67.67%, respectively. Prediction of Biosynthetic Gene Clusters (BGC) of Secondary metabolites revealed the presence of antimicrobial peptides, bacteriocins, and carotenoid genes, which have potential industrial applications. The secondary metabolite analysis and proteomic analysis corroborated with genomic data. Based on whole-genome analysis, strains ILSM3011 and ILSM3012 are considered to represent novel species of the genera *Jeotgalibacillus* and *Microbacterium*, respectively. Our ongoing studies will further validate their taxonomic status and assess their potential for bioprospecting.

Keywords: Chilika Lagoon, *Penaeus indicus*, gut microbiome, Whole Genome Sequencing(WGS)

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Indian Seaweeds as Sustainable Ocean-Derived Food Resources: Nutritional profiling, Anti-diabetic Potential and Safety Analysis

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ABSTRACT

The global burden of diabetes continues to rise at an alarming rate, intensifying the need for sustainable, diet-based preventive and management strategies. In this context, under-utilised seaweeds (marine macroalgae) represent a promising class of ocean-derived nutraceuticals that can be produced without arable land or freshwater inputs and possess bioactive properties relevant to metabolic health. They offer high nutritional content and are rich in bioactive molecules possessing anti-oxidant and anti-diabetic compunds.This study investigates selected native seaweed taxa from the Mandapam Coast (Tamil Nadu) and Okha (Gujarat), India, through integrated nutritional profiling, antioxidant evaluation, α-amylase inhibitory assays, heavy metal analysis, and DNA barcoding-based species authentication. Proximate analysis revealed favourable nutritional characteristics, including appreciable protein content, complex non- glutenous carbohydrates, and mineral-rich ash. Antioxidant assays demonstrated significant free- radical scavenging activity, indicating the potential to mitigate oxidative stress. In vitro α- amylase inhibitory assays revealed marked enzyme inhibition, suggesting a capacity to modulate post-prandial glucose release and support glycaemic regulation.Heavy metal concentrations (As, Cd, Cr, Pb and Ni) were assessed to ensure safety for human consumption, while DNA barcoding enabled precise species identification, addressing challenges associated with morphological plasticity and cryptic diversity.Collectively, the findings indicate that, with appropriate quality control and sustainable harvesting practices, under-utilised Indian seaweeds can serve as safe, nutrient-dense, and bioactive-rich nutraceutical resources, offering a practical, ocean-based dietary approach to support metabolic health and combat the growing prevalence of diabetes.

Keywords: Blue foods, Macroalgae, DNA barcoding, Anti-diabetes, Functional foods, Proximate composition, Heavy metals.

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Biostimulant Efficacy of *Amphiroa ephedraea*: A Novel Calcareous Red Alga for Sustainable Crop Enhancement

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ABSTRACT

Marine macroalgae are increasingly recognised as promising bioresources for sustainable agriculture due to their diverse biochemical constituents and capacity to enhance plant growth and resilience. However, calcareous red algae remain largely underrepresented in biostimulant research despite their unique metabolite profiles. This study investigates the biostimulant potential of aqueous extracts derived from *Amphiroa ephedraea*, a comparatively novel calcareous alga collected along the Gujarat coastline. Species identity was validated through DNA barcoding to ensure precise taxonomic confirmation and reproducibility of the algal material. Compositional analyses revealed a metabolite-rich extract containing phenolics, flavonoids, tannins, minerals, and nitrogenous compounds. To preserve the native complexity of the algal matrix, the extract was utilised in its unclarified form without centrifugation, thereby retaining both soluble metabolites and fine particulate fractions, including polysaccharides, mineral residues, and structurally bound bioactives. This whole-extract approach ensured the delivery of the complete spectrum of bioactive compounds potentially contributing to biostimulant function. The application of Amphiroa extract to tomatoes resulted in significant enhancements in germination and photosynthetic pigment composition. Increased chlorophyll a/b ratios and elevated carotenoid content indicated improved photosynthetic performance and photoprotective capacity. Biochemical assays showed marked upregulation of superoxide dismutase, catalase, and ascorbate peroxidase activities, accompanied by increased proline accumulation and reduced malondialdehyde levels. These responses collectively reflect an enhanced tolerance to oxidative stress and improved membrane stability. Overall, the findings establish *Amphiroa ephedraea* as a potent marine bioresource with demonstrable biostimulant efficacy. Its physiological and biochemical effects, combined with the retention of full-spectrum bioactive constituents, highlight its potential for incorporation into ocean-derived biostimulant formulations. Furthermore, the utilisation of this understudied algal species broadens the commercial resource base for the rapidly expanding seaweed biostimulant industry, offering valuable opportunities for scalable product development within emerging marine biotechnology and start-up ecosystems.

Keywords: *Amphiroa ephedraea*, Marine biostimulant, Antioxidative enzymes, Photosynthetic pigments, Sustainable agri-biotechnology

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Bioactive Potential Of Venom-Derived Peptides From Sea Urchin And Cone Snail Along The Goa Coast

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ABSTRACT

Marine invertebrates have emerged as promising reservoirs of novel bioactive molecules having capacities for drug development. Among them, venomous species such as cone snails and sea urchins produce a wide spectrum of peptide toxins that potently and selectively modulate a range of targets such as ion channels, receptors, and signaling pathway of physiological processes making it potential therapeutic. Conus venoms comprise a large variety of biologically active peptides (conopeptides or conotoxins) that are employed for prey capture and other biological functions. The present study investigates the bioactive and proteomic potential of cone snails (*Conus biliosus*, *C. ebraeus*) and sea urchins (*Stomopneustes variolaris*, *Temnopleurus cf. toreumaticus*) inhabiting the rocky intertidal zones of the Goa coast. Species were identified morphologically and confirmed by DNA barcoding.Venom ducts from the cone snails and the gonads and spines of sea urchins were dissected for peptide extraction. Cone snail venom was processed using 2% acetic acid extraction followed by reduction and carboxyamidomethylation, while sea urchin tissues were hydrolyzed enzymatically using trypsin. The extracts were characterized by UV-Visible spectroscopy, reverse-phase HPLC, and LC-MS. Distinct chromatographic peaks and peptide sequences were identified that matched with the NIST library. Bioactivity screening through hemolytic assays by using fresh sheep red blood cells revealed concentration dependent lysis. *Conus biliosus* venom extract showed consistent high hemolysis with 76.37 ± 8.73 and 100.19 ± 6.77 from 25 to 200 µg/ml. It represent good candidate to check anticancer and antiviral activities. Venom from spines of sea urchins shows hemolysis with 100.12±9.76 and 98.08±9.75 in *T. toreumaticus* and *S. variolaris*, respectively at concentration 200 µg/ml. This indicate that spines carries venomous peptides.These findings highlight the chemodiversity and potent bioactivity of venom-derived peptides from Goa's marine invertebrates. The study can be further explored for analgesic, and neuroprotective activities.

Keywords: Cone snail, Sea urchin, venom peptides, hemolytic assay, LC-MS, HPLC, Goa Coa

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Harnessing Marine Microbiomes for Waste Valorization into PHB: Advancing Bio-Based Solutions to Marine Plastic Pollution

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ABSTRACT

Oceanic plastic debris has escalated the worldwide pursuit of bio-based, biodegradable polymer substitutes like polyhydroxyalkanoates (PHAs). In the present work, our marine bacterial repository consisting of isolates from sponges, corals, and sediments off the Gopalpur coast of Odisha were explored for PHA production on waste substrates such as agro-industrial wastes to achieve circular biomanufacturing. Over 200 marine isolates were initially screened by staining with Nile Red and Sudan Black B staining. The highest PHA producing strains were combined to form a mixed marine consortium (MMC) that could grow in low salt & nutrient conditions. MMC was grown on low-cost substrates containing waste potato, waste bread, and soybean seed extract, and dairy whey (1–10% v/v), with maximum biomass production occurring at a substrate concentration of 4–5%. Growth was tracked with OD_{600} measurements for 72 h, in the range of 1.5–2.1, suggesting effective utilization of carbon from waste streams. PHA was recovered as PHB granules from the separated biomass using the tri-solvent method following pretreatment with sodium hypochlorite. FTIR spectra of polymers showed strong ester carbonyl bands at 1722–1725 cm^{-1} and C–O stretching vibrations at 1283 cm^{-1}, with resemblance to commercial PHB standards. GC–MS analysis of methanolyzed extracts identified methyl-3-hydroxybutyrate as main monomer demonstrating the production of PHB-rich PHA. Smooth plastic films were prepared by solvent casting of the extracted PHA granules and FESEM images were captured.
Linking marine microbiome to exploiting waste and green extraction protocols may aid in sustainable bioplastic production with reduced economic and environmental burden for advancing circular bioeconomy and reducing marine plastic pollution.

Keywords: Marine microbial consortia[1], Polyhydroxyalkanoates (PHA/PHB)[2], Waste valorization[3], Circular bioeconomy[4], Marine plastic pollution mitigation[5]

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From Freshwater Model to Blue Economy: Identification of a Non-Canonical Wnt Modulator for Controlled Regenerative Acceleration and Therapeutic Stabilization.

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ABSTRACT

Marine Cnidarians like jellyfish possess biological immortality driven by the Wnt signaling pathway. This master regulator is highly conserved from the freshwater model *Hydra viridissima* to humans. Its modulation allows for targeting two distinct goals: 1) correcting Wnt dysregulation (e.g., Alzheimer's, cancer) and 2) accelerating tissue repair. However, bioprospecting is limited by the difficulty of screening deep-sea invertebrates. We propose *Hydra* as a cost-effective marine proxy to unlock this Ocean Pharmacopeia. Hydra were bisected (n=12) and observed at 24/48/72h; regeneration rate and asymmetry were quantified. A Lithium pulse (1mM, 1h) accelerated regeneration by 12-14h vs Control but increased tentacle asymmetry, confirming Wnt hyperactivation. Supplementation with 4mM DL-Tryptophan and 2mM D-Tryptophan separately accelerated early morphogenesis but restricted later growth. Importantly, the Lithium + DL/D-Trp combination maintained accelerated regeneration (8-10h gain) while completely rescuing symmetry. All phenotypes showed 100% penetrance. These findings identify a non-canonical metabolic node, hypothesized here as the Ancestral Indole Modulator, that allows for rapid yet symmetric repair, preventing the oncogenesis associated with Wnt acceleration. The ability to utilize D-Tryptophan suggests an adaptation to scavenge bacterial metabolites, a trait possibly conserved in microbiome-rich marine relatives. This validates a scalable platform for Blue Economy drug discovery, pointing toward indole-based metabolites for controlled Wnt acceleration in regenerative medicine and stabilizing therapies for Alzheimer's and cancer.

Keywords: Hydra Model System, Marine drug discovery, Wnt Signaling, Regenerative Medicine, Indole Metabolism

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Screening for Hydrolytic Enzymes Producing Bacteria from Sediments

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ABSTRACT

Microorganisms found in terrestrial and coastal regions represent a rich yet widely underexplored source of hydrolytic enzymes with ecological and industrial significance. In this study, we explored bacteria capable of producing three key extracellular enzymes, namely chitinase, amylase, and protease, isolated from the fish- market soil, beach sand, and garden soil. Chitinase-producing strains were isolated from the soil obtained from the fish market and screened on Minimal Salt Medium containing agar plates, supplemented with 1% colloidal chitin prepared from shrimp shell waste. The clearance of media around the isolated colonies confirmed chitin degradation. Chitinase activity was quantified by estimating the reducing sugar content through the DNSA method. Additionally, bacteria showing amylase and protease activity were isolated from beach sand and garden soil samples. Amylase-producing strains were screened for their activity on starch agar plates, and the formation of clear halo zones after iodine flooding confirmed starch degradation. Amylase activity was quantified by measuring the reducing sugars released from starch using the DNSA method. Similarly, protease-producing strains were screened on agar plates supplemented with skimmed milk, resulting in the development of transparent zones around the colonies, indicating casein hydrolysis. Quantitative analysis was done using the azocasein assay, where the release of peptide fragments upon substrate hydrolysis was measured spectrophotometrically at 440 nm. Several isolates showed promising extracellular hydrolytic enzyme activity. Their ability to degrade biopolymers, such as chitin, starch, and proteins, highlights their role in ecological and industrial processes, including organic matter decomposition, biowaste conversion, environmental remediation, and enzyme production. Overall, this study provides insights into the functional diversity of bacterial communities and their potential to produce hydrolytic enzymes for industrial applications. Further studies are needed to optimise enzyme production and activity.

Keywords: Hydrolytic enzymes, Chitinase, Amylase, Protease, Enzyme activity

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Unveiling The Secondary Metabolite Of Marine *Curvularia Verruculosa* Khw-7 Through Comprehensive Genomic And Chemical Analyses

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ABSTRACT

Marine microorganisms are widely recognized as prolific producers of structurally diverse secondary metabolites with significant biotechnological and pharmaceutical relevance. In the present study, a fungal strain designated KHW-7 was isolated from seawater collected from the Gulf of Khambhat, India, and taxonomically identified as *Curvularia verruculosa* KHW-7. Whole-genome sequencing (WGS) of the strain was performed using a next-generation sequencing platform, followed by comprehensive genome assembly and annotation employing multiple bioinformatic pipelines. Genome mining using the antiSMASH platform revealed 25 putative secondary metabolite biosynthetic gene clusters (BGCs), predominantly associated with terpene, non-ribosomal peptide synthetase (NRPS), and type I polyketide synthase (T1PKS) pathways. To the best of our knowledge, this study reports the first whole-genome sequence of

C. verruculosa. The genomic architecture suggests a substantial biosynthetic potential for the production of bioactive metabolites and industrially relevant enzymes, warranting further exploration for their functional and commercial applications. Chemical profiling of the fungal extract through GC–MS analysis identified 4H-pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6- methyl, as a major constituent. This compound is known for its antimicrobial, antioxidant, and anticancer properties, underscoring the bioprospecting value of the strain. Additional details on the bioactivity and application potential of the identified metabolite are presented in the accompanying poster.

Keywords: *Curvularia verruculosa* KHW-7, whole-genome sequencing, secondary metabolites, marine microorganism, anticancer compound

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Bioprospecting Of Fish Gut Associated Actinomycetes

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ABSTRACT

Oceans host immense, yet underexplored microbial diversity, offering remarkable opportunities for discovering novel bioactive compounds and beneficial microorganisms. Among these, marine animal–associated microbes represent a unique ecological niche, yet fish gut associated actinobacteria remain significantly underexplored. In this study, we investigated the functional potential of actinobacteria isolated from the gut of Indian squid (*Uroteuthis duvaucelii*) and Indian mackerel (*Rastrelliger kanagurta*), focusing on their pharmaceutical, probiotic, and plant growth-promoting properties. From 39 bacterial isolates, one promising strain designated SQA4 was isolated.

SQA4 exhibited notable antimicrobial activity, producing inhibition zones of 14–16 mm against *Staphylococcus aureus* and 12 mm against *Candida albicans*. Its crude ethyl acetate extract showed strong anti-tubercular activity with 31% inhibition of *Mycobacterium smegmatis* and 61% inhibition of *Mycobacterium tuberculosis* H37Rv at 200 µg/mL. The strain also demonstrated 72.5% antibiofilm inhibition against *Acinetobacter baumannii* and 62.1% antioxidant scavenging activity.

Physiologically, SQA4 produced multiple hydrolytic enzymes (amylase, lipase, protease, cellulase), utilized diverse carbon and nitrogen sources, and tolerated a wide pH range (3–11). It also displayed strong PGP traits, including ammonia and acetoin production, IAA synthesis, phosphate and zinc solubilization, and nitrogen fixation. Probiotic evaluation showed positive for acid and bile tolerance, good MATH adhesion, and strong auto-aggregation, coaggregation, and biofilm formation, indicating robust colonization potential. Overall, SQA4 emerges as a multifunctional marine-derived bacterium with promising applications in therapeutics, agriculture, and probiotic development.

Keywords: Actinobacteria, Antimicrobial, Antibiofilm, PGP (Plant growth promotion) and Probiotics.

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Deep-sea fungal hydrophobins as adaptive biointerfaces for functional surface modification

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ABSTRACT

Hydrophobins are powerful class of proteins with less than 125 amino acids, present in fungal spores, hyphae and fruiting bodies. Marine fungus produces hydrophobins for dispersion and adhesion to different surfaces. Surface active nature of the protein finds wide application as foam stabilizer in food products and for surface modifications. Hydrophobins were screened from marine fungal strains isolated from deep sea water and sediment samples. A potential isolate, *Cladosporium* sp. NIOT68 was isolated from the Arabian Sea at a depth of 1500 m. Genome mining revealed the presence of four hydrophobin encoding genes HFBI-IV. Based on the hydrophobicity (GRAVY score of 0.135) of the predicted proteins, HFBI was cloned into *Pichia pastoris* host under AOX1 promoter. Positive transformants were confirmed by colony PCR and transformants were selected based on small scale expression studies in buffered minimal methanol medium. Varying concentrations of methanol from 0.5 to 2% were used to induce the expression level of HFBI. After 96 h of 0.5% methanol induction, the transformant PP15 produced a highest level of 103 mg/L of HFBI. HFBI was purified by affinity column and the molecular weight was found to be of 8 kDa using SDS-PAGE. The activity of HFBI was confirmed through oil displacement assay. In order to anlyse the surface modification property of recombinant HFBI, varying concentrations of purified HFBI was coated onto glass slides and the surface topology was visualized. The recombinant HFBI from *Cladosporium* sp. would be a promising source for surface modification and its application in biosensor platforms.

Keywords: Deep-sea fungus, Hydrophobins, Surface active proteins.

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"Harnessing Mytella strigata Mussel Foot Protein for Regenerative Marine Biomedicine: Dual In Vitro–In Vivo Evidence of Superior Wound Repair"

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ABSTRACT

Marine mussel foot proteins are the class of foot proteins which is secreted from the mussels.It have the adhesive properties that helps in strongly attached to the surfaces.It can be achieved by the presence of unique amino acid L-3,4-dihydroxyphenylalanine (DOPA).These bioadhesive macromolecules have the excellent biomedical application particularly in wound healing and tissue restoration.In this work, MFP from Mytella strigata- a well known mussel species which is not assessed to have wound healing and bio adhesive properties from any in vitro and in vivo experiments.MFP will be extracted by using Acid -Urea based methodology and then the extract will be subjected to dialysis.In vitro Scratch assay on the fibroblast cell line [3t3] may determine the wound healing and cell adhesion properties in order to identify biocompatibility and regeneration potential.There will be a significant increased rate in the wound closure and significant increase in cellular adhesion determined by comparing MFP-treated cells with untreated controls.Tissue adhesion tests may confirm the studied protein as a putative biological alternative for synthetic agents.Invivo,wound healing studies will be conducted on experimental animals which further confirms the significant improvements in the rates of wound contraction and epithelium regeneration.
This study may confirms that MFP of Mytella strigata,a marine derived biomolecules may be used in modern wound healing products due to their strong adhesive and biocompatible properties.So it may become a top candidate for developing advanced adhesive technologies instead of stitches and staples.This study concludes that using marine organisms in biotechnology is both useful and sustainable.Ocean-derived materials can play an important role in regenerative medicine. In future the research will focus on advanced purification, molecular characterization and formulation development which can be evaluated and used in real clinical applications.

Keywords: : Mussel foot protein[MFP], Mytella strigata, marine bioadhesive, wound healing,
,marine biotechnology.

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Uncovering Novel Functional Genes in Deep Sea Microbes : A Metagenomic Perspective on Bioprospecting

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ABSTRACT

Metagenomic diving into deep sea sediments of Bay of Bengal signifies the ecological diversity and natural resources. Studies on microbial diversity and their functional capabilities at deep depth of Bay of Bengal remain poorly explored. In this study, we performed shotgun metagenome sequencing of deep-sea sediment collected at 1750 m in the Bay of Bengal on Illumina platform. We aimed to understand the microbial diversity and their functionals. Taxonomic analysis based on Kraken2 indicated the predominance of phylum Bacillota followed by Pseudomonadata, Actinomycetota, Myxococcota, and others. We further identified 3 metagenome assisted genomes as Mesobacillus subterraneu, Cytobacillus oceanisediminis, and Fictibacillus arsenicus.

The functional annotation of the complete metagenome assembly revealed presence of 6 class of antibiotic drug and 61 Biosynthetic Gene Clusters. KEGG analyses indicated presence of metabolic pathways, biodegradation pathways, and biogeochemical cycles such as carbon cycle, sulfur cycle and nitrogen cycles. Search against PlasticDB database revealed presence of 29 types of plastic degrading enzymes, capable of degrading 27 different plastic polymers. Out of these, 14 were natural polymers and 13 were synthetic polymers. The highest number of plastic degrading enzymes associated hits were involved in the degradation of polyacetic acid followed by polyhydroxyalkanoates, polyethylene glycol, and others. The presence of various degradation genes underscores that Bay of Bengal deep sea sediments represent a highly dynamic environmental niche for further exploration.

Keywords: Bay of Bengal, Metagenomics, Microbial plastic degradation, Microbial ecology, Deep Ocean.

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Characterization of amylase from Sardinella longiceps gut associated Bacillus subtilis OS40 for Aquaculture Biofilm Control

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ABSTRACT

Biofilm-associated infections remain one of the most persistent problems in aquaculture, as pathogens embedded within extracellular polymeric matrices display high tolerance to antibiotics and disinfectants. This challenge has increased interest in probiotics and their secreted enzymes as targeted biofilm-disrupting tools, particularly amylases capable of degrading polysaccharide components of the biofilm structure. The amylase produced by *Bacillus subtilis* OS40 was evaluated to determine its suitability for postbiotic applications under aquaculture- relevant conditions. OS40 maintained strong activity close to neutral pH, with a clear optimum between pH 7–8, and retained functionality over a broader pH window than the commercial α- amylase control, which declined rapidly above pH 6. Temperature profiling showed that OS40 remained active across 40–50 °C, indicating superior thermal stability compared to the commercial enzyme, which showed a decline in activity at elevated temperatures. SDS–PAGE analysis revealed a distinct protein band in the ~60–55 kDa range, consistent with partially purified bacterial amylases. 16S rRNA sequencing confirmed OS40 as *Bacillus subtilis* (GenBank accession number PV685121), clustering tightly with reference *subtilis* strains with strong bootstrap support. This taxonomic placement, combined with its robust enzymatic characteristics, positions OS40 as a promising candidate for postbiotic development in aquaculture. Future work will focus on testing the purified OS40 amylase against biofilm- forming aquaculture pathogens, including *Vibrio* spp. and *Aeromonas* spp., to evaluate whether enzymatic degradation of EPS can disrupt established biofilms or enhance the performance of existing control strategies. These studies will help assess the potential of OS40-derived amylase as a targeted antibiofilm postbiotic for sustainable aquaculture.

Keywords: Probiotic screening; Antibiofilm activity; Amylase characterization; *Bacillus subtilis*; Aquaculture pathogens

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Synthesis Of Diphenyl Ether Derivatives Inspired By Marine Sponge Metabolites With Antimalarial Activity

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ABSTRACT

Marine sponges are a rich source of structurally intriguing diphenyl ethers, many of which exhibit notable ecological and pharmacological properties, including antiparasitic activity. These natural architectures offer a useful blueprint for designing new therapeutic candidates. In the present work, diphenyl ether derivatives inspired by sponge-derived metabolites were synthesized through a streamlined and environmentally conscious route. The key transformation was carried out using the ruthenium catalyst $[Ru(p\text{-cymene})Cl_2]_2$ (5 mol%), in the presence of Ammonium acetate (NH4OAc) giving upto 88% yields of the desired diphenyl ether containing imidazole scaffolds. Ammonium acetate served a dual function in the reaction, namely the nitrogen source required for imidazole formation and oxidation of ruthenium to the active ruthenium (II) species, enabling efficient cyclization. The synthesized derivatives were characterized using FTIR, ^{1}H NMR, ^{13}C NMR, and LC-MS to confirm their structural integrity and purity. Following characterization, selected derivatives were evaluated for antimalarial activity. Several compounds showed encouraging mortality against Anopheles and Culex mosquitoes. Some of them displaying activity trends of up to approximately 80% mortality indicating their potential as promising lead candidates. Although detailed quantitative data are still under assessment, the initial findings support the continued exploration of diphenyl ether systems for antimalarial applications. Future efforts will focus on expanding the library of analogues, examining structure–activity relationships, and gaining mechanistic insights to guide the development of improved candidates.

Keywords: Marine natural products, Diphenyl ethers, Antimalarial activity, Sponge metabolites, Synthetic derivatives

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Isolation, Characterization, and Antimicrobial Profiling of Mangrove-Derived *Micromonospora* Against the Aquaculture Pathogen *Vibrio parahaemolyticus*

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ABSTRACT

Antibiotic resistance has emerged as a major global health challenge, largely driven by the misuse of antimicrobial agents. Repeated or inappropriate exposure enables bacteria to develop survival strategies that render antibiotics ineffective. In aquaculture, the problem is worsened as resistant pathogens compromise both productivity and disease management. Among these, *Vibrio parahaemolyticus* is particularly significant, causing vibriosis and acute hepatopancreatic necrosis disease (AHPND) in shrimp and fish, while also posing risks to human health through gastroenteritis, wound infections, and septicemia. This dual threat emphasizes the need for new natural antimicrobials to mitigate rising resistance.

Mangrove ecosystems are recognized as rich reservoirs of *Actinomycetes* capable of producing structurally diverse bioactive metabolites. This study explored mangrove sediments from Honnavar, Karnataka, to isolate and characterize *Actinomycetes* with bioactive potential. Twenty-four isolates were recovered, and preliminary screening identified two potent candidates, ACT-C and ACT-Q. Both primary perpendicular-streak assays and secondary agar- well diffusion revealed strong inhibition against *V. parahaemolyticus*. MIC and IC_{50} assays confirmed high potency, particularly for ACT-C. SEM analysis showed substrate mycelia with spore clusters, and 16S rRNA sequencing classified both isolates under the genus *Micromonospora*. Further FTIR analysis identified functional groups associated with antimicrobial activity.

These findings highlight mangrove-derived *Actinomycetes* as a promising source of new antimicrobial compounds for controlling *V. parahaemolyticus* and addressing antimicrobial resistance in aquaculture.

Keywords: *Actinomycetes*, antimicrobial resistance, bioactive metabolites, Mangrove sediments, *Vibrio parahaemolyticus*.

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Neuroprotective effects of polysaccharide rich extract of Marine macroalgae Padina boergesenii in cuprizone induced multiple sclerosis in Wistar rats

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ABSTRACT

Multiple sclerosis (MS) is a chronic, immune-mediated neurodegenerative disorder characterized by demyelination of the central nervous system, leading to progressive neurological dysfunction. Recent studies have primarily focused on exploring natural bioactive compounds with neuroprotective and immunomodulatory potential to mitigate MS. Marine macro-algae, particularly *Padina boergesenii* (a brown seaweed), is rich source of bioactive compounds, including polysaccharides such as alginate, laminarin and fucoidan confirmed by FTIR, flash chromatography and HPLC. The present study aims at investigating the neuroprotective effects of polysaccharide rich extract of *Padina boergesenii* (PSREPB) in cuprizone induced MS in Wistar rats. Novel object recognition and Morris water maze tests were performed to estimate the cognitive function in rats which was found to be significantly ($p \leq 0.001$) improved in PSREPB treated animals. Additionally, motor coordination was also significantly ($p \leq 0.001$) improved in PSREPB rats as accessed in the open field, locomotor activity and rotarod tests. Biomarkers associated with mitochondrial biogenesis (PGC1-α, Cytochrome-C and SIRT1), inflammation (TNF-α, IL-6), neuroprotection (BDNF), and demyelination (MBP) in brain tissue were estimated using ELISA and all these markers were improved by PSREPB treatment. Histological reports using Luxol fast blue (LFB) staining suggesting the status of remyelination and H and E staining also supported the neuroprotective behavior of PSREPB. The findings of the present study, for the first time, reported the pre-clinical evidence of *Padina boergesenii*, against MS and concludes that the polysaccharide of this macro-alga showed remyelination as well as neuroprotective effects and offers a potential novel source of bioactive molecules against MS.

Keywords: Cuprizone, *S. wightii*, Polyphenols, Demyelination, Multiple Sclerosis, and Neuroprotection.

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Unlocking the Potential of Seaweed: Kappaphycus alvarezii Extracts as a Source of Bioactive Compounds against microbes and insects

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ABSTRACT

This study focuses on analyzing the phytochemical composition and bioactivity of *Kappaphycus alvarezii* extracts to explore their potential applications as antimicrobial and insecticidal agents. Extracts were prepared using acetone and ethanol, and a range of analyses were conducted to assess their bioactivity. Phytochemical screening revealed the presence of phenols, tannins, flavonoids, and terpenoids in both extracts, with the ethanol extract exhibiting a higher concentration of phenols. The acetone extract showed more DPPH radical scavenging activity, indicating stronger antioxidant potential. Antimicrobial assays demonstrated the inhibitory effects of both extracts on various bacteria and fungi, with the acetone extract showing slightly stronger antibacterial activity and the ethanol extract exhibiting greater antifungal potential. Notably, *Bacillus cereus* was resistant to both extracts. Insecticidal assays revealed dose- dependent and time-dependent mortality of pulse beetles upon exposure to the extracts. Chemical characterization using HPLC and GC-MS identified various bioactive compounds in the extracts, including phenolic compounds, fatty acids, terpenoids, and steroids, providing insights into the chemical basis for the observed bioactivities. The findings suggest that *K. alvarezii* holds potential as a natural source for developing novel antimicrobial and insecticidal agents for applications in agriculture, food preservation, and pharmaceuticals.

Keywords: *Kappaphycus alvarezii*, Antimicrobial activity, Insecticidal activity, Bioactive compounds, Food preservation.

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Therapeutic Application of Marine Collagen Peptide (MCP) on wound healing in animal model (In vivo)

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ABSTRACT

Acute full-thickness wounds require prolonged healing periods, thereby increasing the risk of infection. Severe infections can cause ulceration, tissue necrosis, and potentially fatal outcomes. Marine-derived biomaterials have emerged as promising alternatives for accelerating wound healing due to their sustainability, low immunogenicity, and strong biocompatibility. This study aimed to evaluate the efficacy of a jellyfish-derived Marine collagen peptide (MCP) hydrogel for topical application in a rat model in promoting full-thickness wound healing. Marine collagen peptide was extracted from jellyfish, an environmentally sustainable and cost-effective marine source. The hydrogel was formulated with sodium alginate in three concentrations 1%, 3%, and 5% representing low, medium, and high doses, respectively. The *in-vivo* wound-healing experiments were conducted using rats, and wound closure was monitored daily. The efficacy of the MCP-SA hydrogel was compared to a standard collagen gel (Collagen Gel SynerHEAL). The percentage of wound closure was calculated to assess healing efficiency. Topical application of the jellyfish collagen-alginate hydrogel demonstrated a marked effect on wound healing. Noticeable wound reduction began by the 4th day, with substantial improvement by the 8th day. The 5% hydrogel group showed approximately 85.8% wound closure on day 8, surpassing the standard collagen gel, which showed 77.5% closure. Complete healing occurred within 8-10 days, with smaller wound areas and nearly closed surfaces at the end of the study period. These results indicate that the MCP-SA hydrogel effectively accelerates wound healing by promoting reepithelialization, collagen deposition and angiogenesis and offers a sustainable approach for biomedical applications.

Keywords: Marine collagen peptide, sodium alginate, jellyfish collagen, hydrogel, wound healing, reepithelialization, angiogenesis, biocompatibility

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Blue Bioplastic Revolution: Sustainable PHA Production Using Marine Bacillus cereus

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ABSTRACT

The alarming surge of plastic pollution in marine ecosystems has reached a critical point, driving the need for ocean-safe, biodegradable materials aligned with blue economy and sustainability goals. This study investigates Bacillus cereus as a potent marine-associated bacterium for the production of polyhydroxyalkanoates (PHAs)—biodegradable and biocompatible polymers with immense potential in eco-packaging, marine coatings, and biomedical applications. Utilizing fruit peel-based carbon sources and hesperidin, a citrus-derived flavonoid, as a natural metabolic modulator, B. cereus achieved a PHA yield of 78.83% CDW, as confirmed by HPLC analysis. Molecular docking studies revealed hesperidin-mediated inhibition of citrate synthase, effectively redirecting acetyl-CoA flux from the tricarboxylic acid (TCA) cycle toward PHA biosynthesis. This redirection enhances intracellular carbon retention and promotes polymer accumulation without genetic modification. Comparative analysis with previous reports demonstrates significant improvement: marine B. cereus MCCB 281 yielded ~68.3% CDW using glycerol, starch-based fermentation reached ~60.5% CDW, and rice bran substrates produced ~35.5% CDW. Most industrial PHA producers are Gram-negative bacteria, such as Cupriavidus necator and Pseudomonas species. Biomaterials produced from these bacteria pose endotoxin contamination risks and require expensive purification; Gram-positive Bacillus cereus offers an endotoxin-free, biocompatible, and cost-effective alternative for biomedical-grade bioplastic production. Integrating molecular docking, waste valorization, and marine biotechnology, this platform represents a scalable and sustainable innovation for circular blue-economy ventures. The technology's dual advantage—environmental remediation and biomedical safety—positions it as a promising startup solution for next-generation bioplastic manufacturing aimed at reducing marine pollution while supporting green industrial growth

Keywords: PHA, *Bacillus cereus*, marine biotechnology, biowaste valorization, blue economy, biodegradable plastics

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Bioprospecting of marine bacterium *Microbacterium oxydans* AM4 for production of yellow pigment

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ABSTRACT

The bioprospecting of marine microorganisms has emerged as a critical area of research, aimed at discovering novel bioactive compounds with potential applications in pharmaceuticals, biotechnology, agriculture, and environmental sustainability. Among various marine metabolites, marine pigments have garnered considerable interest due to their structural diversity, greater stability, and multifunctional bioactivities, which often surpass those of terrestrial counterparts. These bio-pigments can serve as safer alternatives to synthetic dyes, which exert detrimental effects on both living organisms and the environment. The present study, for the first time, reports the production of a yellow pigment by the marine bacterium *Microbacterium oxydans* AM4, exhibiting metal-ion biosensing characteristics. This bright yellow-coloured bacterium was identified through morphological, phylogenetic, and biochemical characterisation. The production medium was optimised via one-factor-at-a-time (OFAT) approach, revealing that supplementation with 1% (w/v) mannitol in Zobell's marine broth supported maximum pigment production. In contrast, elevated concentrations of organic nitrogen sources, such as yeast extract and peptone, had a negative effect on pigment synthesis, indicating that maintaining a high C/N ratio is essential for enhanced yield. Furthermore, the purified yellow pigment was characterised using various analytical techniques, suggesting its carotenoid-like nature. Interestingly, this pigment was found to be useful as a biosensing system for detecting metal ions, particularly ferric ions. Overall, its chromophoric characteristics and ability to undergo spectral changes in response to metal ion interactions make it a promising candidate for developing efficient and eco-friendly detection methods for environmental monitoring and remediation technologies.

Keywords: Marine, bacterium, yellow pigment, fermentation, metal-ion detection

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The Acidic Alliance: Marine Xylanase Enzymes Against Lignocellulose

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ABSTRACT

The escalating global energy demand necessitates sustainable alternatives to fossil fuels. To combat this global pursuit lignocellulosic biomass could be used as a renewable and abundant substrate for bioethanol production; however, its interconnected structure composed of cellulose, hemicellulose, and lignin, yet again pose a substantial challenge for efficient hydrolysis. Lignocellulose needs pretreatment that could help for efficient conversion to fermentable sugars. The mesophilic enzymes cannot be used in this extreme environment. Marine bacteria are known for their enzyme production due to adaptations to extreme conditions, including acidic environment, hypersaline habitat, high pressures and extreme temperatures and hence can be used for the production of fermentable sugars. Xylan, the predominant hemicellulose polymer, requires enzymatic degradation by endo-β-1,4-xylanases to release fermentable sugars. Acidic xylanases, in particular, are advantageous for saccharification due to their high catalytic efficiency and stability under acidic conditions typical of biomass pretreatment.

In this study, marine bacterial isolates from mangrove sediments were screened for xylanase activity at acidic pH. Six isolates exhibited significant enzyme activity and stability under acidic conditions, indicating strong acidic potential. Preliminary assays confirmed their functional resilience, suggesting suitability for lignocellulose hydrolysis. Current work focuses on detailed biochemical characterization, including pH and temperature profiling, and assessment of lignocellulose degradation efficiency.

These findings highlight the promise of marine acidic xylanases as biocatalysts for integrating enzymatic hydrolysis for saccharification, reducing reliance on extreme chemical pretreatments. This approach not only advances need of sustainable biofuel generation but also valorizes marine microbial resources as a reservoir of industrially relevant enzymes.

Keywords: Marine bacteria, acidic xylanases, lignocellulose bioconversion, saccharification, extremozymes

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Investigation of Potential Sponge-Associated Microbial MAGs and Their Secondary Metabolite Potential in Ircinia sp.

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ABSTRACT

Marine sponges host structured microbial communities whose metabolic interactions influence host ecology and chemical complexity. To explore the microbial component of this system, we performed microbial genome-resolved metagenomic analysis of *Ircinia sp*. Following shotgun sequencing, rigorous filtering, assembly, and binning, a subset of high-quality metagenome- assembled genomes (MAGs) was identified. Five MAGs were prioritized based on completeness, low contamination, and correspondence to microbial lineages repeatedly reported in sponge microbiomes. These genomes were taxonomically placed and examined for functional potential. Beyond core metabolic capabilities, each MAG harbored genomic features suggestive of specialized or host-linked roles. Particular attention was directed to biosynthetic regions and chemical-producing loci, where patterns consistent with the capacity to generate **secondary metabolites** were observed. These biosynthetic signatures, together with metabolic network exploration, indicate that the selected microbes may contribute to the chemical repertoire and ecological stability of the *Ircinia sp.* holobiont.

This work outlines a focused genomic investigation into microbial associates of *Ircinia sp.*, revealing candidate symbionts with encoded potential for chemical innovation. The findings emphasize the role of sponge-associated microbes as reservoirs of unexplored metabolic and biosynthetic diversity.

Keywords: Marine symbiosis, *Ircinia* microbiome, Genome-resolved metagenomics, Specialized metabolism, Microbial associations, Functional potential

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Extraction, characterization and application of high-quality agar polysaccharide from unexplored Gelidium micropterum Kützing species from Indian water

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ABSTRACT

Agar is an important polysaccharide widely used in the food industry, pharmaceuticals, cosmetics, microbiology, and molecular biology applications. The demand for agar is steadily rising worldwide, but the expansion of production of high-quality raw materials is constrained due to the shortage of quality raw materials. This research investigates *Gelidium micropterum*, a red seaweed species growing along the Indian coastline and also having potential for its cultivation in tanks/ponds, as a potential source of high-quality agar polysaccharide. The extraction process involved a hot water extraction method with various concentrations of alkaline pre-treatment of NaOH i.e. 4, 6, 8 and 10% (w/v) and native agar without NaOH treatment. The resulting agar yields ranged from 16.97% to 26.03%, with corresponding gel strengths between 855 ± 51 and 2078 ± 55 g/cm². Notably, 8% and 10% NaOH pre-treatments yielded agar with superior gel strength and thermal properties, surpassing those reported for other Gelidiales species under similar conditions. Structural characterization was performed using FT-IR, ^{13}C- NMR, and ^{1}H-NMR spectroscopy, confirming similarities with standard agar. The extracted agar's molecular weights were in the range of 5704-7276 kDa. Sulphate content varied from
0.175 ± 0.082% to 6.197 ± 0.446% across treatments. The agar also supported microbial growth at lower concentrations than commercial agar, indicating promising application potential. These findings highlight *G. micropterum* as a viable and sustainable source of high-quality agar, contributing to the diversification of raw materials and supporting the development of the marine bioresource sector

Keywords: Agar, Agarophytes, *Gelidium micropterum*, FT-IR, NMR

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Biodiversity and Pharmacological Potential of Cone Snails and Sea Anemones from the Indian Coast

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ABSTRACT

Indian coast has rich marine biodiversity, is a home of variety of venomous invertebrate's viz., cone snails and sea anemones. These organisms possess unique venom compositions that have evolved for predation and defence, and they represent a significant yet under-explored resource for medicinal applications. Venom bioactive compound has potential in discovery of a novel drug to treat various diseases viz., cancer, Alzheimer's, diabetes, infectious diseases, etc. and against a threat of antimicrobial resistance. The review encompasses biodiversity and chemo- diversity study of cone snails and sea anemones and, focusing on the pharmacological potential of their venoms. For instance, the neurotoxins derived from cone snails have been instrumented in the development of novel analgesics, while the cytotoxins from sea anemones show promise in cancer treatment. Despite the promising applications, significant challenges persist such as sustainable harvesting and optimizing extraction techniques. This study underscores the importance of continued research into the venomous invertebrates of the Indian coast, advocating for interdisciplinary approaches to unlock their therapeutic potential. By understanding the diversity and functionality of these venoms, we can pave the way for innovative drug development that addresses various medical needs, ultimately contributing to the field of marine pharmacology.

Keywords: venomous marine invertebrates, cone snail, sea anemone, Indian coast, venom, drug discovery

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Development Of A Marine Dopamine–Carboxymethyl Chitosan Conjugate: Integrated Structural, Physicochemical, And Functional Biomaterial Assessment

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ABSTRACT

This study reports the extraction of chitin (CH) from the gladius of *Doryteuthis sibogae* and its subsequent conversion to carboxymethyl chitosan (CMC), yielding 23.6% CMC. FT-IR characterization confirmed efficient carboxymethylation through prominent peaks at 1692 and 1460 cm^{-1}. In parallel, dopamine (DA) was isolated and characterized from the brain tissues of the deep-sea shark *Etmopterus pusillus*, collected from 10°55.920′ N and 75°5.275′ E during the Sagar Sampada Cruise (Cruise No. SS420). DA extraction was performed using 50 mM phosphate-buffer (pH 2.5) with methanol (80:20) followed by purification through RP-HPLC, where the standard DA exhibited a retention time of 3.181 minutes although isolated DA at 3.181 minutes. *E. pusillus* showed a DA yield of 11.7%. UV-Vis spectroscopy revealed a 280 nm in the Standard DA, whereas 244 nm in purified DA, while fluorescence analysis showed Standard DA excitation at 280 nm and emission at 325 whereas, purified DA excitation at 317 nm and emission at 396 nm. FT-IR spectra of the DA displayed characteristic O–H/N–H stretching (3200–3500 cm^{-1}), aromatic C=C stretching (1600 cm^{-1}), and C–O vibrations (1200 cm^{-1}). LC- MS analysis detected a molecular ion peak of DA at 177 m/z, corresponding to a sodium adduct, while the standard DA exhibited 154 m/z. ^{1}H-NMR confirmed catechol and aliphatic proton signals, with minor aromatic variations reflecting chemical modifications of DA. Thermal analysis showed purified DA stability up to 270 °C with 26.39% weight loss. Conjugation of CMC with DA was validated by UV-Vis (λmax 281 nm), FT-IR (amide peaks at 1550–1650 cm^{-1}), and MALDI-TOF (507.04 m/z). DLS revealed a hydrodynamic size of 211.2 nm, and the conjugate exhibited enhanced thermal stability up to 330 °C. Overall, this workflow establishes a reliable protocol for DA isolation and CMC-DA conjugate synthesis with possible functional foods and neurological disorders.

Keywords: CMC, DA, RP-HPLC, LC-MS, NMR

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Harnessing *Nerite* Shell Chitosan And Mango Seed Starch For Sustainable Polymer Innovation

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ABSTRACT

Marine and agro-waste resources offer a promising pathway to mitigate the escalating plastic pollution crisis. This study explores the transformation of *Nerite* shells abundant along Mumbai's intertidal coast along with discarded mango seeds into a biodegradable plastic. Chitosan was extracted from *Nerite* shells through deproteinization (3.5% NaOH, 65 °C, 2 h), demineralization (1 N HCl), and deacetylation (50% NaOH, 110 °C, 30 min), achieving a yield of 14.5%. Starch was recovered from mango seed flour (dried at 50 °C for seven days) using aqueous extraction with a recovery efficiency of 96%. Both biopolymers were blended in a 1:1 (v/v) ratio with sorbitol as a plasticizer to form a translucent, flexible film. FTIR analysis confirmed characteristic chitosan peaks at 3433 cm^{-1} (O–H/N–H stretching), 1476 cm^{-1} (amine bending), and 875 cm^{-1} (β-1,4-glycosidic linkage), verifying successful deacetylation and polymer integrity. The starch was validated through FTIR and iodine complexation, producing a blue- black coloration. The resulting bioplastic exhibited good flexibility, smooth texture, and structural cohesion, indicating strong inter-polymer compatibility and potential for eco-friendly packaging and marine-safe applications. By valorizing shells and fruit waste, this study demonstrates a sustainable, low-cost model integrating coastal biodiversity with circular bioeconomy principles. The approach supports India's blue biotechnology and ocean sustainability goals, showcasing how locally sourced biowaste can be transformed into high- value materials that contribute to pollution reduction and environmental resilience.

Keywords: *Nerite* shell , Chitosan, Mango seed, Starch , Bio-plastic

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Bioprospecting of Lingula anatina: Antioxidant and Anti-Metastatic Potential

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ABSTRACT

The study evaluates the bioactivity of *Lingula anatina* methanol extract (LME), emphasizing its antioxidant and anti-metastatic potential in vitro. The extract, obtained by cold percolation, vacuum distillation, and freeze-drying, yielded 1.51–2.25%. Phytochemical analysis confirmed the presence of alkaloids, saponins, flavonoids, phenolics, and terpenoids, indicating a rich biochemical profile. Quantitatively, LME showed high alkaloid (46.82 mg CE/g) and phenol (0.614 mg GAE/mg) contents with moderate flavonoids (0.008 mg QE/mg). FTIR analysis revealed functional groups such as fluoro, sulfonate/sulfonamide, phenolic, anhydride, and alkene, while GC-MS profiling identified 66 compounds dominated by hexadecanoic acid methyl ester (21.55%), methyl stearate (10.52%), and eicosapentaenoic acid methyl ester (10.29%), confirming the presence of bioactive lipid constituents. Antioxidant-assays, including DPPH, nitric oxide, hydroxyl radical, ferric reducing antioxidant power (FRAP), and total antioxidant capacity (TAC), demonstrated concentration-dependent free radical scavenging activity. LME exhibited approximately 50% DPPH inhibition and 83.3% hydroxyl radical scavenging at 1000 µg/mL, suggesting strong antioxidative potential comparable to standard antioxidants.

Wound healing and metastasis-related assays revealed distinct cellular responses. In fibroblast (L929) cells, LME enhanced wound closure and cell migration up to 58% at 48 h, whereas in HeLa carcinoma cells, proliferation occurred without migration, suggesting inhibition of metastatic movement. Gelatin zymography confirmed that LME induced MMP-9 activity without altering MMP-2, implying matrix remodelling rather than motility. Microscopic analysis revealed apoptotic features in treated HeLa cells, including chromatin condensation and membrane blebbing, with an apoptotic index of 48.65% (±4.57), supporting its pro-apoptotic and anti-metastatic role.

Overall, *Lingula anatina* methanol extract demonstrates significant antioxidant efficacy and potential anti-metastatic properties through modulation of MMP activity and induction of
apoptosis in cancer cells. Highlighting its promise as a marine-derived bioactive compound for therapeutic applications.

Keywords: *Lingula anatina*, antioxidant, MMP-9, apoptosis, anti-metastatic, marine bioactive compounds, wound healing.

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Neutralising Properties of Marine Extracts Against Scorpion Venom: A Bioprospective Approach

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ABSTRACT

Scorpion envenomation is a major public health concern in the tropical and subtropical region. Currently, antivenom therapy is the only promising therapy in case of severe scorpion envenomation treatment. Given the narrow specificity of the antivenoms and the requirement of strict storage conditions, researchers have been exploring natural compounds with capability of neutralising the adverse effects of the venom. Most research studies aimed at identifying biomolecules with venom neutralising properties have focused on land-based organisms. However, despite the vast biodiversity of marine life, reports on the potential of marine organism extracts with venom neutralising properties remain relatively scarce. The objective of this study was to evaluate the ability of marine organism extracts to neutralize certain toxic effects caused by scorpion venom. The results of this study suggests that the marine organism extracts represent a promising source of bioactive molecules capable of mitigating the toxic effects of envenomation, thereby contributing to the development of novel therapeutic strategies for scorpion envenomation treatment.

Keywords: Marine Extracts, Scorpion Envenomation, Venom, Neutralisation, Bioactive Compounds.

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Chemical Investigation of Marine Bacteria: A Treasure Mine for Drug Discovery

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ABSTRACT

Discovery of bioceuticals is merely the first step in the biodiscovery process. The most significant challenge is converting these products into effective medicines due to the massive costs associated with getting a new drug to market. The discovery and commercialization of bioceuticals require a multidisciplinary approach that integrates biology, genomics, natural product chemistry, bioactivity testing, industrial bioprocessing, legal aspects, market analysis, and knowledge exchange. In this context, Oceans, which are rich in ecological biodiversity, can be regarded as an untapped resource for prospecting novel bioactive compounds. In light of the fact that marine bacteria frequently interact symbiotically or mutualistically with sponges as a valuable source for new natural products. To uncover the treasure for the discovery of novel bioactive compounds from marine bacteria. This study encompasses the bioprospecting of bacterial isolates to identify a hit molecule for therapeutic applications, followed by the discovery of hidden, unique metabolites with biological potential. To achieve this goal, a chemical approach will be employed, which involves bioassay-guided fractionation, dereplication, and chromatographic separation, utilizing high-resolution mass spectrometry (HR-MS) and nuclear magnetic resonance (NMR) spectroscopy. This integrative technique enables the detection and structural elucidation of a novel metabolite in the drug discovery pipeline.

Keywords: Drug discovery, Dereplication, Bioprospecting, Mass spectrometry, Sponge-associated Bacterium

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Development Of Biopolymer Based Wound Healing Patch Using Biowaste

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ABSTRACT

The increasing need for biocompatible and eco-friendly wound-healing materials has encouraged the use of natural polymers from sustainable resources. In this study, a biopolymer-based wound- healing patch was formulated using chitosan, cellulose, and starch, known for their excellent biological properties. The selected biowastes *Nerite* shells, banana stems, and mango seeds are rich in chitin, cellulose, and starch, respectively, and possess bioadhesive, biodegradable, and non-toxic characteristics, making them ideal for biomedical applications. Chitosan, cellulose, and starch were extracted with yields of 14.5%, 48%, and 96%, respectively. The extracted polymers were confirmed using Fourier Transform Infrared (FTIR) spectroscopy which showed characteristic functional group peaks for chitosan, cellulose, and starch. Chitosan exhibits anti- microbial activity, cellulose provides a structural framework and maintains a moist environment, while starch enhances film formation and flexibility properties essential for effective wound healing. These biopolymers were used to synthesize a hydrogel film by dissolving them in dilute acetic acid and crosslinking with sorbitol, forming a flexible and stable matrix suitable for wound-healing applications. This research supports SDG 12- Responsible Consumption and Production, by promoting the sustainable utilization of marine and agricultural waste for the development of eco-friendly biomedical materials.

Keywords: *Nerite* shell, Biopolymer, Biowaste, Wound-healing, Anti-microbial

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Biphasic Angiogenic Response Of *Nerite* Sp. Extract And Its Bioactive Potential

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ABSTRACT

Marine ecosystems are prolific yet underexplored reservoirs of unique bioactive compounds with immense biomedical potential. Among these, intertidal gastropods remain largely untapped despite their biochemical diversity. This study examines the angiogenic modulation potential of an extract derived from *Nerite* sp., a common intertidal gastropod, using the chick chorioallantoic membrane (CAM) model.Comparative groups included a pro-angiogenic standard (heparin), an anti-angiogenic standard (quercetin),and appropriate vehicle and normal controls. Vascular parameters such as branching pattern, CAM area, and vascular density were quantified along with embryo growth indices. Acute toxicity and cell-viability assays on normal fibroblast cell lines (ATC work) assessed cytotoxicity and proliferative response.*Nerite* extract (50–250 µg/mL) was non-toxic and induced maximal proliferation at 250 µg/mL, confirming its safety and cell-supportive nature. In the CAM assay, a biphasic, concentration-dependent response was observed at lower concentrations (50 µg/mL) the extract reduced secondary and tertiary vessel formation with distorted, parallel branching indicating anti-angiogenic activity, whereas higher concentrations (250 µg/mL) enhanced organized branching, vascular density, and well-defined vasculature suggesting pro-angiogenic potential. Embryo weight remained unaffected.Further ATC studies are in progress to evaluate cytotoxicity on cancer cell lines for anti-angiogenic concentrations and wound-healing assays for pro-angiogenic concentrations. Ongoing histological and protein-denaturation analyses aim to clarify inflammation-linked angiogenic pathways. Overall, *Nerite* sp. emerges as a sustainable marine bioresource exhibiting dual, concentration-dependent angiogenic modulation with applications in wound healing and cancer therapeutics.

Keywords: *Nerite sp.*, CAM, Angiogenesis modulation , Wound healing , Marine Bioactive

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Exploring Marine – Sourced Hyaluronic Acid For Therapeutic Applications

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ABSTRACT

Marine molluscs possess a varied biochemical profile and structurally organized tissues, making them valuable sources of bioactive compounds. After consumption and processing, molluscan shells are often discarded, contributing to environmental waste. However, these molluscan shells contain an organic matrix where glycosaminoglycan such as Hyaluronic acid (HA) play a key role *in* bio mineralization and structural reinforcement, helping regulate crystal deposition and shell strength. In the soft body tissues, HA contributes to osmotic balance, hydration, elasticity, and protection against oxidative stress, which are essential for movement and physiological resilience in fluctuating marine environments. In this study, HA was extracted from the body mass and shell powder of *Nerite sp.* and *Meretrix meretrix t*o evaluate both biological sources. Higher yields were obtained from the body mass; however, extracting HA from shell material provides an environmentally beneficial use for a frequently discarded resource. Anti - oxidant activity assessed by the DPPH assay indicated measurable free radical scavenging capacity in extracts from both sources. The presence of HA was confirmed through FTIR spectroscopy, showing characteristic functional group peaks. This study highlights molluscan derived HA as a valuable bioactive compound, with future work focusing on its potential application in the dermocosmetic industry and other oxidative-stress-linked therapeutic avenues.

Keywords: Hyaluronic acid, *Nerite sp.*, *Meretrix meretrix*, Anti - oxidant, dermocosmetic industry

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Pan-Genomic Exploration of the Genus Kocuria to Identify Genomic Determinants Influencing Antibiotic Biosynthesis Potential

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ABSTRACT

The genus *Kocuria*, belonging to the family Micrococcaceae, has traditionally been regarded as a non-pathogenic, commensal group of Actinobacteria. However, recent studies show that these bacteria have remarkable metabolic flexibility, strong stress tolerance, and the ability to produce interesting secondary metabolites, including compounds with potential antibiotic activity. This suggests that *Kocuria* could be an underexplored source of new or improved antibiotics. In this study, we are analyzing the pan-genome of both publicly available *Kocuria* strains and strains from our own collection. By comparative genomics, we aim to identify which genes are core (shared by all strains), accessory (present in some), and strain-specific. Particular focus is placed on biosynthetic gene clusters and genes linked to stress adaptation, as these often play key roles in antibiotic production. The outcomes of this work are expected to highlight strains with strong biosynthetic potential, reveal new pathways that may enhance antibiotic yield, and guide future strain improvement and metabolic engineering efforts. Overall, this study emphasizes how pan- genomics can support the search for new bioactive compounds and strengthen antibiotic development pipelines.

Keywords: Pan-genome; Comparative genomics; Secondary metabolites; Biosynthetic gene clusters (BGCs); Antibiotic yield enhancement; Metabolic engineering.

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Chemical investigation and isolation of secondary metabolites from Sea urchin Stomopneustes variolaris from Anjuna Goa

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ABSTRACT

Marine ecosystems cover more than 70% of the globe's surface with significant biological variety and enormous potential for marine bioproducts. Chemical investigations on marine organisms have led to the discovery of new bioactive natural compounds. Marine natural products play an important role in biomedical research and drug development, either as drugs or as lead structures for bioinspired chemical drug synthesis. To date, several marine natural products have been identified, and the search continues. This study highlights the isolation of natural products from marine organism Sea Urchin Stomopneustes variolaris. Sea urchin samples collected from Anjuna, Goa were extracted with solvents like methanol and chloroform to obtain crude extract. Sequential fractionation was then carried out with solvents of increasing polarity. The butanol fraction was investigated to study its chemical composition. Purification of the butanol fraction with high performance liquid chromatography resulted in the isolation of six pure compounds. The six compounds were identified and characterised with the help of nuclear magnetic resonance spectroscopy (^{1}H NMR and ^{13}C NMR), FT-IR spectroscopy and mass spectroscopy. The study led to the identification and isolation of molecules from Sea Urchin S. variolaris needed to understand the chemical variability within species to develop new molecules with potential application in medicine.

Keywords: Sea urchin, Marine natural products, High performance liquid chromatography, Nuclear magnetic resonance spectroscopy, Mass spectroscopy

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A novel approach to functional foods: encapsulation of seaweed-derived salt in culinary oils

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ABSTRACT

Reformulating salt with healthier alternatives is vital in functional food innovation. This study evaluates *Kappaphycus alvarezii* (K salt) encapsulated with groundnut or coconut oil as a salt substitute, analyzing physicochemical, antioxidant, nutritional, and sensory properties. Groundnut oil+K salt showed high antioxidant capacity (0.83 mg g^{-1}) and favourable lipid (1.67 µg g^{-1}) and mineral profiles, with a low Na: K ratio (0.09). FTIR analysis revealed strong amide bands, suggesting encapsulation. E-nose results confirmed distinct aroma profiles: nutty-roasted (groundnut) and citrus-floral (coconut). Sensory evaluation (n = 50) validated acceptance. These findings support oil-encapsulated K salt as a viable, health-oriented salt replacer.

Keywords: Encapsulation, Functional food, Seaweed salt, Sensory evaluation, *Kappaphycus alvarezii*

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Unveiling the Biocatalytic Potential of Marine Agarolytic Bacteria in Blue Biotechnology

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ABSTRACT

Agar is a complex polysaccharide. It is a significant yet underutilized hydrocolloid owing to its rigid gel forming properties and recalcitrant polysaccharide matrix that hinder depolymerization. It can be degraded by both chemical and enzymatic saccharification. Acid hydrolysis is the most commonly used method but it has detrimental environmental impacts and concerns. Therefore, effective enzymatic degradation of agar via agarase enzymes is a viable eco-friendly substitute. Systemic enzyme hydrolytic depolymerization of agar by α- and β-agarases can provide valuable bioactive neoagarooligosaccharides and 3,6-anhydro-L-galactose, which possess prebiotic and antioxidant activities, and hold promises for various other pharmaceutical applications. However, most reported agarases exhibit limited stability over temperature and pH range, restricting their industrial applications. This highlights the need for discovering agarases producing bacteria from diverse environments. Marine microbiome represents a prolific reservoir of agarolytic taxa equipped with agarases that are capable of degrading complex polysaccharide under broader physiochemical conditions. Recent advances highlight genera such as *Zobellia, Vibrio, Microbulbifer, Pseudomonas* and *Aliagarivorans* as key players in microbial agar degradation. Although, Indian coastal environment has yielded multiple agarolytic isolates but their enzymatic pathways, metabolic fate of degradation, and formation of by-products remains poorly elucidated.

In this study, enzyme families and associated metabolic pathways of agarolytic marine bacteria were comparatively assessed through computational exploration of curated enzymatic datasets. This synthesis highlights the untapped potential of marine agarolytic bacteria as reservoirs of industrially relevant enzymes and precursors for bioactive compound synthesis, providing new perspectives for sustainable blue biotechnological innovation.

Keywords: Agarase, Polysaccharide depolymerization, Marine bacteria, Glycoside hydrolases, Polyextremozymes.

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Phosphate-Functionalised Cellulose From *Sargassum* Waste Biomass As A Sustainable Dye Bioadsorbent

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ABSTRACT

Marine macroalgae are abundant in tropical and temperate regions and serve as rich sources of bioactive compounds and polysaccharides while contributing to CO_2 sequestration and coastal ecosystem balance. Brown algae such as *Sargassum* contain up to 70% carbohydrates, primarily cellulose, fucoidan, laminarin, and alginate. In this study, *Sargassum* biomass collected from the Goa coast, India, was utilised for cellulose extraction using the sodium chlorite method, yielding approximately 33% of dry biomass. This approach efficiently removed non-cellulosic components without employing harsh acid-alkali treatments. The extracted algal cellulose (AC) was further phosphorylated using a green urea-DAP method to produce anionic phosphorylated algal cellulose (ACP). Structural characterisation by FTIR, XRD, SEM, TGA, and EDX confirmed successful phosphate incorporation (bands at 835 and 926 cm^{-1}), reduced crystallinity (CrI: 55.87% to 29.87%), and a phosphorus content of 14.01 wt%, corresponding to a degree of substitution of 1.15. SEM revealed a porous, heterogeneous surface conducive to adsorption. The anionic ACP exhibited excellent adsorption performance toward cationic methylene blue dye, with kinetics fitting the pseudo-second-order model and isotherm analysis following the Freundlich model, indicating chemisorption and multilayer adsorption. The preparation process, based solely on air-drying and grinding, offers a cost-effective and scalable route without energy- intensive steps. This work presents a sustainable strategy for valorising waste *Sargassum* biomass into functional phosphate-based adsorbents for efficient dye removal and water remediation applications.

Keywords: Macroalgae, *Sargassum*, Cellulose extraction, Phosphorylation, Methylene blue dye

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Hunting cryptic venom peptides in the zoanthid Zoanthus sansibaricus through predictive transcriptome-mining approach

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ABSTRACT

Zoanthids (Order Zoantharia) are commonly known to carry structurally diverse non-peptidic secondary metabolites, including zoanthamines, palytoxins and other bioactive compounds. In contrast, their complex venom systems remain comparatively underexplored, especially in comparison other cnidarians like anemones. Transcriptomic explorations and low-molecular weight peptide fraction studies in a few zoanthid species have revealed novel bio-active peptides with therapeutic potential. In the present study, this transcriptome-guided venom discovery approach was applied to *Zoanthus sansibaricus*, a commonly found cosmopolitan zoantharian species on Indian coasts. High-quality de novo transcriptome assembly was annotated using established workflows and subsequently mined using specialized venom prediction pipelines. Candidate transcripts were screened for characteristic toxin motifs and activity centres, where several predicted peptides showed structural and functional signatures indicative of venom functionality. These identified venom-like peptide transcripts could be subject to ecological validation through targeted LC–MS/MS searches against multi-omics derived databases for this species. Synthetic production of these peptides for bioactivity assays could help characterize extent of bioactivity type and applications. Our findings demonstrate the prospect of transcript based bio-active peptide prediction as primary strategy for uncovering cryptic peptide diversity in non-model marine invertebrate groups like zoanthids.

Keywords: venom, zoanthids, transcriptome,bioactive peptides, cnidarian

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Antibacterial Metabolites from Marine Sponge-Associated Bacterium: A Metabolite Profiling Approach

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ABSTRACT

Antimicrobial resistance (AMR) has become one of the most critical and rapidly rising global threats, leading to a decline in the effectiveness of existing antibiotics against infectious diseases. According to the World Health Organization's report on antimicrobial resistance acquired bacterial priority pathogens list, there is an urgent need to explore novel bioactive compounds with potent antibacterial properties. Marine sponges, recognized as a major source of novel bioactive metabolites, serve as hosts for diverse microbial communities. These symbiotic bacteria are known to produce structurally unique secondary metabolites with significant pharmaceutical potential. In the present study, bacteria isolated from the marine sponge were screened for antibacterial activity against a series of clinically important pathogens. Among the associated bacteria, one isolate exhibited remarkable inhibitory activity against the clinical strain *Staphylococcus aureus*, indicating the presence of potent antibacterial constituents. To characterize the bioactive components, metabolite profiling of the active crude extract was performed using Triple quadrupole LC-MS/MS (Liquid chromatography-mass spectrometry). The analysis revealed several previously reported bioactive metabolites with known antibacterial efficacy. This study highlights the significance of marine sponge-associated bacteria as promising source of significant antibacterial compounds. Furthermore, integrating metabolite profiling with bioactivity screening offers an effective way for the discovery of novel or known natural products with therapeutic potential.

Key words: Marine sponges, Sponge associated bacteria, Antimicrobial resistance, Antibacterial activity, secondary metabolites

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Characterization Of Estuarine Metal-Tolerant Bacteria For Bioremediation And Plant Growth Promotion

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ABSTRACT

Heavy metals are present everywhere and its accumulation posses threat to aquatic as well as terrestrial life forms. Marine metal-tolerant bacteria are known to tolerate metals by adapting to various mechanisms. This study focuses on isolation and characterization of metal-tolerant bacteria from mangrove environment for their potential biotechnological applications for bioremediation and as plant growth promoters. Fifty-one different strains of bacteria showing distinct colony characteristics were isolated from water and sediment samples of Old Goa mangrove sites and subjected to increasing concentrations of metals. Six bacterial isolates demonstrated tolerance to heavy metals, namely Cu, Co, Zn and Fe at high concentrations (2000 ppm) signifying that the metals might have deleterious effect on the living biota at higher concentrations. The amount of metal absorbed by these isolates was determined by Atomic Absorption Spectroscopy (AAS) which revealed that strain 6 absorbs highest amount of Fe, strain 9 absorbs highest amount of Zn and strain 33 absorbs highest amount of Cu and Co. EPS extraction studies also showed that strain 33 produces higher amount of EPS as compared to other cultures, thus, having higher efficiency to absorb the selected metal. SEM analysis revealed that metal-tolerant bacteria strains aggregate in the presence of metals, whereas they grow as single isolated colonies in the absence of these metals (control). Further, application of these metal-tolerant bacteria isolates in bioremediation of heavy metals in wastewater by immobilization using sodium alginate beads and plant growth promotion will be carried out.

Keywords: metal-tolerant bacteria, mangrove, bioremediation, plant growth promotion

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From Mangrove to Biorefinery: Discovery and Optimisation of Extracellular Xylose Isomerase Producers

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ABSTRACT

Mangrove ecosystems harbour microorganisms uniquely adapted to extreme conditions—fluctuating salinity, temperature, and nutrient levels—making them promising sources of industrially robust biocatalysts. Xylose isomerase (glucose isomerase E.C. 5.3.1.5) is one such enzyme with clear commercial value: it converts D-xylose to D-xylulose, a critical step in bioethanol and high-fructose syrup production. As xylose constitutes up to 40% of lignocellulosic biomass, efficient xylose isomerase enzymes are essential for renewable biofuel development. However, the industrial bioethanol producing Saccharomyces cerevisiae cannot metabolize xylose directly, while alternative xylose-fermenting yeasts require costly NAD(P)H cofactors and produce undesirable xylitol by-products. Consequently, bacterial xylose isomerase offers superior industrial advantages for xylose bioconversion.

In the present study, 27 bacterial isolates from Goan mangrove regions were screened and identified for producing xylose isomerase activity. To quantify this activity accurately, two common detection methods were compared—Cysteine-carbazole-sulfuric acid method and Cysteine hydrochloride- sulfuric acid method. The Cysteine hydrochloride-sulfuric acid approach proved most reliable for distinguishing xylose from xylulose. The enzyme localization was mapped (extracellular, periplasmic, and intracellular) across all isolates. Luteimonas sp. emerged as the strongest producer, with the highest extracellular activity at 2.098 U/mL, suggesting its potential for scaled enzyme production. Subsequently, production conditions were optimised to maximize enzyme activity from Luteimonas sp., including parameters such as media salt composition, pH, temperature, incubation time and carbon/nitrogen sources by RSM. The extracellular secretion profile and optimized production parameters position this strain as an economically attractive candidate, minimizing costly cell disruption and purification steps for both xylose bioconversion and biofuel production.

Keywords: Xylose isomerase, Extracellular, Mangroves, Biofuel, RSM

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Deciphering Process Variables for Enhanced Melanin Yield from Marine Actinobacteria.

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ABSTRACT

Marine actinobacteria represent exceptionally rich yet underexplored source of melanin-producing bacteria, offering pigments with superior structural stability and biological functionality compared to their terrestrial counterparts. Their adaptation to saline, high-pressure, and nutrient-variable marine environments enables the biosynthesis of melanin with enhanced antioxidant, UV-protective, and metal-chelating properties, making them highly prospective for pharmaceutical and cosmetic applications. Despite this potential, large-scale melanin production remains limited due to inherently low biosynthetic yields, complex extraction procedures, and a lack of systematic process optimization strategies.

In the present study, marine actinobacterial isolates were isolated from Estuarine mangrove systems and coastal sediments with a salinity range of 20 to 37 ppm, screened for pigment production, and cultivated under varying nutritional conditions to evaluate yield enhancement. A 4300% or 43-fold increase in melanin synthesis was achieved through the supplementation of *L*-tyrosine (as a precursor) and trace copper ions (as a cofactor) to Soyabean Casein Digest medium. To address the extraction bottleneck, a Response Surface Methodology (RSM) framework was employed to optimize parameters such as alkaline extraction strength, acid precipitation ratio, and incubation time. The model predicted importance of boiling time as well as Acid base ratio required for a better yield.

This integrative study bridges marine microbial bioprospecting with data-driven process optimization, offering a scalable and sustainable route for melanin biomanufacturing. By leveraging the metabolic diversity of marine actinobacteria and refining production workflows through statistical design, this work highlights new directions for transforming marine bioproduct discovery into industrially viable applications.

Keywords: Actinobacteria, Melanin, Tyrosine, RSM, Acid-Base extraction.

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Forged in Fire and Acid: Machine Learning Blueprints for Bacterial Poly-Extremozyme

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ABSTRACT

Global boiling from fossil fuels necessitates the rapid adoption of renewable resources to reduce emissions, cool the planet, and ensure environmental sustainability.The conversion of renewable biomass to simplest sugers in the industry requires endoglucanases with extreme acidic and thermophilic activity; however, extant enzymes have little or no combined extremophilic properties. We address this by combining multi-database integration and machine learning-based protein design.

The bacterial endoglucanase data from BRENDA, UniProt, NCBI, and CAZy were integrated into an automated harmonisation pipeline and subjected to stringent taxonomic validation (NCBI Taxonomy) to filter non-bacterial entries. This provided approximately 150 high-confidence sequences across six major phyla: Firmicutes, Actinobacteria, Proteobacteria, Bacteroidetes, Thermotogae, and Fibrobacteres, annotated with measured pH and temperature optima. Enzymes were classified as acidic (pH< 5), thermolytic (T>50°C), or acidothermolytic (pH <5 and T >50°C). Ensemble models (random forest, XGBoost, neural networks) were trained with multi-level feature extraction, including sequence (HMMER, SignalP, ProtParam), structure (AlphaFold2, DSSP), and active site geometry (PyMOL), and optimised using Bayesian techniques (Optuna). The results of the cross-validation showed that both the prediction of pH and temperature had an R^2 exceeding 0.80, and the analysis of feature importance indicated the key residues based on SHAP values.

Variants are thoroughly computationally validated for stability (FoldX DDG, Rosetta, GROMACS 100-ns MD at pH 5/50 °C), catalytic competence (QM/MM transition states, AutoDock substrate binding, PROPKA3 pKa shifts), and product profile analysis to understand the production of side products (multi-substrate docking, transglycosylation pathway modelling, product inhibition constants).

Keywords: Acidothermolytic endoglucanase, Global Boiling, Ensemble modelling, Predictive enzymology, Machine Learning

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From Waste to Value: Sustainable PHA Production by Coastal Bacteria

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ABSTRACT

Polyhydroxyalkanoates (PHAs) are biodegradable biopolymers synthesized by microorganisms as intracellular carbon and energy reserves under nutrient-limiting conditions. They serve as promising sustainable alternatives to petrochemical-based plastics. In this study, bacterial isolates obtained from coastal ecosystems were screened for their ability to produce PHAs. The isolates were further subjected to substrate optimization. The substrates used were, burnt oil, fish waste, and fruit & vegetable waste. The experiment was carried out with short and long incubation periods (3 and 10 days respectively). Among all the isolates, SP10, showed the maximum PHA production in terms of both % and concentration ((47.514± 9.126 % and 157.515 ± 7.179 mg/L) respectively. For the optimization experiment with short incubation time, isolate D6, with fish waste as substrate was the highest PHA producer (56.529±0.869%). Among the substrates, the highest production of PHA (%) was exhibited by Fish waste > Burnt oil > Fruit & vegetable waste. For the experiment with longer incubation period, isolate D6, with burnt oil as substrate was the highest PHA producer (49.868 ± 5.626%, 55.958 ± 10.568 mg/L). In terms of substrates, PHA production was maximum in Burnt oil > Fruit & vegetable waste > Fish waste. A significant difference ($P<0.01$) in the production of PHA was observed during different incubation times. PHA production by the isolates was observed to be 1.17X higher after 3 days of incubation compared to when incubated for 10 days. These findings highlight the potential of coastal bacteria for cost-effective and sustainable PHA production using organic waste substrates.

Keywords: Polyhydroxyalkanoates, coastal, substrates, sustainable, organic waste

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Infestation Of Isopods And Copepods In The Gills Of The Grey Eel Catfish (Plotosus Canius, Hamilton 1822) From The Tropical Islands Of India

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ABSTRACT

Crustacean parasites are among the most diverse organisms that have a significant impact on aquaculture and wild fisheries. The heavy infestation of parasites leads to restlessness, reduced growth, impaired respiration, and can cause the death of the fish. The aim of this study is to report the parasitism of different types of crustacean ectoparasites from a single host fish species, *Plotosus canius* Hamilton,1822. The *Plotosus canius* is also known as the Grey Eel Catfish (order Siluriformes, family Plotosidae), found chiefly in estuaries and coastal marine environments, exhibiting an amphidromous nature. The study was conducted from May 2025 to September 2025, during which a total of 32 individuals of *P. canius* were collected from the Chouldary region. The body surface, gill chambers, and buccal cavity were then examined for the presence of parasites. Four species of parasitic crustaceans were collected, including one species of a branchiuran, *Argulus sp.,* one species of copepod, *Ergasilus sp.,* and a Cirolanidae isopod, *Eurydice sp*., as well as praniza and zupea larvae of a *Gnathia* species. *Gnathia* and *Ergasilus sp* are present and heavily infested in the gills. The other two ectoparasites are found attached to the body surface near the mouth, upper gill chamber, body surface and at the base of the fins. This study also recorded the new host-parasitic relationship between *Eurydice sp* and the catfish *Plotosus canius*.

Keywords: Crustaceans; Catfish; Parasitic relationship; Gills; South Andaman

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Metagenomic Mining Of Qs Genes From Indian Deep-Sea Sediments: *In Silico* Characterization Of Qq Enzymes Through Qsp Database

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ABSTRACT

Deep-sea sediments host diverse microbial communities that use quorum sensing (QS) and quorum quenching (QQ) to regulate ecological interactions, yet their depth-related distribution remains unclear. We analysed Arabian Sea sediments (334–992 m) using shotgun metagenomics, metagenome-assembled genomes (MAGs), and a curated quorum-sensing/quenching protein (QSP) database. A total of 359 QSPs were identified across four sediment samples. Shallow sediments (SS1, SS2) showed higher abundance and diversity of QS and QQ elements, particularly AHL-mediated systems and acylase/lactonase enzymes, indicating active microbial interactions and competition. Deeper sediments (SS3, SS4) exhibited reduced QS diversity but were enriched in AI-2, DSF, and c-di-GMP components, reflecting adaptation to oligotrophic, high-pressure conditions. Correlation analysis revealed coordinated activity between QS regulators and QQ enzymes, suggesting complex regulatory integration. MAG-derived proteins displayed conserved motifs in lactonases, acylases, and c-di-GMP phosphodiesterases, with docking confirming functional interactions. Psychrophilic taxa were strongly associated with QSPs, highlighting their ecological role in cold habitats. Overall, this study reveals depth- dependent variability in microbial signaling networks and identifies deep-sea sediments as potential reservoirs of bioactive communication molecules.

Keywords: Deep-sea sediments, Quorum sensing, Quorum quenching, Ecological interactions, Metagenome

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Cold-Active Quorum-Quenching Enzyme From Deep-Sea Vibrio Sp. Sat06 For Biofilm Control In Food-Processing Pipelines

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ABSTRACT

Quorum-quenching (QQ) enzymes offer a sustainable approach to control biofilms in food-processing environments. From 21 psychrophilic deep-sea isolates, *Vibrio* sp. SAT06 displayed broad-spectrum QQ activity against both short- (C6-HSL) and long-chain (3-oxo-C12-HSL) acyl-homoserine lactones. The active enzyme, an EAL-domain-containing protein, exhibited cold-active hydrolytic activity (0–15 °C) under alkaline conditions, enhanced by Mg^{2+} and Ca^{2+} ions. HPLC and acidification assays confirmed its ability to degrade acyl-homoserine lactones. Functionally, SAT06 reduced biofilm biomass by 40–60% in *Listeria monocytogenes* and *Pseudomonas fluorescens*, downregulated the biofilm regulator *agrA*, and restored antibiotic susceptibility in resistant pathogens. Mechanistic analysis indicated dual activity via lactone ring hydrolysis and cyclic di-GMP modulation, supported by Congo red assays. The cold-active stability of SAT06 under food-processing conditions, along with proof-of-concept coating studies in a model food-grade pipeline, underscores its potential as a durable, food-safe anti- biofilm agent.

Keywords: Quorum-quenching enzymes, Psychrophilic bacteria, Deep-sea sediments, Biofilms, Food-process

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From diversity to function: metagenome-assembled genomes insight into bay of bengal microbial communities

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ABSTRACT

The Bay of Bengal (BoB) harbors microbial communities shaped by inputs from major river systems, mangroves, and coastal wetlands, making it a globally significant. However, the identity and metabolic potential of most of these microorganisms remain poorly understood. To advance our knowledge of these communities, we analyzed metagenome-assembled genomes (MAGs) recovered from 71 water samples collected along five major BoB transects-Krishna, Godavari, Vizag, Chilika, and Mahanadi-spanning diverse offshore gradients. From these samples, we reconstructed 1,602 bacterial and 92 archaeal MAGs (≥50% completeness and ≤10% contamination), representing 14 bacterial and 5 archaeal phyla. At the phylum level, the dominant bacterial MAGs belonged to Pseudomonadota, Bacteroidota, Actinomycetota, and Cyanobacteria, while the archaeal MAGs were classified into Asgardarchaeota, Halobacteriota, Nanobdellota, Thermoplasmatota, and Thermoproteota. Species-level taxonomic classification indicates that many of these MAGs likely represent previously unknown microbial taxa. Furthermore, all archaeal MAGs selected for downstream analysis unveiled functional potential in carbon catabolism, methanogenesis, sulfur assimilation and dissimilation pathways, oxidative phosphorylation, and phototrophic energy conversion. Additionally, archaeal metagenomes encoded industrially relevant enzymes-including oxidoreductases, proteases, lipases, and alcohol dehydrogenases-widely applied in baking, brewing, food processing, dairy production, and animal feed industries. Notably, we identified a rhodopsin-based light-harvesting archaeal species, Kariarchaeum pelagium, within BoB waters. Together, these metagenome-assembled genomes provide a foundational resource for uncovering novel microbial diversity in the Bay of Bengal and for linking taxonomic novelty with functional potential in this globally significant marine ecosystem.

Keywords: Bay of Bengal, MAGs, Bacteria, Archaea, Diversity, Function

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Monsoon-Influenced Functional Reorganization of Dinoflagellate Communities across the Zuari–Mandovi Estuarine Continuum

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ABSTRACT

The Zuari–Mandovi estuarine system in the eastern Arabian Sea, shaped by strong monsoonal forcing and river– coast interactions, provides a dynamic tropical environment for evaluating ecosystem responses to seasonal hydrographic variability. This study assesses dinoflagellate diversity, functional traits, and trophic strategies along a river-to-offshore transect from January 2024 to February 2025, offering new insights into how microphytoplankton communities reorganize across monsoon transitions.

Dinoflagellates accounted for nearly 40% of total phytoplankton species richness and were classified into autotrophic, mixotrophic, and heterotrophic nutritional modes to elucidate functional restructuring. Estuarine stations consistently exhibited high species richness and were dominated by heterotrophs for much of the year, with Protoperidinium spp. showing pronounced peaks during late post-monsoon and early pre-monsoon periods. Mixotrophs exhibited seasonal pulses, driven by elevated abundances of Tripos furca and Peridinium spp., while nutritionally unclassified taxa, such as Metadinophysis sp., contributed episodically to increased cell densities. Offshore regions showed frequent cyanobacterial occurrences outside bloom periods and experienced brief mixotroph surges associated with Trichodesmium blooms in April and Gymnodinium blooms in May. Autotrophs, including Pyrophacus spp., were comparatively sparse and appeared mainly during the late post-monsoon to early pre-monsoon interval.

Across seasons and hydrographic settings, dinoflagellate assemblages were predominantly structured by mixotrophs and heterotrophs, reflecting their central role in carbon cycling, grazing pathways, and microbial food- web coupling. By integrating species composition with nutritional modes, this study highlights functional diversity as a powerful approach for assessing coastal ecosystem resilience and supporting sustainable ocean- health monitoring in monsoon-influenced tropical environments.

Keywords: Dinoflagellate functional diversity, Seasonal variability, Mixotrophy, Heterotrophy, Estuarine– offshore gradient

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Deep-ocean microbial frontiers: picophytoplankton persistence in the deep south tropical indian ocean

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ABSTRACT

Marine picophytoplankton are the Earth's most abundant photosynthetic organisms, playing a
vital role in the biological and biogeochemical cycling. While their distributions in surface waters are well documented, their presence and ecological significance in the deep ocean remain poorly explored. This study investigates the vertical and spatial occurrence of picophytoplankton across the South Tropical Indian Ocean's (STIO) extensive aphotic zone, spanning depths from the surface to 5,250 m. Sampling was conducted during a research cruise (16 March–1 May 2021) aboard RV Sindhu Sadhana, covering 1.98°S–20.99°S and 61.25°E–90.47°E across five stations.Flow cytometry and epifluorescence microscopy confirmed the presence of Synechococcus,Prochlorococcus, and picoeukaryotes throughout the deep water column. Maximum abundances reached 10^3 cells mL^{-1} for Synechococcus and Prochlorococcus, and 10^2 cells mL^{-1} for picoeukaryotes, broadly proportional to their epipelagic distributions. Abundances were lowest in the mesopelagic zone but increased again in the bathypelagic and abyssopelagic layers. An exception was observed near the 90°E Ridge, where westward transport by the South Equatorial Current resulted in Synechococcus concentrations several orders of magnitude higher than at the surface, with Prochlorococcus and picoeukaryote levels comparable to surface waters. Relative to epipelagic means, Prochlorococcus showed the lowest contribution (~9%) in the aphotic zone,followed by picoeukaryotes (~42%) and Synechococcus (~44%), collectively contributing measurable carbon biomass at depth. These findings reveal that picophytoplankton persist far beyond the photic boundary, highlighting their overlooked role in sustaining microbial communities and supporting biological and biogeochemical processes within the deep STIO.

Keywords: Picophytoplankton; Synechococcus, Prochlorococcus; Deep Ocean; Aphotic Zone; South Tropical Indian Ocean; Biogeochemical Cycling

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Exploring the potential of arctic microbes of kongsfjorden for bio-hydrogen production

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ABSTRACT

The quest to hunt for microbial communities providing value products like biohydrogen have triggered multiple diversity analysis globally. Biohydrogen, a high calorific valued carbon-neutral fuel, is currently the need of hour to mitigate various climate change issues. Dark fermentation is one of the common methods involved in biohydrogen production, however it requires an average temperature range of 30-35°C for optimal utilization of substrates. Roughly 10% of world land lives in cold adaptations, where biohydrogen production processes requiring elevated temperatures often adds extra operational charges. There comes the need for microbes, specifically from extremophilic conditions, including polar environments to produce biohydrogen within their unique frosting adaptations. In this regard, the current study aimed to perform a microbial diversity analysis of Kongsfjorden sediment samples procured around the five sites at Ny-Alesund during the Indian Arctic Expedition 2025 using nanopore metagenomic sequencing, to identify various biohydrogen producing microbial groups. The physico-chemical profiles of sediments collected were compared with microbial diversity using canonical correlation analysis. Dominant groups were inclusive of *Firmicutes*, *Bacillus* and *Proteobacteria.* Further, biohydrogen potential (BHP) experimental setups using glucose as carbon source. The water displacement and Gas Chromatography were used as detection measures for biohydrogen. Results suggest over 50ml hydrogen production within a week of setup, suggesting potential of arctic microbes to generate biohydrogen. Such findings would help highlight the untapped potential of Arctic microbial consortia for sustainable biohydrogen production as a climate-resilient energy solution.

Keywords: Kongsfjorden, Bio-hydrogen, Dark fermentation, Sediment samples, Microbial diversity

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Coupling of nitrification and carbon fixation in clam-associated microbial communities of a tropical estuary

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ABSTRACT

Chemoautotrophic nitrifiers link the marine nitrogen and carbon cycles by oxidizing reduced nitrogen compounds to obtain energy for inorganic carbon fixation, yet their ecological functioning within benthic microhabitats remains underexplored. This study investigated the seasonal variations in nitrification and dark carbon fixation (DCF) activities within the tissues of the estuarine clam Polymesoda erosa and the ambient sediment during pre-monsoon, monsoon, and post-monsoon seasons. Clam foot, gill, and mantle tissues and sediment samples were incubated with radiolabeled NaH14CO3 and 15NH4Cl to measure DCF and nitrification rates respectively alongside analysis of sediment physicochemical parameters. Results revealed similar seasonal trends of both processes in clam tissues, with the highest nitrification and carbon fixation rates of 16.03 ± 1.68 nM g dry wt-1 h-1 and 0.55 ± 0.023 µMC g dry wt-1 h-1 respectively during the monsoon in the gill tissue, indicating that nitrifiers act as active chemoautotrophs driving DCF. The nitrification rates were one order higher in P. erosa tissues compared to sediments. Significant positive correlation between nitrification and DCF ($p \geq 0.001$) suggests functional coupling of these processes within the clam. The correlations between nitrification and DCF with pH ($p \geq 0.05$), DO ($p \geq 0.001$), Eh ($p \geq 0.01$) and H2S ($p \geq 0.05$) highlights influence of physicochemical conditions on the former processes. These findings reveal that P. erosa hosts metabolically active nitrifying chemoautotrophs contributing to both nitrogen transformation and inorganic carbon assimilation. The observed coupling of nitrification and carbon fixation highlights the role of the clam as a biogeochemically dynamic microhabitat that enhances benthic productivity and resilience. Overall, this study brings out the role of clam-associated microbial communities in driving carbon-nitrogen cycling under changing environmental conditions in tropical estuarine ecosystems.

Keywords: Mangroves, Nitrification, *Polymesoda erosa*, Carbon fixation, Chemoautotrophs

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Microbial Nitrate- and Sulfate-Driven Methane Oxidation in the Cold Seep Sediments of the Krishna–Godavari Basin.

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ABSTRACT

Nitrate- and sulfate-dependent anaerobic methane oxidation (N-DAMO and S-DAMO) are microbially mediated processes that play a crucial role in mitigating methane emissions, a potent greenhouse gas. This study highlights the activity of these processes and the associated microbial taxa regulating them. The methane oxidation rates across both processes ranged from 21.37 to 14371.96 nM g^{-1} d^{-1}. In the S-DAMO experiments, a significant positive correlation was observed between methane oxidation activity and sulfate concentrations at 10 mM ($r = 0.881$; $p < 0.01$), 20 mM ($r = 0.970$; $p < 0.001$) and 30 mM ($r = 0.857$; $p < 0.05$). Both sulfate and methane concentrations decreased markedly across all experimental setups ($p < 0.001$), with methane oxidation activity being approximately 9-fold higher at 20 mM sulfate concentrations compared to the other concentrations. The dominant microbial groups driving S-DAMO included Methanobacteriaceae, Cenarchaeaceae, Nitrososphaeraceae, Idiomarinaceae, Planctomycetaceae and Pirellulaceae, indicating their significant contribution to carbon sequestration in cold seep ecosystems. In the case of N-DAMO, methane oxidation showed strong positive correlations with nitrate concentrations of 10 µM ($r = 0.890$; $p < 0.01$), 20 µM ($r = 0.858$; $p < 0.05$) and 30 µM ($r = 0.805$; $p < 0.05$), with oxidation rates being 5.98-fold higher at 10 µM nitrate concentrations compared to the other concentrations. A significant decline in both nitrate and methane levels was observed from day 0 to day 60 ($p < 0.001$). The microbial taxa associated with N-DAMO included Nitrosopumilus, Methanobacteria, Verrucomicrobia, and Planctomycetes, reflecting their roles in coupling methane and nitrogen cycling. Overall, the N-DAMO process exhibited 16.92-fold higher methane oxidation activity than S-DAMO, suggesting that nitrate-dependent methane oxidation could represent a major methane sink in cold seep or gas hydrate-bearing sediments.

Key words: nitrate, sulfate, methane oxidation, sediment, archaea, bacteria

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Synergistic Toxicological Effects of Microplastics and Heavy Metals on Soil Enzymes and Microbial Communities in the Indian Sundarbans Mangrove Ecosystem

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ABSTRACT

The Indian Sundarbans, a UNESCO World Heritage Site and one of the largest mangrove ecosystems globally, faces increasing co-contamination by heavy metals and microplastics (MPs). This study examines their combined effects on soil properties, enzymatic activities, and microbial communities across ten intertidal sites (S1–S10), offering an integrated view of contamination impacts. Soils were slightly alkaline (pH 7.4–7.85), moderately saline (12.8– 16.4 ppt), and fine-textured, encouraging pollutant retention. Pollution indices—enrichment factor (2.01–9.90), geoaccumulation index (−1.93–3.32), contamination factor (0.48–3.01), and pollution load index (0.51–1.86) showed pronounced spatial differences, with sites S2, S3, and S10 exhibiting lower contamination. MPs ranged from 27 to 131 fragments / kilogram of soil, sized 100–300 µm, mainly polyethylene (PE) and polyethylene terephthalate (PET); polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC) were confirmed by Raman spectroscopy. Heavy metals (Pb, Cu, Ni, Cd, Zn, Cr) correlated strongly with MP abundance, suggesting synergistic pollutant accumulation. Co-contamination markedly inhibited soil enzymes CMC cellulase, β glucosidase, urease, alkaline and acid phosphatases, aryl sulfatase, and phenol oxidase disrupting essential carbon, nitrogen, phosphorus, and sulphur cycling. MPs enhanced metal adsorption and bioavailability, intensifying toxicity through interactive mechanisms. Principal component analysis (PC1: 77.4% variance) identified strong co-variation between metals and MPs, defining the key pollution gradient. Microbial analysis revealed co-contamination acted as an ecological filter, enriching stress- tolerant Firmicutes and Proteobacteria (Bacilli and Gammaproteobacteria) and reducing diversity. Alpha diversity metrics (Abundance-based Coverage Estimator-ACE, Shannon) declined notably under pollution, hinting at nutrient cycling vulnerability. Cluster analysis categorized sites into three groups: Cluster I (S4, S9, S5, S6) with high contamination, enzymatic suppression, and low diversity; Cluster II (S2, S3, S10) with low contamination, high microbial richness, and enzyme activity; and Cluster III (S7, S1, S8) with intermediate contamination and biological function. This study shows that MPs and heavy metals together inhibit enzymes, alter microbes, and disrupt nutrient cycles, highlighting the need for integrated monitoring and remediation to protect the Sundarbans.

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Taxonomic Insights into Deep-Sea Microorganisms from Tuticorin region, Southern coast Using Culture-Independent Nanopore Sequencing

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ABSTRACT

The deep-sea environment presents extreme ecological challenges, including low light penetration, reduced oxygen availability, high hydrostatic pressure, and limited nutrient resources. Microorganisms inhabiting such environments have evolved remarkable physiological and metabolic adaptations, making them an important focus of marine microbial ecology and bioprospecting. Despite the ecological importance of the Indian Ocean, studies on microbial diversity from the deep waters off the southeast coast of India remain limited.

In this study, sediment was collected from a depth of 100 m in the Tuticorin deep-sea region, Tamil Nadu, and subjected to full-length 16S rRNA-based high-throughput sequencing using Oxford Nanopore Technologies. Bioinformatic analysis revealed a diverse microbial community spanning both bacterial and eukaryotic taxa. Proteobacteria emerged as the dominant phylum, followed by Firmicutes, Bacteroidota, Actinobacteriota, Elusimicrobiota, Fusobacteriota, and Myxococcota, while notable eukaryotic groups included Apicomplexa, Amoebozoa, and Phragmoplastophyta. This indicates that the ecosystem supports a mixed assemblage of heterotrophs, chemotrophs, and parasitic or symbiotic forms, reflecting the ecological complexity of the Tuticorin offshore environment.

The presence of diverse functional groups suggests ongoing nutrient processing, adaptation to reduced light zones, and active microbial participation in biogeochemical cycling. The current findings provide the first detailed genomic snapshot of microbial diversity in the Tuticorin deep- sea water column and contribute valuable baseline data for future studies on deep-sea microbial ecology, biotechnological potential, and environmental monitoring in the Indian Ocean region.

Keywords: Deep sea, Taxonomic diversity, Functional analysis, Proteobacteria, Nanopore Sequencing.

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Nitrogen and sulfur cycling microbes and coupled processes in organic-poor coastal sediments

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ABSTRACT

Microbially-driven nitrogen (N) and sulfur (S) cycling processes in coastal sediments are complex and interlinked, with important ecological implications. However, these linkages have been mostly studied in organic-rich environments, while mostly overlooked in organic-poor sediments (organic carbon < 0.79%).

In this study, the bacterial communities carrying out N and S transformations in organic-poor coastal sediments (obtained from a tropical lagoon) are examined using 16S rRNA metabarcoding data. Predictive functional analysis identifies key genes, modules and pathways involved in N and S cycling, while correlation-based network analysis elucidates potential N and S coupling mechanisms. Network analysis reveals the genetic potential for and linkages between assimilatory nitrate and assimilatory sulfate reduction processes. Nitrogen fixation likely occurs in these sediments, and is primarily attributed to the heterotrophic activity of sulfate-reducing bacteria. The genetic potential for dissimilatory nitrate reduction processes in these surface sediments is also revealed to be significant. These findings demonstrate that organic-poor sediments are not microbial "deserts", but harbor active and interconnected N and S transformation pathways, with implications for nutrient metabolism and GHG emissions from such ecosystems. Our study thus provides a theoretical basis for detailed investigations into biogeochemical coupling of N and S cycling in these overlooked coastal ecosystems.

Keywords: nitrogen cycling, sulfur cycling, functional gene, network analysis, sediment microbiome

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Growth responses of culturable deep sea sediment bacteria from the gulf of kutch region to temperature, ph and salinity

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ABSTRACT

Marine sediments serve as dynamic microbial habitats shaped by fluctuations in environmental variables such as salinity, temperature, pressure and pH etc. In this study, sediment samples were collected during Cruise No. 406 of FORV Sagar Sampada from a depth of 429 m in the Gulf of Kutch region (21°26.642’ N, 67°52.27’ E), where the surface salinity and temperature were recorded as 36 PSU and 31°C, respectively. Serial dilutions of the sediment were plated on Zobell Marine Agar to obtain culturable bacterial isolates. A total of 36 bacterial isolates were recovered at ambient room temperature, while 21 psychrotolerant isolates were obtained at 5–8°C. No growth was observed at 60°C, indicating the absence of thermotolerant culturable bacteria. pH tolerance assays revealed strong growth between pH 6 and 9, suggesting a predominantly neutrophilic to mildly alkaliphilic bacterial community. Salinity tolerance of the isolates indicated robust growth between 1.5% and 5.5% NaCl, characteristic of moderately halotolerant marine bacteria. Growth gradually decreased at 6.5%, and only a few isolates survived at 7.5–8.5% NaCl, demonstrating strong osmotolerance and potential halophilic traits. These findings highlight the physiological diversity of culturable bacteria from the sediment samples of the Gulf of Kutch region. The initial results provide further scope for exploring their potential applications in marine biotechnology and environmental sustainability.

Keywords: Marine sediments, culturable bacteria, salinity tolerance, pH adaptation, Gulf of Kutch

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Methanotrophic and denitrification activity in coastal ecosystems

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ABSTRACT

Coastal ecosystems, influenced by strong land–sea gradients, harbour microbial communities that process about one-half of the global biogeochemical flux of biologically important elements, such as carbon, nitrogen, phosphorus, sulphur and iron. Denitrification, a major microbial process in these systems, transforms fixed nitrogen (NO_3^-) into N_2, acting as a significant nitrogen sink in permeable coastal sediments. Simultaneously, methane (CH_4) production and consumption in coastal sediments is controlled by methanogenic and methanotrophic microorganisms, contributing to greenhouse gas fluxes at the sediment–water interface. Both methanotrophic and denitrification activity plays a significant role in environmental ecology. In this study, bacterial isolates obtained from sediments of mangrove areas, salt pans and aquaculture shrimp ponds were assessed for their methane oxidation activity and denitrification activity under aerobic and anaerobic conditions using gas chromatography. The methanotrophic activity, ranged from $1x10^{-6}$ nM cell^{-1} d^{-1} to $9.38x10^{-7}$ nM cell^{-1} d^{-1}. While the denitrification ranged from 0.02 ngN cell^{-1} d^{-1} to 8 ngN cell^{-1} d^{-1}. High methanotrophic and denitrification activity was observed in anaerobic conditions. Most of the isolates that exhibited denitrification activity were from aquaculture shrimp ponds, while the isolates that exhibited methanotrophic activity were from mangrove ecosystem. Dual activity under oxic and anoxic conditions was observed in the isolate E94 which was from an aquaculture shrimp pond. These findings suggest that coastal sediments include microbial communities capable of both methanotrophic and denitrification activities, which contribute to significant biogeochemical processes in coastal ecosystems.

Keywords: Coastal ecosystem, Methane oxidation, Denitrification, Anaerobic condition, Biogeochemical cycle

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Biogeographic and Pan-genomic Classification of Novel *Salinispora* species from the Neil island (Shaheed Dweep, India), the Andaman Sea.

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ABSTRACT

The obligate marine actinomycete genus *Salinispora* is a key subject in biotechnology due to its dedication of a substantial portion of its genome to synthesizing species-specific secondary metabolites, compounds critical for drug discovery. This investigation focuses on isolating and classifying new members of this genus from the biodiverse Neil island (Shaheed Dweep, India) in the Andaman Sea, India, a well-preserved marine ecosystem rich in coral reefs and mangroves. Using stringent, low-nutrient, high-salinity media, three discrete actinobacterial isolates demonstrating morphological and physiological concordance with *Salinispora* were successfully drawn from a total library of fifteen recovered strains from the island's marine sedimentary matrix. This isolation from the unique biogeographic location of Neil Island is significant because *Salinispora* speciation is driven by ecological differentiation with specific secondary metabolite profiles defining distinct environmental niches rather than just geographic isolation. The traditional method of 16S rRNA gene sequencing is inadequate for definitive classification, as the three recognized *Salinispora* species (*S. arenicola*, *S. tropica*, *S. pacifica*) share over 99% sequence identity. Therefore, this study employs pan-genomic analysis and the ultimate goal is to integrate the biogeographic origin of the Neil island isolates with pan-genomic data to precisely redefine taxonomic boundaries and formally classify new *Salinispora* species. This targeted, genomic approach promises to move natural product drug discovery away from random searching toward an efficient, phylogenetically informed strategy by identifying novel, location-specific biosynthetic gene clusters.

KEYWORDS: Neil island, indigenous marine *Salinispora*, pan-genomics

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Molecular characterization of porpitidae and siphonophora (cnidaria: hydrozoa) and their associated bacterial communities from the arabian sea.

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ABSTRACT

Jellyfish are free-swimming high water content (>95%) marine organisms, and have a rich diversity of symbiotic microbes. Gelatinous zooplankton such as *Porpita* (Blue Button) and *Physalia* (Portuguese Man o' War) are part of the neustonic food web in the ocean. These permanent pelagic organisms play a significant role in marine systems and interact with a broad range of microbial consortium. In this study, samples of *Porpita* and *Physalia* were collected from shelf waters of central west coast of India. A total of eight bacterial isolates—four from each organism—were obtained through culture-based methods. Molecular identification of bacterial isolates was carried out using 16S rRNA gene sequencing; also DNA barcoding of the jellyfish was carried out using COI gene sequencing. Preliminary results revealed the presence of diverse bacterial taxa such as *Stutzerimonas, Rossellomorea, Bacillus,* and *Acinetobacter*. These findings provide the understanding of host–microbe associations in gelatinous zooplankton dwelling in tropical coastal waters. Further investigation of these bacterial isolates may provide insights on their ecological roles, potential symbiotic functions, and their applicability in the comprehensive context of marine living resources and ecosystem health as studies on the bacterial flora associated with these species from the Indian waters remain limited.

Keywords: *Porpita*, *Physalia*, bacterial diversity, 16S rRNA, COI gene.

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Resilience in Oligotrophic Seas: Taxonomic and Functional Structuring of Tintinnid Communities Across the Tropical Indian Ocean

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ABSTRACT

Tintinnids are vital microzooplankton grazers that regulate pico- and nano-plankton communities and play a significant role in carbon transfer within marine food webs. However, their ecological and functional roles across the Indian Ocean remain insufficiently explored. This study provides one of the most comprehensive assessments of tintinnid diversity to date, analyzing assemblages from surface and chlorophyll-maximum (Cmax) waters across 22 stations in the northeastern (NEIO), equatorial (ETIO), southeastern (STIO), and southwestern (SWTIO) tropical Indian Ocean. A total of 107 species belonging to 13 families were recorded, with regional richness ranging from 60 to 69 species. Twenty-nine species occurred across all regions, indicating broad ecological niches, while others displayed regional endemism. Clear vertical partitioning was evident, with Cmax waters supporting a higher number of exclusive species in every region. Tintinnid abundance ranged from 2 to 31 ind. L^{-1}, and carbon biomass varied between 1.7 and 123.6 µg C m^{-3}. Dominant taxa varied by region and depth: Steenstrupiella steenstrupii (NEIO), Rhabdonellopsis apophysata (ETIO, SWTIO), and Epiplocylis undella (STIO) characterized surface waters, while Proplectella fastigata dominated Cmax layers in ETIO, STIO, and SWTIO, with Eutintinnus tenuie prevailing in NEIO—patterns that reflect underlying hydrographic and trophic gradients. Functional diversity based on lorica oral diameter (LOD; 8–104 µm), grouped into 25 size classes, revealed broad prey-size ranges (prey
≈ 25% LOD). Most tintinnids (surface: 58–76%; Cmax: 86–88%) belonged to the 8–40 µm LOD classes, indicating strong reliance on pico- and nano-plankton typical of oligotrophic tropical waters. High overlap among prey-size classes highlights substantial functional redundancy and suggests strong community resilience to environmental variability. Overall, this study advances understanding of tintinnid ecological functioning and emphasizes their critical role in sustaining carbon flow and trophic stability in the tropical Indian Ocean.

Keywords: Tintinnids, Functional diversity, Lorica oral diameter; Tropical Indian Ocean; Trophic resilience

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Climate-mediated trophic shifts and ecological resilience of phytoplankton in the eastern indian ocean.

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ABSTRACT

Climate-driven Ocean warming and intensified stratification fundamentally restructure marine phytoplankton communities. However, their niche and trophic dynamics remain unclear, especially in the Eastern Indian Ocean (EIO)—a climatically sensitive and understudied basin. To fill this gap, phytoplankton community structure, trophic strategies, and ecological tolerance were investigated from hydrologically distinct regions: North Eastern IO (NEIO), Equatorial IO (EqIO), and South Tropical IO (STIO) during 2021 Spring inter-monsoon. Phytoplankton abundance was highest in southern NEIO, with diatoms dominating overall, although diatom richness and abundance declined southward. Dinoflagellates maintained similar distributions but exhibited greater trophic plasticity—spanning obligate autotrophy, mixotrophy, and heterotrophy—particularly in oligotrophic STIO. Trait-based classification revealed eurytopic generalists (broad tolerance, 71% abundance), thriving under stable, stratified conditions and showed variable, resilient responses; and stenotopic specialists (narrow tolerance, 29%), often associated with harmful algal blooms, and highly sensitive to episodic nutrient enrichment and environmental fluctuations. Among dinoflagellates, mixotrophs at all stations emerged as key trait driving stability, while strict autotrophy and heterotrophy were confined to stenotopic specialists. Generalized Additive Models showed eurytopic mixotrophs maintain stable distributions under warming and stratification, aligning with climate resilience predictions. Model projections suggest that mixotrophs will outnumber traditional autotrophs in high-emission scenarios, causing shifts in primary productivity and carbon export efficiency in the EIO and other tropical basins. Our results provide key parameters for predictive ecosystem models and valuable recommendations for adaptive management of marine resources.

Keywords: Climate Change, Dinoflagellates, Eastern Indian Ocean, Eurytopy, Stenotopy, Phytoplankton, Trophic Plasticity

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Free-living versus particle-associated bacteria in the Arabian Sea: Present understanding and future perspectives

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ABSTRACT

The Arabian Sea, a biogeochemically dynamic region shaped by monsoonal productivity and a pronounced oxygen minimum zone (OMZ), hosts diverse microbial communities that play a central role in the degradation of organic matter and the cycling of carbon and nutrients. Past studies have mainly focused on the microbial diversity at discrete depths of the water column. However, major knowledge gaps persist because existing studies rarely distinguish between free-living (FL) and particle-attached (PA) microbial communities across water-column layers and often employ inadequate size-fractionation approaches. Furthermore, the influence of microbial colonization on sinking particles, niche specialization, and metabolic differentiation along depth gradients particularly across the euphotic zone and the oxygen minimum zone (OMZ) remains poorly understood. This review integrates current knowledge of FL and PA microbiomes in the Arabian Sea, critically evaluates methodological and conceptual limitations in existing literature, and highlights the absence of integrated depth-resolved FL-PA datasets, multi-omics analyses (e.g. metagenomics), and systematic particle characterization (size distribution, composition, sinking rates). Addressing this knowledge gap is crucial for advancing mechanistic understanding of microbial mediation of carbon export, remineralization processes, and biogeochemical functioning in this climate-sensitive basin.

Keywords: Free living bacteria, particle associated bacteria, Oxygen Minimum Zone, sinking particles.

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Physiological response of cold seep bacteria to stressors.

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ABSTRACT

Cold seep is a unique hydrocarbon rich ecosystem where methane and hydrogen sulfide seeps out from the sediment. The extreme conditions like high pressure, cool temperature and pollutants such as methane and hydrogen sulfide regulates the physiology of bacteriathriving there. In the present study, the physiological response of the isolated bacteria were tested using 13 different substrates, 5 metals ranging from 2mM to 10mM and 11 antibiotics. Among the 66 potential isolates that were screened for extracellular enzyme production using substrate amended agar plates, 27 isolates were selected for further study on metals and antibiotics. The metal tolerance assay was performed using agar dilution method and antibiotic resistance was determined using epsilometer. Among these 27 isolates, 22.22% showed multiple substrate utilization and metal tolerance, 70.37% of isolates shows an inverse relationship between extracellular enzyme activity and metal tolerance and 7.4% were able to utilise only one substrate with low metal tolerance. Most of the isolates showed antibiotic resistance to 27% of the antibiotics tested. Overall, the majority of bacterial isolates from cold seep ecosystem demonstratestradeoff between extracellular enzyme production and metal tolerance with limited exceptions of multiple stress resistance. Their integrated stress response indicates adaptive stress physiology that enable their survival in this extreme environment.

Keywords: Cold seep, Physiology, Extracellular enzymes, Metal tolerance, Antibiotic resistance.

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Microbial Community Shifts Across Oxygen Gradients in the Bay of Bengal: Insights from the Visakhapatnam OMZ Transect

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ABSTRACT

Oxygen Minimum Zones (OMZs) are key oceanic regions where dissolved oxygen (DO) declines sharply with depth, shaping distinct microbial communities that regulate global biogeochemical cycles. Along the Visakhapatnam transect of the Bay of Bengal, a depth-stratified 16S rRNA metagenomic analysis revealed shifts in microbial community composition and functional traits that corresponded to steep oxygen gradients. Dissolved Oxygen (DO) concentrations decreased from 4.6 ml/L at the surface (0 m) to 3.2 ml/L at 50 m, reaching the OMZ core between 250-500 m (DO < 0.25 ml/L) before slightly rising to 0.9 ml/L at 1000 m. Surface and subsurface layers (0-50 m), which have higher oxygen levels, were dominated by Cyanobacteria (21.5-15.4%), Actinobacteria (8.5-14.4%), and Proteobacteria (29.7-40.8%), reflecting photosynthetic productivity and aerobic carbon cycling. In contrast, the hypoxic OMZ core (250-500 m) hosted anaerobic and microaerophilic taxa, such as Marinimicrobia (SAR406, 3.8-2.8%), Parcubacteria (OD1, 2.7-6.2%), Planctomycetes (7.2-6.6%), Chloroflexi (1.9-1.6%), Verrucomicrobia (3.4-2.2%), and denitrifying Proteobacteria (55-59%). These groups drive nitrogen and sulphur transformations, including denitrification and anammox, that sustain productivity under oxygen-depleted conditions. At 1000 m, where DO was 0.9 ml/L, the community composition shifted again. There was an enrichment in Firmicutes (20.1%), Peregrinibacteria (4.7%), and Proteobacteria (59.3%), indicating adaptation to deep, low-oxygen, yet metabolically active niches. These research findings highlight that OMZ-associated bacteria, particularly SAR406, OD1, Planctomycetes, and Proteobacteria, serve as sentinels of marine deoxygenation, maintaining nutrient cycling and ecological stability as low-oxygen regions expand under climate change.

Keywords: Oxygen Minimum Zone, Deep Sea Bacteria, Bay of Bengal, 16S Metagenomics, biogeochemical cycles

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Microbial decomposition and the associated bacterial community in the copepod carcasses: implications for rapid remineralisation of organic matter in tropical waters.

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ABSTRACT

Copepods, the most abundant zooplankton in aquatic ecosystems, play a crucial role in carbon cycling through both their life processes and mortality. Although copepod carcasses may constitute a substantial proportion (25-50%) of the total vertical flux of particulate organic carbon (POC) to the deep ocean, their decomposition dynamics remain insufficiently characterised. Microbial degradation of zooplankton carcasses represents an important pathway for nutrient regeneration, elemental recycling, and microbial production in aquatic ecosystems. In the present study, we investigated the temporal progression of copepod carcass decomposition and the associated bacterial community dynamics using a culture-based approach. Laboratory incubation experiments with *Acrocalanus longicornis* carcasses at 28°C revealed rapid bacterial colonisation within 5–6 hours post-mortem, followed by extensive microbial degradation of internal tissues within 12–24 hours. Only the chitinous exoskeleton remained by the fourth day. Bacterial strains isolated from the decomposing carcasses were identified to be Gram-negative, predominantly coccoid forms. Furthermore, the study identified notable shifts in bacterial community composition across different stages of decomposition, indicating a dynamic microbial succession throughout the process. The results enhance the understanding of microbial-mediated degradation of copepod carcasses. The study implies that rapid degradation and substantial remineralisation of copepod carcasses occur within the water column rather than sequestration in the tropical waters. Further, this study provides an insight into a preferential diet-induced bacterial community shift in the carcass decomposition process and provides a basis for future investigations into species-specific bacterial roles in copepod carcass decomposition.

Keywords: Zooplankton, Copepod carcasses, Microbial decomposition, Remineralisation, Bacteria

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Soil microbial community in mudflat, halophyte and mangrove sediments

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ABSTRACT

In the present study, we investigated the taxonomic and functional diversity of bacterial communities in semi-arid tidal marsh sediments of Diu, India, across three vegetation regimes: mudflats, halophyte-dominated zones, and mangroves. Using 16S rRNA amplicon sequencing and shotgun metagenomics, we characterized microbial diversity, community structure and metabolic potential across soil depths. The metagenomic assembled genomes (MAGs) revealed a total of 10 bacterial phyla across all three sediments. Pseudomonadota was consistently the most abundant phylum across all samples, reaching maximum relative abundances followed by Bacillota. Alpha and beta diversity analyses revealed higher richness and evenness in mangrove sediments compared to halophyte and mudflats, while PCoA clustering indicated clearly vegetation-driven differentiation of microbial assemblages. Functional annotation of metagenomic datasets highlighted higher genes associated with metabolism based on the KEGG database for all three soils, with the dominance of carbohydrate metabolism and amino acid metabolism followed by xenobiotic degradation, underscoring the ecological role of these microbial communities in sustaining marsh resilience in mangrove soils compared to mudflats and halophyte soil. The metagenomic analysis revealed the presence of carbohydrate-active enzymes (CAZy) gene families for all sediments samples with a large numbers were found in mangrove sediments. The majority of CAZy were dominated with glycoside hydrolase (GHs) which hydrolyze all complex carbohydrates in halophyte and mangrove sediments. The EggNOG functional pathways revealed metabolism of sulphur, potassium, nitrogen and phosphorus with their roles in biogeochemical cycles. This study provides the a comprehensive metagenomic insights into microbial ecology of Indian semi-arid tidal marshes and establishes a baseline for understanding their role in coastal biogeochemical processes under changing environmental conditions.

Keywords: coastal ecosystem, microbial community, functional annotation, coastal vegetation, metabolic annotation

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2.	Functional and Taxonomic Profiling of Arabian Sea Seamount Sediments Reveals Microbial Diversity and Resistance Potential
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Macroalgae–thraustochytrid partnerships across climatic frontiers: tropics and polar regions.

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ABSTRACT

Thraustochytrids are marine fungal-like unicellular eukaryotic microorganisms belonging to the Kingdom Stramenopila. Studies on macroalgae–thraustochytrid interactions reveal their occurrence across contrasting climatic regions, from the tropics to the Arctic. Based on a four-year-long study of macroalgal samples collected from beaches in Goa, brown, red, and green algae served as substrata for thraustochytrids. Colonization rates ranged from 17 to 58% of specimens, with isolates belonging to the genera *Oblongichytrium*, *Schizochytrium*, *Ulkenia*, and *Thraustochytrium*, while *Labyrinthula* sp. was detected once on the green alga *Bryopsis hypnoides*. These tropical thraustochytrids were generally more prevalent during dry seasons than in monsoons. Complementary investigations in the Arctic showed nine types of macroalgae during August 2023, of which two species, one green alga (*Ulva*) and one brown alga (*Stoechospermum*), showed thraustochytrid colonies on pine pollen baiting, representing 22% thraustochytrid-positive algae. Together, these findings highlight the broad biogeographic distribution and ecological significance of macroalgae–thraustochytrid associations across both polar and tropical environments.

Keywords: Thraustochytrids, fungoid protists, seaweeds, tropical macroalgae, Arctic macroalgae

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Functional and Taxonomic Profiling of Arabian Sea Seamount Sediments Reveals Microbial Diversity and Resistance Potential

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ABSTRACT

The Arabian Sea harbors ecologically and biotechnologically significant microbial communities, yet sediment-associated diversity and functions remain underexplored. Here, we integrated metagenomic, pigment, and chemical analyses to investigate two seamount sediment samples (SM1 and SM7) from the Arabian Sea. Distinct physicochemical conditions were observed—SM1 was enriched in inorganic nitrogen species (nitrate, nitrite, and ammonia), while SM7 exhibited higher levels of organic carbon, total nitrogen, and photosynthetic pigments, reflecting differences in substrate availability. These environmental contrasts shaped microbial assemblages: SM1 displayed lower diversity dominated by Actinomycetota and fungi, whereas SM7 supported a broader community including fungi, protists, metazoans, and viruses. Functional annotation revealed nitrogen metabolism enrichment in SM1 and enhanced carbohydrate metabolism and novel gene content in SM7. Both sites encoded antibiotic and metal resistance genes, with SM7 exhibiting greater diversity, including mupirocin, triclosan, and sulfonamide resistance, along with stress adaptation pathways. Collectively, our findings highlight strong environment-driven variation in microbial, functional, and resistome profiles, underscoring Arabian Sea sediments as reservoirs of metabolic versatility and adaptive potential with implications for environmental resilience and biotechnological exploration.

Keywords: seamount, metagenomics, Oxford Nanopore sequencing, functional annotation

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Host–microbe interactions in the deep sea: unlocking antifouling metabolites from microbial symbionts

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ABSTRACT

Deep-sea bacteria represent an underexploited reservoir of antifouling metabolites, offering a sustainable alternative to conventional, eco-friendly chemical agents. The harsh conditions of the deep-sea drive these microbes to generate a diverse array of metabolites with antifouling activities. In the present study, 57 bacterial isolates associated with amygdalam and 37 isolates associated with brittle star and sea urchin were screened for antibiofilm activity against test strains Staphylococcus haemolyticus and Bacillus paramycoides. None of the amygdalum-associated isolates showed strong antibiofilm activity, whereas eight isolates from brittle star and sea urchin exhibited significant antibiofilm inhibition. This suggests a potent, multi-target mechanism for regulating microbial colonization. The bioactive metabolites from these isolates were mass-cultured, extracted using ethyl acetate, and profiled through Liquid Chromatography– High Resolution Mass Spectrometry (LC-HRMS). The extracts from three active isolates showed distinctive chromatographic peaks corresponding to known antifouling metabolite classes. Early-eluting peaks (0.92–0.98 min) suggested polar diketopiperazines, heterocyclic compounds known for disrupting microbial adhesion and modulating quorum sensing pathways critical for biofilm formation. A prominent peak at 21.45 min was attributed to a derivative of organoselenium diselenide, a powerful metabolite associated with oxidative stress induction and irreversible biofilm disruption. These findings emphasise the chemical richness and strong antifouling potential of deep-sea microbial symbionts. This study reveals deep-sea microbial symbionts as a promising source of antifouling metabolites, with correlation analyses guiding the discovery of key bioactive compounds for sustainable antifouling applications.

Keywords: deep-sea bacteria, antifouling, bioactive metabolites, diketopiperazine, organoselenium

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Ecophysiological and pigment-based responses of cultivated seaweeds to monsoonal seasonality and heat stress in the eastern Arabian sea

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ABSTRACT

Seaweeds are key primary producers in marine ecosystems and contain diverse photosynthetic and photoprotective pigments, primarily chlorophylls and carotenoids, that function as natural colourants and powerful antioxidants, making their commercial value to pharmaceutical and cosmetic industries. Although the Indian coastline hosts rich seaweed diversity, especially within the Rhodophyta, pigment characterization remains limited for many cultivated species. In this study, major pigments were quantified using high-performance liquid chromatography (HPLC) in three economically important red seaweed species, *Kappaphycus alvarezii*, *Hydropuntia edulis*, and *Gracilaria salicornia*, cultivated along the southwest coast of India from September 2023 to April 2024. Seasonal assessments revealed distinct species- specific pigment profiles and marked seasonal variability across growth phases. The exotic species *K. alvarezii* exhibited its highest growth rate during the winter monsoon (WM; 5.97 ± 0.34% day^{-1}), concurrent with peak chlorophyll *a* concentrations (73.37 µg g^{-1}). However, its chlorophyll *a* levels declined substantially during the spring intermonsoon (SIM; 66.94 µg g^{-1}), likely due to increased irradiance and thermal stress. In contrast, the native species *H. edulis* maintained consistently high chlorophyll *a* concentrations across all seasons, including the warmer SIM period, demonstrating pronounced thermal resilience. *G. salicornia* showed moderate growth and persistently low pigment concentrations throughout the cultivation period. Overall, the results highlight distinct eco-physiological disparities among the three seaweed species in response to seasonal environmental variability. *H. edulis* emerged as the most climate- resilient species, maintaining high pigment content throughout the study period, unlike the exotic species *K. alvarezii*, which exhibited reduced pigment concentrations under elevated environmental conditions. These results emphasize the utility of pigment-based indicators for assessing seaweed physiological status and provide valuable insights for optimizing seaweed mariculture practices in India.

Keywords: Seaweeds, Kerala, Pigments, HPLC, Chlorophylls

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Dynamics of microbial populations in the Mandovi-Zuari estuarine complex

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ABSTRACT

Estuaries are dynamic transition zones between land and sea, characterised by strong physicochemical gradients and continuous inputs from riverine, catchment, and anthropogenic sources. These environments support high microbial diversity but are also vulnerable to contamination from allochthonous microbes transported through runoff, agricultural drainage, sewage discharge, etc. Enteric pathogens are of particular concern due to their known capacity to survive, disperse, and intermittently increase in abundance, especially during the monsoon season. Their persistence poses significant risks to public health, fisheries, and coastal communities. In this study, we examined the seasonal and spatial variability in microbial abundance, with an emphasis on enteric *Salmonella* spp., *Shigella* spp., and *Escherichia coli* O157:H7, along with key environmental parameters across seven sampling events (2021–2023), across upper, mid, and mouth stations of the Mandovi and Zuari estuaries of Goa. The results indicated inter-seasonal and inter-annual variability in bacterial abundance, driven by key abiotic factors. The suspended particulate matter (SPM) was high in monsoon 2023, which coincided with high PO_4 concentrations, and appeared to enhance microbial survival by providing protective microhabitats. The *E. coli* O157:H7 was also higher in the monsoon of 2023. The total bacterial count (TBC) was high at the mid-estuary during the two pre-monsoon seasons, while the total viable count (TVC) was high at the mouth during the monsoon of 2023 in both the estuaries. The *Shigella* spp. occurred consistently across seasons, while *Salmonella* spp. appeared only during the post-monsoon of 2022 and the monsoon of 2023. Overall, monsoon- driven hydrodynamics influenced microbial fate, yet patterns were estuary-specific, shaped by local hydrodynamic regimes and source inputs. This study provides insights into the dynamics of estuarine microbial ecology that will be useful in coastal management and the prediction of coastal hazards due to enteric pathogens in changing climatic scenarios.

Keywords: Monsoon, Estuary, Coastal assessment, Enteric pathogens, Mandovi- Zuari

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Mineralogical And Geochemical Indicators Of Hydrothermal Activity In The Banded Iron Formations Of Goa

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ABSTRACT

Archean banded iron formations (BIFs) are essential lithologies for studying early Earth processes, especially redox evolution and ocean chemistry. The greenstone belts of the Singhbhum, Bastar, Dharwar, and Bundelkhand cratonic nuclei in peninsular India include BIFs. This study focuses on the BIFs of Goa, part of the Dharwar Supergroup, to evaluate their mineralogical and geochemical signatures and to understand their genesis.

The changing chemical conditions in the depositional environment are reflected in the distinctive rhythmic banding of silica and iron oxides in these BIFs. Geochemical analysis of rare earth elements, trace elements, and major elements reveals distinct environmental signals. A strong positive europium (Eu) anomaly points to the influence of high-temperature hydrothermal fluids, whereas a negative cerium (Ce) anomaly reflects mildly oxidizing conditions and partial oxygenation of seawater during deposition.

These findings shed new light on how hydrothermal activity influenced early ocean oxygenation in the Archean, positioning the Goa BIFs as a key archive for unraveling the complex depositional dynamics of early Earth.

Keywords: Archean, banded iron formations (BIFs), hydrothermal, Dharwar, Goa

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Molybdenum Isotope Evidence For Episodic Sulfidic Pulses Driven By Methane Flux In Marine Sediments

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ABSTRACT

Molybdenum (Mo) concentrations and isotope ratios provide a sensitive archive of past sulfidic conditions and methane-driven redox oscillations at the sediment–water interface in marine settings. Episodic methane expulsion enhances hydrogen sulfide production through sulfate-driven anaerobic oxidation of methane (AOM), facilitating thiomolybdate (MoS_4^{2-}) formation and its preferential sequestration into solid phases. The recent identification of extensive methane-seep fields in the Krishna–Godavari Basin offers a unique opportunity to reconstruct such transient sulfidic events. Here we present high-resolution Mo concentrations, Mo-isotope ratios ($\delta^{98}Mo$), and pyrite sulfur-isotope compositions ($\delta^{34}SFeS_2$) from a seep-site core (SSD-045; 1760 m water depth). Pyrite-S contents (0.13–
2.54 wt%), Mo concentrations (1–17.4 ppm), and $\delta^{98}Mo$ values (+0.3 to +2.37‰) exhibit multiple Mo- enrichment peaks (>2 ppm) that coincide with strongly ^{34}S-depleted pyrite, indicating repeated pulses of enhanced sulfidization at the sediment–water interface. Mo enrichment coupled with seawater-like $\delta^{98}Mo$ (~2.2‰) supports episodic thiomolybdate precipitation during high-flux methane events. Deviations from this covariance at greater depths likely reflect overprinting by Mo associated with Fe- oxyhydroxide and sulfide mineral phases, which possess a broader isotopic range (0.1–1.5‰). Ongoing Mo-speciation analyses aim to disentangle primary depositional signatures from diagenetic modification, enabling reconstruction of methane-driven redox dynamics through late Quaternary sedimentation.

Keywords: Sulfur istope, Molybdenum enrichment factor, Molybdenum isotope, methane seep, K-G basin

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Tracing Provenance To Pollution: Reviewing Rare Earth Geochemistry Of India's East Coast

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ABSTRACT

India's eastern coastline hosts extensive estuarine and mangrove systems where Rare Earth Elements (REEs) record both natural processes and human impacts. This review compiles and analyzes existing research on their distribution and geochemical behavior, highlighting implications for sediment provenance, pollution sources, and coastal biogeochemical cycling. REE patterns are generally flat but show notable element-specific variations. Cerium (Ce) anomalies range from absent to distinctly negative or positive, with negative anomalies linked to Ce scavenging and the reduction of insoluble Ce(IV) to soluble Ce(III) under alkaline, reducing conditions, and positive anomalies reflecting alternative geochemical processes. Europium (Eu) anomalies vary from slightly negative to positive, suggesting changing redox conditions and diverse sedimentary inputs. Gadolinium (Gd) anomalies span approximately 0.8 to 1.22, with distinctive signatures reported from sites such as Pichavaram, Nagavali, Vamsadhara, and Subarnarekha. Collectively, these datasets reveal a coastline influenced by both natural sedimentary inputs and localized anthropogenic activities, allowing differentiation of river-dominated systems from those impacted by aquaculture and industrial effluents.

Keywords: Rare earth elements, East Coast, mangroves, estuaries.

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Multiproxy Reconstruction of Sediment Provenance, Monsoon Intensity, And Depositional History On The Inner Shelf Off Goa, Arabian Sea

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ABSTRACT

This study integrates sedimentological, mineralogical, and geochemical proxies from a 5.5 m core retrieved from the inner continental shelf off Goa, western India, in order to reconstruct monsoon-driven changes in sediment provenance and depositional conditions over the past ~350 years. The grain-size variations, dominated by silt with subordinate clay and minor sand, reflect a low-energy depositional regime periodically interrupted by short-lived high-energy events associated with intensified fluvial discharge.

Clay-mineral assemblages are characterised by abundant smectite (20–60 %) and kaolinite (20– 55 %), with lesser illite (5–25 %) and chlorite (≤15 %). Enhanced smectite–kaolinite proportions indicate intensified chemical weathering and stronger terrigenous flux from the Western Ghats during wetter monsoon phases. Periods enriched in illite and chlorite signify reduced weathering and greater contributions from reworked or less altered continental sources.

Organic geochemical data show total organic carbon contents of 0.5-3.0 wt%, TOC/TN ratios between 5 and 25, and $\delta^{13}C$ values from -26 ‰ to -21 ‰ (VPDB), suggesting a mixed marine-terrigenous origin of organic matter. Intervals of high smectite and kaolinite, high TOC/TN ratios, and isotopically light $\delta^{13}C$ correspond to increased continental runoff and delivery of organic matter during intense monsoon phases after ~1750 CE. By contrast, intervals enriched in illite with lower TOC and heavier $\delta^{13}C$ values reflect reduced terrestrial input and higher marine productivity during weaker monsoon states, such as the late Little Ice Age.

Collectively, these records indicate that post-Little Ice Age warming intensified the southwest monsoon, thereby increasing fluvial sediment supply, primary productivity, and organic matter preservation on the inner shelf of the Arabian Sea off Goa.

Keywords: Grain size analysis, Clay Mineralogy; Organic Geochemistry, Arabian Sea; Sediment Provenance

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Pyritization May Archive The Influence Of Sulfate-Aom And Bioturbation Activities In Marine Sulfidic Shelf Sediments

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ABSTRACT

Organoclastic sulfate reduction and anaerobic oxidation of methane (AOM) coupled to sulfate reduction (SO42--AOM) are key processes regulating organic matter degradation and methane (CH4) consumption in marine sediments. We analyzed C-S-Fe, Mo, and U geochemistry in a sediment core collected from the shallow, seasonally hypoxic shelf off the West Coast of India (WCI; Eastern Arabian Sea) at 28.5 mbsl to study the past influence of benthic and AOM activity. Porewater profiles showed high hydrogen sulfide (ΣH_2S) concentrations and a shallow sulfate-methane transition zone (SMTZ; 143-303 cmbsf). Molybdenum/Uranium enrichment factor ratio (MoEF/UEF) indicates persistently sulfidic porewaters during sediment deposition, attributed to SO 2--AOM. The high-resolution pyrite sulfur isotope (δ34S) record reveals two sulfidization trends (Trend I and II), characterized by isotopic fluctuations. Depleted δ^{34}SCRS values may be attributed to early diagenetic Fe-sulfidization under open system conditions at the sediment-water interface involving benthic reworking during normoxia. In contrast, enriched δ^{34}SCRS values reflect diminished benthic activity under hypoxic conditions and pyrite precipitation from 34S-enriched ΣH_2S diffusing upward from the SMTZ. Furthermore, increasing δ^{34}SCRS values (Trend II) below 336.5 cm suggest overprinting of early-stage sulfidization by deep burial sulfidization linked to SMTZ deepening. Therefore, the observed δ^{34}SCRS variability reflects sulfidization resulting from mixing of isotopically distinct pyrite produced under variable benthic activity and vertical CH4 flux. Although focused on the seasonally hypoxic shelf off WCI, the findings of this study provide broader implications for understanding the coupled influences of bioturbation, CH4 flux, and redox variability on sulfur cycling and trace-metal enrichment in shelf sediments globally.

Keywords: Sulfate reduction, Anaerobic oxidation of methane, Organoclastic sulfate reduction, Sulfidization, Bioturbation, Sediment-water interface

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Methanotrophy-Driven Carbon Isotopic Signatures Of Sedimentary Organic Matter Unveil Dynamic Evolution Of A Methane-Seep System Off The East Coast Of India.

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ABSTRACT

Recent discoveries of active methane seep sites off Mannar basin along the east coast of India have opened new avenues for research on the evolution of cold seep ecosystems and their relationship with underlying methane reservoir formation in this region. Here, we present for the first time, organic-geochemical evidence of past methane-seepage activities in a sediment core retrieved from the newly discovered methane cold seep site off Mannar Basin. The significant negative excursion in bulk $\delta^{13}C_{TOC}$ of the cold-seep sediments compared to nearby reference non-seep sediments suggests a substantial contribution of methanotroph-derived organic carbon to the seep sediment organic pool. The strong ^{13}C depletion (-112.4 ‰ to -54.6
‰ VPDB) observed in archaeal biomarkers such as crocetane and PMI, along with the presence of relict shells of chemosymbiont-bearing bivalve Calyptogena, and a concurrent negative $\delta^{13}C_{TOC}$ excursion provide tell-tale signatures of paleo methane-seep events and associated anaerobic methane-oxidation (AOM) activities at the study site. Based on the organic-geochemical data, and the presence of relict Calyptogena shells in sediments, we propose a protracted period of episodic methane seepage events spanning across the MIS-3 to mid-Holocene, with a declining seepage intensity towards the Holocene. The episodic depletion in $\delta^{13}C_{TOC}$ reveals four intermittent high methane flux events. Our study highlights that $\delta^{13}C_{TOC}$ can serve as an important proxy for reconstructing past methane-seep activities, particularly when integrated with lipid biomarkers and their isotopic fingerprints.

Keywords: Cold-seep, AOM, Lipid biomarkers, Methanotrophy, Calyptogena

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Lipid Biomarker Evidence For Paleo-Methane Seepage In Active Seep Sediments From The Krishna-Godavari Basin, Bay Of Bengal

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ABSTRACT

Recent studies have reported the presence of 22 active and relict cold-seep sites (~638- 1960 mbsl) in the Krishna-Godavari (K-G) basin on the eastern continental margin of India. Some of these cold-seep sites are associated with shallow gas hydrate deposits and proliferates a chemosynthetic ecosystem fueled by methane (CH_4) and hydrogen sulfide (H_2S) . In this study, we have carried out a high-resolution $\delta^{13}C_{TOC}$ coupled with lipid biomarker analysis on a sediment core spanning 36.4 kyr to trace the paleo methane seepage activity at the K-G basin seep site. The $\delta^{13}C_{TOC}$ range from -23.5 to -14.2‰ (VPDB). Distinct negative excursions in $\delta^{13}C_{TOC}$ values indicate the contribution of AOM-derived biomass to the sedimentary organic matter. These negative excursions are associated with the presence of authigenic carbonates, along with remnants of chemosynthetic clam shells belonging to Calyptogena sp., at distinct depths, suggesting episodic methane/H_2S seepage at the seep site. Further, lipid biomarker analysis reveals the presence of diagnostic biomarkers of sulfate-dependent anaerobic oxidation of methane (SD-AOM), including 2,6,10,15,19-pentamethylicosane (PMI) and its unsaturated derivatives, along with minor contributions of crocetane and squalene at multiple depth intervals. These molecular signature indicates intense methanotrophic activity during the past 36.4 kyr. The present sulfate methane transition zone (SMTZ), delineated between 460-500cmbsf, occurs at a deeper depth, indicating a decrease in methane flux in recent times, which is controlled by the shale tectonics of the basin. The current SMTZ is associated with archaeal biomarkers and Calyptogena sp., indicating admixture of paleo and present SMTZ. The variable distribution and concentrations of biomarkers at different depths in the studied core support temporal variations in methane flux. Highly 13C-depleted carbon isotope ratios of archaeal biomarkers in sediments (-118.1 to -64.6 ‰) demonstrate the incorporation of 13C-depleted biogenic methane.

Keywords: cold seep, methanotrophy, fatty acids, compound-specific isotope ratios, biomarkers, methane seepage.

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Paleo-Radiocarbon Ventilation Ages Of Deep Water In The Southwest Indian Ocean Basin

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ABSTRACT

Radiocarbon ventilation age estimates on coexisting planktic and benthic foraminifera in a marine sediment core (SK312/09) from Southwest Indian Ocean (SWIO) suggest a significant change in the deep ocean circulation for the last 35,000 years. (Benthic - Atm) age offsets showed a unique pattern compared to the global trends. Ventilation age was low during the glacial period and highest during the Holocene. However, in most of the earlier studies ventilation age was found to be higher during glacial events (Last Glacial Maxima, Heinrich Stadial 1, and Heinrich Stadial), when the North Atlantic input of deep water was reduced. This suggests the possibility of well-ventilated deep water intrusion in the SWIO during the glacial time. There is another possibility of dead carbon intrusion in the region during the Holocene. The dead carbon may come from mantle-derived CO_2 from the deep-sea volcanic activity. Further research in the SWIO, utilizing cores located away from the active volcanic and hydrothermal areas, is necessary to isolate and clarify the exact contributions of these competing factors. Understanding the regional topography of the deep basins is critical in constraining the role of the deep ocean in carbon storage and release across glacial and interglacial periods.

Keywords: Ventilation age, Foraminifera, Holocene, Last Glacial Maxima, Heinrich Stadial

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Understanding The Variations In Strength Of The Oxygen Minimum Zone Of The Eastern Arabian Sea Since The Last Deglaciation

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ABSTRACT

The Arabian Sea Oxygen Minimum Zone (OMZ) is one of the most important and intense OMZ of the world. The purpose of this study is to better understand the factors influencing the fluctuations in the Eastern Arabian Sea OMZ from the deglaciation to the Holocene. This will help us in further understanding and predicting the nature of the OMZ. In this study we have analysed the core SK-376/GC-02 (water depth: 614 m) with proxies (U, Mo concentrations and Ni/Co ratio) using Q-ICPMS. The ~15.5 Kyr study reveals that during Heinrich Stadial-1 (HS-
1) low U concentrations and low Ni/Co ratio indicate a weakened OMZ which could be the result of gradual strengthening of winter monsoon winds or incursion of oxygen rich southern sourced watermasses (Singh et al., 2007). During the Bolling-Allerod (B-A) higher concentration of U and Mo indicates a moderately strengthened OMZ which possibly suggests a strong summer monsoon (Singh et al., 2007). During the Younger Dryas (YD) the low U and Mo concentrations with low Ni/Co ratio infers a weaker OMZ possibly due to strengthening of winter monsoon induced vertical mixing. In the Holocene the increased Ni/Co ratio and U and Mo ratio suggests a gradual transitioning towards anoxic conditions indicating an increasing OMZ strength.The study reveals that the Eastern Arabian Sea OMZ exhibited significant temporal variability, primarily controlled by changes in monsoon intensity and ventilation dynamics since the deglaciation to the Holocene.

Keywords: Eastern Arabian Sea, Oxygen Minimum Zone, Deglaciation, Holocene, Palaeoceanography.

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The Impact Of Smectite-Illite Transformation On Strain Accumulation In Subduction Wedges: A Geodynamic Modeling Approach

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ABSTRACT

We investigate the role of the smectite-to-illite transformation in controlling earthquake generation within accretionary wedges. This reaction introduces a mechanical dichotomy: dehydration-induced overpressure weakens the main fault, while illite formation strengthens the sediment matrix. This heterogeneity fosters the development of locked asperities essential for strain accumulation. Using **I2VIS** geodynamic simulations with a visco-plastic framework, we model the interaction between thermal gradients, phase transitions, and fluid pressure. Our models demonstrate that the mineral transformation creates a distinct, strong zone that acts as an updip barrier to slip, defining the upper limit of the seismogenic zone. The consistency of these findings with data from the Nankai Trough underscores the necessity of incorporating mineral physics into seismic hazard assessments.

Keywords: Subduction, Geodynamic Modelling, Seismogenesis

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Heat Flow Structure And Geothermal Architecture Of The Andaman–Nicobar Subduction Zone From Curie Depth Analysis

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ABSTRACT

This study presents a comprehensive assessment of the geothermal regime and tectonic framework of the Andaman–Nicobar Subduction Zone using marine magnetic anomaly data. Curie Point Depths (CPDs) were estimated through radially averaged power spectral analysis, enabling the derivation of regional heat flow patterns. The results reveal significant spatial variability in CPDs that closely correspond to major tectonic domains. Intermediate CPDs characterize the Ninetyeast Ridge, trench region, and the Alcock and Sewell Rises, reflecting their structurally complex and overthickened crustal nature. Deep CPDs dominate the forearc and the continental crust of the Mergui area, indicating relatively colder lithospheric conditions. Conversely, shallow CPDs in the Andaman back-arc basin particularly along the Andaman Sea Spreading Center and west of Sewell Rise highlight elevated heat flow associated with active magmatism and hydrothermal circulation.

Heat flow estimates, based on a thermal conductivity of 2 W/m-K and a Curie temperature of 580 °C, delineate two major high-heat-flow trends: a NE–SW-oriented trend along Segment A of the back-arc spreading region, and a N–S trend along the volcanic arc. Low heat flow in the forearc reflects thermal blanketing by thick sediments and the influence of the underlying Burma continental sliver. Variations between measured and calculated heat flow are attributed to hydrothermal recharge discharge systems. The comparison of CPDs with Moho depths indicates deeper CPDs beneath sediment-covered oceanic domains and shallower CPDs in the forearc, while elevated CPDs near the volcanic arc suggest a shallow, magnetised and potentially serpentinised mantle wedge.

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A Hot Ridge Under Cold Sediments: Decoding Heat Flow In The Guaymas Basin

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ABSTRACT

Heat flow at the seafloor is a key indicator of lithospheric cooling, magmatic activity, and hydrothermal circulation. The Guaymas Basin, located in the central Gulf of California, represents a young sediment-filled spreading center where rapid deposition (hundreds of meters to several kilometers per million years) and persistent magmatic intrusions interact to shape the basin's thermal regime. In this study, we report seismic evidence for an extensive bottom- simulating reflection (BSR) across the northwestern part of the basin. By combining BSR depths with measured thermal conductivities, we estimate spatial variations in geothermal gradients and surface heat flow. The BSR-based heat flow values are significantly lower than those expected from conductive cooling models for mid-ocean ridges, implying that rapid sediment infilling dampens the upward transfer of lithospheric heat. Toward the central and southeastern basin, geothermal gradients increase as magmatic bodies approach the seafloor. Thermal models further indicate that young (<5 kyr) intrusions emplaced at shallow depths (<500 m below the seafloor), together with associated fluid circulation, can enhance surface heat flow by up to a factor of five. In contrast, the northern basin shows weak correspondence between geothermal gradients and intrusion depth, consistent with older, cooled intrusive bodies and waning hydrothermal activity.

Keywords: Gas hydrates, Bottom Simulating Reflections, Hydrothermal venting, Oceanic crust, magmatic intrusion.

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Seismic Sequence Investigation Near Edmond Hydrothermal Field, Central Indian Ridge

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ABSTRACT

Earthquakes along slow-spreading mid-ocean ridges (MORs) provide critical insight into the fault dynamics and associated magmatic or amagmatic crustal accretion processes. We examined the seismic sequences that took place during the year 2020 along the southern Central Indian Ridge (CIR), a slow-spreading ridge segment that hosts the Edmond hydrothermal field. ISC bulletin data (1980–2024) reveal four major seismic sequences between 22–24.8°S, with the year 2020 earthquakes sequence showing pronounced temporal clustering. Using 22,480 P and S arrivals from 321 regional and teleseismic stations, 724 earthquakes were relocated along CIR segment (1-5). A close inspection of the earthquakes along with the seafloor bathymetry suggests a compact and well-defined cluster located at the inside corner of a Non Transform Offset (NTO) between segment 3 and segment 4 of CIR. A probabilistic Centroid Moment Tensor inversion for the Mw~5.5 mainshock, using broadband OBS, and global waveform data, identifies a pure normal mechanism. Independent depth constraints using teleseismic array-beam modeling, by matching observed and synthetic P-pP beams, indicate a source depth of ~11 km for the major events. Together, these results suggest that the 2020 CIR sequence was initiated by tectonic faulting along deep detachment fault within the upper lithosphere, with some probability of brief magmatic pulsation that further reactivated nearby axial faults. This integrated catalog, and OBS waveform approach highlights the fine-scale deformation processes governing seismicity along slow-spreading ridges.

Keywords: Seismic sequence, Non-Transform Offset, Mid-Ocean-Ridge, Ocean Detachment Fault, Moment Tensor Inversion.

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Magma-Rich Rifting Scenario In The Northeastern Bay Of Bengal Under The Influence Of Kerguelen Plume Activity

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ABSTRACT

The Northeastern Bay of Bengal is bordered by Bangladesh on the north, Myanmar on the east and the 85E Ridge on the west. Bangladesh is known to be underlain by oceanic crust with the shelf margin about 200 km onshore. Seaward Dipping Reflectors (SDRs) are found overlying the Precambrian crust and associated with prominent magnetic anomalies. The oceanic crust beneath the Northeastern Bay of Bengal has formed after the transfer of the microcontinents namely Elan Bank, CKP, SKP, etc from the Indian plate to the Antarctica plate. The high quality multichannel seismic profile ION1800 depicts a fairly deep basement between 10 and 8 secs, overlain by sediments as thick as 7 secs. The presence of SDRs along the southern part of the profile suggests subaerial magmatic emplacement. Further the prominent Moho reflector indicates the presence of ~3 secs thick crust.

The present study suggests that the SDRs are the manifestation of the northern extension of the Ninetyeast Ridge, which is considered as the trace of the Kerguelen plume. The thickened oceanic crust (~9 km) is a significant indicator for the magmatic nature of the northeastern continental margin of India. Thus, the Northeastern continental margin of India is magma-rich in nature with the Kerguelen plume as its magmatic source. Further, along-strike variability of the Eastern continental margin of India from magma-poor towards southwest to magma-rich towards northeast is proposed.

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Lithospheric Strength And Deformation Beneath The Rifted Basins Of The East India Margin

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ABSTRACT

Gravity responses to sediment loading along passive margins provide important constraints on the mechanical properties of continental rift systems and adjacent oceanic basins. In this study, seismic reflection data, free-air gravity anomalies, and well information from the East India Passive Margin (EIPM) are examined using 2D process-oriented gravity modelling to quantify the effective elastic plate thickness (T_e) and to understand rifting mechanisms and basin evolution. The lithosphere along the EIPM shows considerable variability across its major structural domains. A narrow necking zone (~40 km) characterizes the southern segment, whereas the central segment contains a ~70 km hyper-thinned and exhumed domain. In the northern segment, the hyper-thinned domain narrows to 30–35 km. Distinct T_e patterns further highlight mechanical differences along the margin. The southern EIPM, adjoining the Southern Granulite Terrain, exhibits low T_e values of 5–10 km. The central segment, offshore the Dharwar Craton, shows moderate T_e values of 15–20 km. In contrast, the northern segment, adjacent to the Eastern Ghats Mobile Belt, displays relatively high lithospheric strength, with T_e values ranging from 25 to 35 km. These variations suggest that the southern, central, and northern EIPM segments evolved through different rifting modes—transform, hyperextended, and hypoextended, respectively. In the adjoining oceanic domain, lithospheric strength increases progressively with plate age, consistent with a thermally controlled cooling-plate model approximated by the 600 °C isotherm. The thick Bengal Fan sedimentation has contributed to high elastic thickness values (T_e > 45 km) over the past ~23 Myr. This substantial rheological strengthening may reflect (1) increased shear-wave velocity anomalies and mantle densification at ~150 km depth, (2) changes in plate curvature driven by massive sediment loading and plate subduction near the Bengal Fan, and (3) modification of lithospheric stress regimes associated with convergence between the Indian Plate and Southeast Asia.

Keywords: East India Passive Margin, Rifted sedimentary basins, Sedimentation, Gravity modelling, Lithospheric strength

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Investigating Offshore Andaman Volcanics And Associated Basins Using Geophysical Datasets

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ABSTRACT

The seismically active Andaman-Sumatra subduction zone has been experiencing oblique convergence between the Indo-Australian and Eurasian plates, and backarc seafloor spreading resulting in a prolonged back-arc basin encompassing a chain of volcanoes, notably the active Barren and the dormant Narcondam volcanoes and seamounts like the Alcock and Sewell Rise. The convergence has developed significant crustal-scale fault systems. Here, we have performed an integrated geophysical investigation to estimate the geometry of the Andaman Nicobar Fault (ANF) branches and its role in shaping the basin morphology. We have used three parallel 2D reflection lines (Lines 1-3) over a volcano-enclosed basin in which we have carried out the velocity, polarity, Q attenuation, and AVA analyses to identify fluid evidence in the basinal deposits. We observe a reverse polarity and drop in the interval velocities; high attenuation, and evidence of polygonal faulting above a fluid-bearing zone. This combined analysis reveals prominent fluid evidence in the sedimentary basin, covering an area of ~ 90 sq km. The migrated seismic sections of the volcano-supported basin reveal positive flower structures, indicating an extension of the eastern side of the crustal-scale strike-slip ANF system, which has influenced fluid migration and its accumulation within the basinal deposits. We then carried out the flattening of the litho-stratigraphic horizons and estimated the migration of the depocenter resulting from the fluctuations in sediment supply from the Irrawaddy River and the evolution of the ANF branch during Neogene. To decipher the crustal architecture beneath Narcondam, Barren, and Alcock we have finally extracted three gravity profiles from satellite-derived Free- air gravity data and employed forward gravity modeling and estimated underplating beneath the Alcock Rise and magmatic conduits within the Narcondam and Barren islands.

Keywords: Andaman, seismic, fluid, seismic,underplating

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Tectono-Thermal Evolution Of The North-West Indian Ocean: An Integrated Geophysical Study

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ABSTRACT

Evolutionary history of the northwest Indian Ocean has been quite complex. It has evolved due to complex processes of seafloor spreading and ridge propagation along the paleo Carlsberg Ridge. Present study sheds light on the tectonic and thermal characteristics of the north-western Indian Ocean. Various tectono-thermal parameters are studied for this analysis viz. Moho depth, Effective Elastic Thickness (Te), loading ratio (F), Curie point depth (CPD), and Geoid-to- Topography Ratio (GTR). The study shows Low to moderate Te values, moderate to high F values and low to moderate CPD values over the aseismic ridges, such as the Laxmi and Laccadive Ridges suggesting excessive internal loading. The CPD variations along the Murray Ridge are close to its Moho depth variations suggesting a relatively warm lithosphere. Thin oceanic crust is observed over the Carlsberg Ridge with significant variations in Te and CPD values all along its extent. High Te values with localized thermal modifications and high GTR values all along the Chain Ridge are observed. The spatial variations in GTR across the study region revealed values ranging from -6 to 10 m/km. Compared to the GTR values obtained over the Arabian Basin (-0.8-4.5 m/km), relatively higher GTR values (-0.6-9 m/km) were found over the East Somali Basin. Comparative analysis of Te with CPD values and GTR indicates that the thermal state and compensation mechanisms are crucial in controlling the lithosphere strength. They broadly demonstrate a positive correlation between Te and Curie depth for the entire region. However, both positive and negative correlation zones are locally observed across the region. The study concludes by showing anomalous change in Te, CPD and GTR values at crustal ages 35 and 65 Ma which are reported as the time for extreme tectonic activity in the geological past associated with Indian-Eurasian collision and Réunion hotspot activity, respectively.

Keywords: NW Indian Ocean, Moho depth, Effective Elastic Thickness, Curie point depth, GTR

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Seismically Induced Soft-Sediment Deformation Structures And Massflow Deposits In A Paleoproterozoic Shelf Setting (Chakrata Formation, Lesser Himalaya, India)

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ABSTRACT

A variety of soft-sediment deformation structures (SSDs) and mass flows of varying rheology are present in the Paleoproterozoic argillaceous Chakrata Formation, Lesser Himalaya. SSD structures (intra- and inter-bed) include contorted/convoluted beds, deformed laminations, load casts, and flame structures, pseudonodules, and sand dykes. Deposits of high- and low-density turbidity currents and sandy debris flows represent mass flows that are included in the Chakrata shelf shale succession. The lateral continuity and recurrent incidence of SSD-bearing disturbed layers through the Chakrata lithopackage indicate a seismogenic origin. The disturbed bed thickness and nature of SSD structures suggest the earthquake shock magnitudes (Mz) of 5 to in excess of 8. It is ascertained that besides generating SSDs, the seismic shocks, at times, caused extreme liquefaction and fluidisation that caused sediment failure and generation of gravity flows. Though from rock record establishment of synchronicity between SSD formation and mass flow generation always remains a challenge in the absence of historical data or adjoining fault systems, the physical association of SSDs and mass flows in the Chakrata Formation allows identification of their co-genetic nature related to seismic activity.

Keywords: Chakrata Fm, earthquake, Lesser Himalaya, mass flow, SSDs

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Geodynamics Of Slab Subduction Along Andaman Sumatra Subduction Zone

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ABSTRACT

The subduction of the Indo-Australian Plate beneath the Eurasian Plate extends over approximately 5600 km, where the oceanic Indian lithosphere descends beneath the Eurasian lithosphere. The Andaman-Sumatra subduction zone forms a key segment of this system, stretching from the Andaman Islands in the north to Java in the southeast. This subduction system exhibits significant variations along its curved geometry, including changes in the age and obliquity of subducting plate. Understanding the structure and geometry of the subducting slab is essential for investigating spatial variations along the plate interface near the trench. The tectonics of the region are further complicated by the presence of several active faults and the subduction of tectonic features such as the Ninetyeast Ridge (NER) and the Investigator Fracture Zone (IFZ). This study focuses on analysing gravity anomalies and earthquake epicenter data along the Andaman-Sumatra subduction zone to better understand the subduction dynamics and lithospheric structure. The computed 3D slab gravity anomaly reveals a smooth, long- wavelength, and symmetric gravity high—up to 80 mGal over the Andaman Arc and exceeding 110 mGal over the Sumatra Arc. The Slab-Residual Gravity Anomaly (SRGA) map is prepared using the derived slab anomaly. Several seismological sections taken perpendicular to the trench are examined to interpret the geometry of the subducted slab. These sections show an increase in the dip angle and depth of penetration of the subducted slab from north to south along the arc. Hypocentral trend surfaces are generated using earthquake epicenter data, which predict the depth to the "middle" of the Benioff Zone. Faults transverse to the arc orientation can be inferred on the basis of earthquake hypocentral distributions that trend at high angles to the overall tectonic trend.

Keywords: Subduction Zone, Ninetyeast Ridge, Slab-Residual Gravity Anomaly ,Trend Surface Analysis

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Seismic Imaging Of Structural Framework And Basin Evolution In The Andaman Forearc Basin

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ABSTRACT

The Indian Plate is obliquely subducting beneath the Eurasian Plate at a convergence rate of ~43 mm/yr in the Andaman–Nicobar segment of the Sunda subduction system. This region, which experienced two major megathrust earthquakes—the 2004 Mw 9.2 Sumatra–Andaman and the 2005 Mw 8.6 events—is among the most seismically active zones globally. The Andaman Forearc Basin, classified as Category II and situated within Seismic Zone VI, is therefore of significant interest for both seismic hazard assessment and hydrocarbon exploration.

This study aims to refine the structural and stratigraphic framework of the Andaman Forearc Basin by integrating geological observations with geophysical datasets, including 2D seismic reflection profiles, potential field anomalies, and findings from previous exploration studies. The research examines the interplay between tectonics and sedimentation to understand how structural evolution has influenced depositional patterns through time. Analysis of sedimentary sequences provides insights into the basin's uplift and subsidence history, contributing to a clearer understanding of the dynamic processes governing forearc development.

High-resolution 2D seismic data obtained from the Directorate General of Hydrocarbons (DGH), covering the region between 12°N and 15°N, form the core of this investigation. Interpretation of four representative seismic lines—two from the northern basin and two from the southern basin—identifies three major sedimentary sequences from the Paleogene to Recent, overlying a highly deformed acoustic basement (~5.5 s TWT). Key structural elements include the East Marginal Fault (EMF), Diligent Fault (DF), and West Andaman Fault (WAF), along with associated features such as backthrusts, diapiric intrusions, piggyback basins, and localized deformation zones. Fault reactivation zones, particularly within the Diligent Fault Zone, reveal compression-related structures such as anticlines and backthrusts affecting Pliocene–Neogene sediments, indicating regional shortening and uplift.

Keywords: Forearc Basin, Andaman, Seismic Interpretation, Subduction, Tectonics.

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Estimating Earthquake Nucleation Depth At The Andaman Subduction Zone From Heat-Flow Values

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ABSTRACT

The Andaman subduction zone is a tectonic area where the Indo-Australian plate moves beneath the Eurasian plate. This oblique subduction results in two types of motion: vertical thrusting at the plate boundary and horizontal slipping along a fault. These movements cause significant seismic activities, including earthquakes and tsunamis.
This study relates the surface heat-flow to the depth of the brittle-ductile transition and the thickness of the seismogenic layer using a thermo-rheological model comprising a viscoelastic half-space characterized by Maxwell rheology and viscosity that varies with temperature. Estimation of earthquake nucleation depth is calculated by equating maximum and minimum differential stress. Maximum differential stress is obtained from depth-dependant Newtonian viscosity and geotherm, computed using surface heat-flow. Minimum differential stress is a function of pore fluid factor. We used heat flow values calculated using the spectral analysis of magnetic datasets.
Earthquake nucleation zone is estimated to be at a depth of 20km, which is comparable with the past seismological observations from that area. The study links the thermal structure to the seismic potential of the Andaman Subduction Zone, thereby contributing to improved regional hazard assessment.

Keywords: Andaman Subduction Zone, Heat flow values, Temperature Gradient, Seismogenic Layer, Maximum and Minimum Differential Stress

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Tectonic Evolution Of The Major Shear Zones Of Southern Indian Shield And Their Offshore Extension Towards The Western Continental Margin Of India Using An Integrated Geophysical Approach

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ABSTRACT

The Western Continental Margin of India (WCMI) is formed during the breakup of India and Madagascar, resulting from distinct rifts that occurred around 90 Ma and 65 Ma, driven by major tectonic activities generated by the Marion and Reunion plumes. This study investigates the tectonics and evolution of the Southern Indian Shield (SIS) and the adjoining Western Continental Margin of India through integrated gravity and magnetic analyses. The Southern Indian Shield is dissected by major shear zones, such as the Moyar Bhavani Shear Zone (MBSZ), Palghat Cauvery Shear Zone (PCSZ) and Achankovil Shear Zone (ASZ), whose offshore extensions towards the WCMI remain poorly studied.

The integrated approach of topography/bathymetry, gravity, and magnetic data is utilized for this study by using the seismic constraints. The free-air and Bouguer gravity anomalies undergo various filtering techniques to isolate the regional and residual gravity anomalies. Magnetic anomalies are used to identify the depth to the magnetic sources using different techniques. The Curie depth of the region is estimated using the magnetic data and is used to identify the thermal structure of the crust. The Radially averaged power spectrum analysis is carried out for both gravity and magnetic data to understand the depth to the gravity and magnetic interfaces. The Moho depth is estimated using the Moho inversion technique, using the power spectrum analysis, and the known values from the available seismically constrained crustal thickness data are taken into consideration for validation of results. Using the integrated approach of gravity and magnetic data, along with the seismic constraints, complemented by available geological and geophysical studies, the joint gravity and magnetic modelling is undergone to understand the crustal architecture of the major shear zones of SIS and the WCMI, to assess the offshore extensions of these major shear zones and to understand their tectonic evolution.

Keywords: Tectonics, WCMI, Shear Zones, Moho variations, Gravity and Magnetics.

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3D Flexural Response Of Lithosphere To Excessive Sediment Loading Beneath The Bangladesh

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ABSTRACT

The sedimentary basins of Bangladesh are one of the most geologically complex regions in South Asia, characterized by thick sediment accumulation of up to ~20 km and ongoing dynamic tectonic interactions. The eastern boundary of Bengal Basin is a passive rifted continental margin that originated from Early Cretaceous (~132 Ma) rifting, followed by seafloor spreading between Greater India and East Antarctica. The flexural behaviour of the lithosphere beneath the Bengal Basin, plays a key role in controlling sediment accommodation space and governing basin subsidence and uplift patterns. In the present study, we have calculated the flexural response to lithosphere to thick sediment loading by considering a simple elastic plate model. For this, the sediment thickness data is gridded over the study region, and an exponential density function is used to estimate the average density of the sediments. In the present work, a Te value of 21 km is assigned to major sedimentary units based on the 300 °C isotherm. Using these inputs, we computed the average depth (~5.6 km) of backstripped basement beneath the Bangladesh. The tectonic subsidence of the lithosphere is matching with water-loaded basement depth derived from plate-cooling model. This inference support the presence of oceanic crust in the onshore Bengal Basin.

Keywords: Passive Continental Rifted Margin, Elastic thickness, Sedimentary Basin, Flexural Rigidity, Flexural Backstripping

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Moho Topography Beneath Bangladesh's Sedimentary Basin: Insights From Seismically-Constrained 3D Gravity Inversion

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ABSTRACT

The sedimentary basins of Bangladesh accumulated maximum ~20 km sediments and influenced by active tectonic processes in the Indo-Burma range and Himalaya orogeny. Accurate mapping of the Mohorovičić discontinuity and crustal thickness beneath the Bangladesh is essential because these paramerters govern regional geodynamics and lithospheric response to loading. In this study, we apply a seismic-constrained 3D gravity inversion to Bouguer gravity anomalies compiled from USGS, GSI, and GFZ satellite datasets, following correction for the substantial sedimentary column using an exponential density–depth relationship. Our results reveal pronounced lateral variations in crustal architecture across the Bengal Basin and the Indo-Burma Subduction Zone. Crustal thickness attains ~34 km beneath the Indo-Burma Range, whereas it thins dramatically to ~14–16 km beneath the central Bengal Basin. Correspondingly, the Moho deepens to ~40 km under the Indo-Burma Subduction Zone and shoals to ~34 km beneath the central basin. These patterns are consistent with active tectonic shortening, crustal underthrusting, and flexural response to extreme sediment loading. The resulting high-resolution crustal model provides new constraints on crust–mantle interactions, basin development, and the tectonic evolution of one of the world's thickest sedimentary provinces.

Keywords: Mohorovičić discontinuity, Crustal thickness, Sedimentation, Seismic-constrained 3D gravity inversion, Indo-Burma subduction zone.

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Morphology And Tectonic Implications Of A Newly Discovered Seamount In The Eastern Arabian Basin

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ABSTRACT

The northwestern Indian Ocean opened as a result of the separation between India and Madagascar in the Late Cretaceous and between India and Seychelles in the Early Paleocene. The second separation event is simultaneous with the arrival of the Réunion plume beneath the Indian lithosphere, which reorganised the spreading centres, forming the Arabian Basin. The eastern Arabian Basin was significantly influenced by these geodynamic events, resulting in the development of several bathymetric highs in the offshore region. The work examines the morphological characteristics and flexure of a previously undocumented seamount in the eastern Arabian Basin, situated near the Laccadive Plateau, utilising high-resolution multibeam bathymetric data. The seamount is situated on a flat seafloor (bathymetry ranges from 4,100 to 4,200 meters) and rises to a maximum depth of 2,740 meters from a depth of 4,200 meters. Residual depth anomalies, isostatic modelling, and seismic data indicate that the feature is situated on oceanic crust. The low effective elastic thickness of 2 km suggests emplacement on a mechanically weak, young lithosphere formed during seafloor spreading along the Carlsberg Ridge. The study implies that the continent-ocean boundary lies to the east of the identified seamount and to the west of the Laccadive Plateau. In addition, the emplacement of the seamount is interpreted as a result of the influence of the Réunion plume or the magma flow during rift propagation in the Arabian Basin or a combination of both.

Keywords: Seamounts, Morphology, Isostasy, Eastern Arabian basin, Laccadive Plateau

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Rift-Related Basement Structures Of The Krishna–Godavari Offshore Basiin, Ecmi: Evidence From Seismic And Potential Field Studies

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ABSTRACT

The Eastern Continental Margin of India (ECMI) originated during the Early Cretaceous as a result of India's separation from Antarctica. Recent studies indicate that this margin is predominantly magma-poor. Using high-quality seismic, gravity, and magnetic data along the ION1000 profile off the Krishna–Godavari Basin in central ECMI, several interpretations have been proposed to explain the presence of an overthickened crust. In this study, we integrate multichannel seismic, gravity inversion, and magnetic spectral analysis to understand the crustal configuration and rifting processes along this region. Analysis of the ION1200 profile reveals distinct rift-related features such as structural domains, major faults, and rifting points, with no direct evidence of magmatic activity. Conversely, the ION1100 profile shows a deep basement overlain by sediments up to 12 km thick and a localized basement high interpreted as continental crustal material representing the outer domain. This overthickened crust may have formed due to limited magmatic intrusion before the onset of seafloor spreading, potentially causing an extension locus jump that transferred this basement high from the Antarctic plate to the Indian plate. Overall, our results suggest that the ECMI is largely magma- poor but exhibits significant along-strike variability in rifting style and crustal structure. Minor magmatic activity during the late rifting phase, however, cannot be excluded. The integrated geophysical interpretation presented here provides a valuable framework for understanding the diversity of rifting mechanisms, magmatic influence, and crustal evolution along other passive continental margins worldwide.

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Depositional History Of A Wave-Dominated, Storm-Infested Argillaceous Late Miocene- Pliocene Shelf From The Boka Bil Formation, Surma Group, Mizoram, India

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ABSTRACT

The late Miocene-Pliocene argillaceous Boka Bil Formation (Surma Group), exposed at the outskirts of Aizawl town, Mizoram, records the depositional history of a wave-dominated clastic shelf, frequently infested by storms. In alternation with wave-rippled silty shale, lenticular siltstone/fine-grained sandstone interbeds with hummocky and swaley cross-stratifications and erosional sole feature like gutter bear undeniable proof for storm action. Process-based facies analysis allowed delineation of fair-weather and storm wave bases on the Boka Bil shelf that allowed categorization of depositional products as i) above fair-weather wave base ii) between fair-weather and storm wave base and iii) close to or below storm wave base. Whereas *Cruziana* ichnofacies dominate distal shelf, dwelling burrows of *Skolithos* are noticed in abundance in storm-infested proximal shelf. Additionally, recurring alternation between sandstone-hosted *Skolithos* ichnofacies and silty-shale hosted *Cruziana* ichnofacies in inner shelf deposit bear indication for storm-prone shelf setting. An operation of geostrophic current is inferred from near coincidence between fair weather wave ripple crest line orientation and gutter trend. Measurement of litholog and documentation of facies stacking pattern allowed identification of a shallowing-up progradational depositional trend in the course of Boka Bil sedimentation in the study area. Water depth range of 4-14 meters is estimated from fair-weather wave ripple data and sediment grain size using Bay of Bengal shelf as a modern analogue.

Keywords: Mio-Pliocene, Boka Bil, Surma, storm, ichnofacies, paleobathymetry

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The Deep Crustal Architecture Of Andaman Arc: An Integrated Geophysical View

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ABSTRACT

The Andaman Arc, a complex active subduction system marking the boundary between the Indian and Eurasian plates, is a critical region for understanding seismic and volcanic hazards. The devastating earthquake of December 26, 2004, has influenced many geoscientists to study the stress conditions and potential field-derived structural interpretations existing in the Andaman Sumatra Subduction Zone. In this study, we analyzed gravity anomalies to model variations in crustal thickness and density, revealing a significant contrast between the accreted oceanic sediments of the forearc and the denser, underlying oceanic crust. The magnetic data used for identifying magnetized bodies and fault systems that segment the arc. Crucially, we integrated a high-resolution spatial and temporal analysis of the b-value, a parameter derived from the Gutenberg-Richter relationship that reflects the stress state and material heterogeneity within the crust. Our results show a pronounced spatial correlation: regions of low b-value, indicative of high crustal stress and potential for large-magnitude earthquakes. These zones are interpreted as areas of strong crustal coupling along the subduction interface. The spatial b-value exhibits an inverse correlation with the gravity anomaly. This integrated model provides a coherent, multi-parameter image of the subsurface. We propose that the arc is characterized by a heterogeneous crust with distinct, stress-partitioned domains controlled by the interplay of the Subducting slab and associated structural inhomogeneities.

Keywords: Gravity and magnetic study, seismicity, b-value, crustal structure, subduction.

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Deciphering Crustal Architecture Beneath The Ninetyeast Ridge Using Multichannel Seismic Reflection Data

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ABSTRACT

The Ninety East Ridge (NER), a notable and distinctive morphological feature, is a linear aseismic ridge in the eastern Indian Ocean, extending approximately 5,500 km in a linear direction along 90°E. In the present study, we utilize 2D multichannel seismic (MCS) reflection data acquired in 2017 over NER, carried out aboard the R/V Marion. A 4.5 km-long Sercel SSRD streamer with 720 hydrophones, used to record seismic data generated by an airgun source covering a total of 176 km-long profile length. The group and shot intervals are 6.25 m and 50 m, respectively. The raw MCS data, initially contaminated by the swell noise, tail buoy noise, and strong multiples, was preprocessed using Echos Paradigm. Following a conventional marine seismic processing workflow, we first implement a bandpass filter, designed with low-cut frequencies of 2 to 5 Hz and high-cut frequencies of 80 to 100 Hz in order to retain the dominant energy, followed by spherical divergence correction, FK filtering (in the shot domain) for coherent linear noise attenuation, WEMA (in shot gather), velocity analysis, NMO corrections, and the Parabolic Radon transform (in NMO-corrected CDP gather) to attenuate long-path multiples, thereby progressively enhancing the data quality and preserving the primary reflection energy. Preliminary interpretation of the Brute stacked image indicates a marked variation in sea floor topography that varies approximately from 2 to 3 km along the seismic profile line, the deformation patterns, along with the presence of volcanic deposits, and zones of chaotic and strong reflections that may indicate complex subsurface structural variations. In the future, we will first complete the post-stack time migration, followed by the depth conversion. Then we will implement PSDM (Pre-Stack Depth Migration) in conjunction with gravity modeling to achieve more reliable geological interpretations of subsurface structures and accurately identify the Moho depth, thereby enhancing our understanding of the nature and tectonic evolution of the crustal architecture of the NER region along the seismic profile.

Keywords: Ridge, Aseismic, Bandpass, Multiples, Velocity

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A High Resolution Biostratigraphic And Palaeoenvironmental Evidence From The Early Maastrichtian Of The Krishna–Godavari Basin, India

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ABSTRACT

The Maastrichtian Stage of the Late Cretaceous is renowned for its profound paleoenvironmental transformations and the expansion of extensive marine ecosystems that favoured the proliferation of organic-walled dinoflagellate cysts. Among these, the family Ceratiaceae, particularly the genus Xenascus, achieved exceptional diversity and abundance. In this study, sedimentary cutting samples from DGU Well "A", representing the Raghavapuram/Chintalapalli Shale Formation of the Krishna–Godavari (K–G) Basin, India, were analyzed for their palynological composition. The assemblage revealed a diverse and well-preserved dinoflagellate cyst population dominated by Xenascus ceratioides, along with other twenty-seven additional taxa. The documentation of last occurrences (LOs) of age-diagnostic species enabled refinement of the biostratigraphic framework for the study area. The consistent presence and acme of X. ceratioides indicate an early Maastrichtian age for the studied succession. This research establishes, for the first time, a well-defined Xenascus ceratioides Acme Zone in the K–G Basin, providing improved biostratigraphic resolution in a region where records are often sparse or stratigraphically ambiguous. Moreover, the composition and abundance patterns of the dinocyst assemblage offer valuable insights into the paleoenvironmental conditions, suggesting deposition in shallow to open marine settings within a low-paleolatitudinal regime during a critical interval of Late Cretaceous Earth history.

Keywords: Xenascus, Maastrichtian, Krishna–Godavari Basin, Biostratigraphy, Paleoenvironment

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Ecological And Socio-Economic Impacts Of Artificial Reef Deployment Along The Maharashtra Coast

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ABSTRACT

The use of artificial reefs (ARs) to improve coastal fisheries and rejuvenate marine coastal environments is becoming more widely acknowledged. Present study aims to evaluate the ecological performance and socioeconomic advantages of artificial reefs deployed along the Maharashtra coast. This study integrates underwater ecological surveys, plankton and benthos assessments, and structured fisher interviews to synthesize the initial field observations along Maharashtra coast. Field investigations using SCUBA and Remote Underwater Vehicle (RUV) platforms revealed marked improvements in local productivity, with higher density and diversity of phytoplankton and zooplankton communities, indicating the establishment of a planktonic food web around the reef modules. Fish larvae were consistently recorded in the periphery of the structures, highlighting their role as micro-nursery habitats. Reef-associated fish assemblages included commercially valuable species such as snapper, grouper, etc. confirming early enhancement of fish biomass. Socio-economic interactions with small-scale fishers indicated multiple positive outcomes: increased catch of larger-sized fish, reduced operational costs due to proximity of fishing grounds, and perceived protection of traditional fishing areas from trawling interference. The preliminary results demonstrate that artificial reefs in Maharashtra serve as effective ecological enhancers and livelihood support systems, with strong potential for strengthening community-based fisheries management. Ongoing monitoring will generate robust evidence to inform state-level policies on artificial reefs, and long-term sustainability under changing climatic conditions.

Keywords: Artificial reefs, Maharashtra coast, Fisheries Enhancement, Socio-Economic Impact, Biodiversity, coastal livelihoods.

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Unravelling Climate Change Effects On Mangroves: Pest Infestations And The Role Of Rainfall In Thane Creek, Mumbai

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ABSTRACT

This study examines how mangrove pest outbreaks and Leaf Area Index (LAI) variations act as early indicators of ecosystem stress with direct consequences for coastal fisheries in an urbanizing, climate-challenged setting. We evaluated spatial patterns of H. puera infestation across upper (riverine) and lower (estuarine) stretches, integrating field assessments of infestation intensity, LAI-based health metrics, and spectral characteristics to detect canopy degradation. Temporal analysis of rainfall amount and distribution revealed correlations between anomalous precipitation patterns and outbreak years, suggesting that altered hydrological regimes under climate variability may trigger or exacerbate pest dynamics. The results show that infestation-driven reductions in canopy cover and LAI degrade habitat complexity, undermining the nursery and refuge functions of mangroves for juvenile finfish and crustaceans. These structural changes are likely to reduce local fishery productivity and resilience, particularly where mangroves interface with heavily impacted urban coastlines. We propose a conceptual model of population succession and ecosystem response during outbreak versus non-outbreak years, highlighting feedback among climate drivers, pest population dynamics, mangrove physiological status, and fisheries outcomes. Management recommendations emphasize routine monitoring using LAI and spectral indices for early detection of stress; rainfall-informed risk assessment to anticipate outbreak windows; targeted restoration and sanitation in high-risk creek stretches; and integrating community-based fishery management with mangrove conservation to maintain ecosystem services. Future research priorities include mechanistic studies on pollutant– pest interactions, long-term succession monitoring, and scaling these approaches to other urban estuaries. Positioning Thane Creek as a sentinel system, this work outlines practical mitigation pathways that link mangrove health preservation to sustaining coastal fisheries in a changing climate.

Keywords: Mangrove pest outbreak, Leaf Area Index (LAI), Thane Creek, Coastal fisheries resilience, Rainfall-driven disturbance

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Integrated Management For Coastal Fisheries And Ecosystems Facing Climate Challenges

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ABSTRACT

Climate change has a significant impact on coastal fisheries and ecosystems, such as changes in species ranges, and productivity. These changes have significant environmental consequences, such as alterations in predator-prey relationships, ecosystem structure, and the extinction of native species that have been vital to productivity in nearshore areas. The economic effects of these shifts are also evident in fishing communities, especially for small-scale and artisanal fishers such as unstable catch composition, and limited access to traditional resources, bringing vulnerability and instabilities in their income. These changes, thereby, disrupt the ecosystem balance, leaving traditional management approaches less effective impacting jobs and food security in areas that rely heavily on these resources, thus influencing the demographics and health of coastal populations. The effects are strongest in "fishing hotspots," where climate- driven species shifts occur rapidly.
Future-ready management systems, such as dynamic harvest strategies and more flexible local co-management, as well as ecosystem-based adaptation measures like restoring natural breeding grounds (mangroves, reefs, seagrass, etc.,), and creating buffer zones to protect the ecological integrity, are the types of solutions that can help coastal fishers cope with climate change. To strengthen this, we must enhance early warning systems for coastal ecosystems and promote alternative coastal livelihood measures. This will protect the health of ecosystems and the people heavily relying on them. Achieving a state of sustainability demands inclusive decision-making, investment in scientific capacity, and the development of adaptive governance frameworks and policies that can respond rapidly to changing biological and social conditions.

Keywords: Climate change, species shift, economic vulnerability, fisheries management, coastal early-warning systems, alternative livelihoods

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Climate-Driven Thermal Front Variability Along The Southwest Coast Of India And Its Influence On Pelagic Fisheries

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ABSTRACT

Global climate variability modifies sea surface temperature (SST) structure and large-scale oceanographic conditions, with direct implications for coastal productivity. Thermal fronts, the dynamic interfaces between contrasting water masses, generate sharp horizontal temperature gradients that intensify vertical mixing, nutrient fluxes, and biological activity. The study examined the influence of SST frontal dynamics along the southwest coast of India on regional biological productivity and pelagic fish distribution. Using a two-decadal (2002–2022) Aqua MODIS 8-day composite SST dataset, we quantified the spatial and temporal variability of thermal fronts and compared their frequency and intensity between 2002–2012 and 2012–2022 in relation to prevailing climate oscillations. Front occurrences were analyzed against pelagic fish landings to determine their role in shaping catch patterns. The outputs generated provide a quantitative baseline for understanding how climate-driven frontal variability regulates coastal productivity and pelagic fish distribution under changing climatic conditions.

Key words; Climate Variability, Thermal Fronts, Pelagic Fisheries, Interannual Trends

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Seaweed As An Ocean Superfood: A Sustainable Pathway To Seaweed-Based Plant Meat

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ABSTRACT

Oceans cover 71% of the Earth and provide one of the richest reservoirs of nutritious living resources. As the global population approaches 10 billion, food from the ocean is gaining strategic significance due to its high productivity, diverse species, and minimal land requirements. Food from the ocean is becoming essential as land-based agriculture faces climate change, land scarcity and freshwater limitations offers an immense opportunity for sustainable nutrition. Seaweed, a nutritious rich ocean superfood, offering, Rich in proteins, omega-3 fatty acids, antioxidants, vitamins, minerals, and dietary fibers, while requiring no land, no freshwater, and serves as a climate-resilient alternative to terrestrial crops and supports carbon sequestration, biodiversity, and coastal livelihoods. Its unique biochemical composition makes it a powerful candidate for advancing ocean-based food innovations.

Building on its superfood profile, seaweed is now driving innovation in plant-based meat. A major emerging development is the creation of seaweed-based plant meat products, including burgers, sausages, nuggets, patties and mince alternatives. Seaweed's natural hydrocolloids naturally mimic meat-like texture, while its umami compounds enhance flavor without artificial additives. When combined with plant proteins such as soy, pea, chickpea, and lentil through extrusion and structuring technologies, these products deliver nutrient-rich, clean-label, and environmentally superior alternatives to traditional meat.

For vegetarians and vegans, seaweed-based meats provide essential nutrients often lacking in plant diets such as iodine, iron, complete amino acids, antioxidants, and omega-3 fatty acids. This innovation offers a novel, scalable, and climate-friendly solution positioning seaweed as a transformative resource for global food security.

Keywords: Seaweed; superfood; hydrocolloids; sustainability and vegan meat.

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Stress Responses Of The Natural Fish Population Of Indian Sundarbans: A Comparative Account Of Nine Species In Relation To Environmental Variables

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ABSTRACT

The natural and anthropogenic perturbations faced by the mangrove estuaries of Indian Sundarbans directly affect its associated natural fish population. This study evaluates the stress levels of nine ecologically and economically important fishes namely Otolithoides biauritus, Harpadon nehereus, Anodontostoma chacunda, Johnius carouna, J. belangerii, Planiliza melinoptera, Arius maculatus, Coilia ramcarati and C. neglecta, in response to environmental variables. Samples were collected from river channels during monsoon 2024 (July to September) from three stations namely, Kumirmari (22°09.661'N 088°54.948'E), Dobanki (22°00.857'N 088°45.567'E) and Frasergunj (21°34.861'N 088°14.157'E) with different salinity regimes. The protein profile of muscles was established by SDS-PAGE and total protein quantified. Biochemical estimations for Hsp70, cortisol, superoxide dismutase (SOD) and catalase were performed on fish muscle, gills, liver and kidney tissues. Water variables (temperature, salinity, pH, dissolved oxygen, transparency and depth) were recorded in situ and nutrients (nitrate, phosphate and silicate) analysed. A comparative account of the findings was established between S1, S2 and S3. A significant spatial variation was observed in the protein profile and biochemical constituents assayed. Spatiotemporal studies are recommended for further elucidation of adaptability of fishes of the Indian Sundarbans.

Keywords: Mangrove estuary, salinity, fish, stress markers

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Seasonal Variability In Ichthyoplankton (Eggs And Larvae) Off Kochi During The Monsoon Period (June–September 2025)

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ABSTRACT

Understanding early life-history dynamics of marine fishes is essential for predicting recruitment success and ecosystem responses to monsoon-driven variability. Monthly ichthyoplankton sampling was conducted off Kochi from June to September 2025 under the ICAR-CMFRI Marine Egg and Larval monitoring programme. Cruise sampling was carried out monthly onboard the CMFRI research vessel F.V. Silver Pompano. Zooplankton collections were performed at 5–30 m depths using Bongo nets, and eggs and larvae were quantified to evaluate monsoon-associated changes in abundance and vertical distribution. Ichthyoplankton exhibited marked seasonal fluctuations corresponding to monsoon hydrography. Round eggs showed a clear monsoon-associated spawning signal with elevated abundance in August and sustained levels in September, indicating a secondary spawning peak following the major pre-monsoon event observed earlier in the year. Oval eggs remained consistently low during the monsoon period, reflecting their sensitivity to turbulence and reduced salinity, and confirming their association with demersal and semi-pelagic taxa favouring more stable pre-monsoon conditions. Larval abundance displayed a pronounced monsoon recruitment pulse, peaking in June, coinciding with enhanced primary productivity and favourable feeding conditions. Across all months, larvae were strongly concentrated in the surface and near-surface layers (5–10 m), highlighting this zone as the primary nursery habitat during the monsoon season. The study provides new baseline information on monsoon-driven ichthyoplankton dynamics along the southwest coast of India. The dual pattern of monsoon recruitment and post-monsoon spawning emphasizes the strong coupling between hydrographic processes and early life-history stages. These findings contribute to improved understanding of ecosystem variability and support future efforts in fisheries forecasting and stock assessment.

Keywords: Ichthyoplankton, Monsoon Dynamics, Spawning Patterns, Larvae, Southwest Coast Of India

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Differential Impacts Of Selective Fishing On Reef Fish Populations Across A Gradient Of Market Demand

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ABSTRACT

The high-value and rising demand for reef-based seafood has increased fishing pressure in previously underexploited regions. Commercial harvests are often selective towards species with high export value. Understanding how the nature of demand influences reef fish communities is crucial for designing strategies that support both fisheries and conservation goals. In this study, we aim to understand how varying levels of demand influence reef fish communities in a data- deficient, commercial fishery in the Andaman Islands. The islands have a relatively nascent history (~30 years) of commercial fisheries, yet management is widely believed to be inadequate. To understand the impacts of selective harvests, we used a three-year dataset from surveys inside and outside the Mahatma Gandhi Marine National Park, a no-take MPA. At each site (N = 24), we performed 50m X 5m underwater belt transects (N = 2-5 per site) to understand the abundance, biomass, and size-class distribution of reef fish communities and $1m^2$ photo quadrats (N = 5-10 per transect) to understand benthic community composition. Similarly, we used market-based surveys to classify fish species based on the level of demand – export, local, and not-consumed. We compared mean abundance and biomass within and outside the MPA for each demand category. Species with export demand showed the largest differences in abundance and biomass, whereas species that are not consumed did not vary significantly. Generalised Linear Mixed Effects Model revealed that this difference was significantly influenced by protection and demand but not by hard coral cover. The study highlights the need to diversify fish consumption patterns and integrate market based approaches in contemporary management practices. Furthermore, we emphasize the need for fisheries management to move beyond no-take protected areas as the sole approach towards conservation and adopt ecosystem-based management approaches.

Keywords: conservation, sustainable fisheries, coral reefs, groupers, islands

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Anthropogenic Threats To India's Coastal Cetaceans: A Focus On Neophocaena Phocaenoides And Sousa Plumbea

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ABSTRACT

Marine mammals, as apex predators, play a vital role in regulating trophic dynamics and maintaining the stability of marine ecosystems. However, they are increasingly exposed to pressures arising from climate variability, extreme weather events, habitat degradation, pollution, and fisheries interactions. These cumulative stressors threaten their populations and disrupt ecosystem functioning. In India, marine mammal strandings have shown a notable increase in recent years, reflecting heightened ecological and anthropogenic pressures and underscoring the need for strengthened monitoring and conservation measures. To investigate these concerns, stranding datasets from the Indian coast were compiled and analysed with a specific focus on two frequently reported species: Neophocaena phocaenoides (Indo- Pacific Finless Porpoise) and Sousa plumbea (Indian Ocean Humpback Dolphin). Each record was systematically categorized based on carcass condition, prominent external observations, sex, growth stage, and spatial–temporal context to infer probable causes of mortality, particularly those associated with direct anthropogenic impacts such as fisheries interactions and vessel strikes. The analysis revealed clear indications of human-related threats contributing to mortality in both species, while also highlighting substantial gaps in post-mortem documentation, carcass assessment detail, and standardized reporting practices. These limitations restrict the ability to confidently determine cause of death in many cases, emphasizing the need for improved diagnostic and response frameworks. Moving forward, the study underscores the importance of capacity building for rapid and accurate cetacean mortality assessments, enhanced stakeholder awareness, and the establishment of coordinated stranding response networks. Strengthening these efforts is essential for developing targeted regulatory measures, mitigating anthropogenic impacts, and ensuring the long-term conservation of vulnerable coastal cetaceans along the Indian coastline.

Keywords: Apex predators, Anthropogenic impacts, Neophocaena phocaenoides, Sousa plumbea, Carcass.

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A Comprehensive Evaluation Of Standard Nutrient Media For Supporting Biomass Production And Culture Stability Of Ulva Spp. In Controlled Land-Based Aquaculture Systems

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ABSTRACT

Seaweed aquaculture is emerging as a strategically important sector in India, driven by increasing demand for biomass for food, feed, biostimulants, pharmaceuticals, and climate-resilience applications. While coastal farming remains prevalent, land-based tank cultivation is rapidly gaining attention due to its advantages in biosecurity, controlled production, year-round harvesting, and compatibility with integrated multi-trophic aquaculture systems. A critical requirement for scaling land-based cultivation is the establishment of efficient nutrient regimes tailored to specific seaweed species and local environmental conditions. However, nutrient media such as PES, MP1, and F/2 medium were originally designed for microalgae or temperate species, and their suitability for Ulva under Indian tropical and subtropical conditions is still poorly understood. The present study aimed to evaluate and compare these three widely used nutrient media for their effectiveness in supporting the growth of Ulva spp. in controlled land-based tank systems. Preliminary observations indicate that Ulva responds differentially to the tested formulations, with Guillard's F/2 medium showing comparatively superior performance in terms of growth rate, thallus integrity, and culture stability. PES and MP1 supported moderate growth but exhibited limitations such as slower biomass accumulation or variable morphology under the tested conditions. These findings suggest that although existing media can sustain Ulva growth, their nutrient composition may not fully meet the physiological requirements of Ulva species adapted to Indian coastal waters. The results underscore the importance of developing species-specific and climate-appropriate nutrient formulations to enhance productivity, reduce culture inconsistencies, and support large-scale land-based cultivation of Ulva. Building upon the insights gained from this comparative assessment, ongoing research efforts are focused on formulating and validating a customized nutrient regime specifically optimized for Ulva spp. This work represents a necessary step toward enabling reliable and scalable seaweed production in India.

Keywords: Seaweed aquaculture, Biomass productivity, Nutrient regimes, Land-based seaweed cultivation, F/2 Medium

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Benthic Substrate Influence On Reef Fish Communities In Selected Lakshadweep Atolls

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ABSTRACT

Benthic substrate characteristics play a crucial role in shaping reef fish communities by influencing their distribution on the coral reefs. However, climate-driven disturbances and increasing human pressures are rapidly altering coral reefs, often leading to shifts from coral algal dominated states in many reefs. Herbivory acts as an essential ecological process that can help maintain coral dominance by mediating coral-algal competition. This study examines the links between benthic substrate composition and reef fish assemblages across four coral atolls in the Lakshadweep archipelago. Underwater visual census data, collected alongside Line Intercept Transects (LIT), were used to evaluate how different benthic components influence fish biomass and functional groups within lagoonal habitats. Among the surveyed islands coral cover was observed to be highest at Kavaratti and Chetlat (55-60%), and comparatively lower at Kalpeni and Agatti (25-35%). Fish biomass varied from 9.63 ± 5.12 SE to 18.90 ± 2.94 kg/100 m², with the greatest biomass recorded at Chetlat, followed by Kavaratti. Herbivore biomass was significantly higher in structurally complex reefs dominated by live coral, particularly at Chetlat and Kavaratti (14.26 ± 4.01 and 8.17 ± 1.31 kg/100 m², respectively). Sites dominated by rubble, rocks, and sea anemones supported comparatively lower herbivore assemblage structure. Among the herbivore functional groups, grazers and scrapers displayed stronger associations with high coral cover, highlighting their reliance on coral rich areas for feeding and shelter. The findings demonstrate a clear ecological interdependence between benthic substrate composition and herbivorous reef fish communities. This underscores the importance of conserving benthic structural integrity to sustain herbivore-driven ecological processes that are critical for maintaining reef resilience in the Lakshadweep Islands.

Keywords: Lakshadweep, Coral reef, Herbivore fishes, Algae, Benthic Substrate

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Valuation Of Habitat-Provisioning Services Of Seagrass Meadows In Chilika Lagoon

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ABSTRACT

Seagrass meadows in Chilika lagoon serve as a breeding habitat for many commercial fish juveniles and prawn fingerlings. As per existing literature, the most dominant prawn species identified in the lagoon were Penaeus monodon and Fenneropenaeus indicus. Habitat provisioning as an ecosystem service is of great importance as it maintains the ecological productivity of the lagoon via the circulation of nutrients across the various sectors of the lagoon due to the movement of the fish and prawns across the lagoon. As per the latest report by Odisha Forestry Sector, ~ 6109.595 metric tonnes of prawns have been estimated in the lagoon for the year 2023-2024. Utilising the data curated from previous literature, the present study evaluated the habitat provisioning ecosystem service provided by the seagrasses to the prawn fingerlings and juveniles in Chilika. But due to several factors, the seagrass meadows are under threat and there is a need for the conservation of these meadows, and, in turn, the prawn fingerlings associated with the seagrass species. For this, two different methods were employed to estimate the economic worth of seagrass meadows as a breeding habitat sector-wise and season-wise: 1. replacement/restoration costs and 2. Willingness to Pay (WTP) for the conservation of these seagrass meadows. This study aims to establish that the loss of seagrass meadows due to various anthropogenic as well as natural stressors affects the survival and ecosystem health of seagrass meadows in Chilika. This leads to a loss of seagrass meadows which ultimately led to a decrease in the amount of prawn fingerlings. Thus, to maintain the economic value of ecosystem services- especially habitat provisioning provided by seagrass in Chilika, we must formulate policies to safeguard and conserve these important seagrass meadows.

Keywords: seagrass, fingerlings, habitat provision, ecosystem services, Chilika

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Nutrient Composition Of The Deep-Sea Shrimp Penaeopsis Jerryi From The Southeastern Arabian Sea

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ABSTRACT

Penaeopsis jerryi is an edible deep-sea penaeid shrimp of considerable commercial value, harvested along the southwest coast of India in the Arabian Sea. In this study, its proximate composition, mineral content, amino acid profile, and fatty acid composition were examined, with particular emphasis on sex-based differences. The proximate components occurred in decreasing order of abundance as moisture, protein, fat and ash. Male shrimp contained higher moisture levels, whereas females exhibited greater concentrations of protein, fat and ash, indicating a more nutrient-rich biochemical profile. Among macro-minerals, phosphorus was the most abundant, followed by magnesium, while iron and zinc were the leading micro-minerals. Gas chromatography analysis showed that palmitic acid (16:0), oleic acid (18:1n-9) and docosahexaenoic acid (22:6n-3) were the predominant saturated, monounsaturated and polyunsaturated fatty acids, respectively, with consistently higher proportions recorded in females. Seventeen amino acids, representing both essential and non-essential categories, were identified in the muscle tissue. Glutamic acid and lysine emerged as the most abundant non- essential and essential amino acids, respectively, and were also found at higher concentrations in females. Overall, the integrated assessment of proximate components, minerals, fatty acids, and amino acids underscores the rich nutritional value of P. jerryi, highlighting its potential as a high-quality deep-sea seafood resource.

Key words: Deep-sea shrimp, Nutritional analysis, Proximate composition, Fatty acid profile, Amino acid profile.

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Mapping The Unmappable: Using Deep Learning Embeddings To Distinguish Cryptic Mangrove Species In Png

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ABSTRACT

Papua New Guinea supports some of the world's most extensive mangrove estates, yet accurate carbon accounting here is stalled by a simple problem: we cannot easily tell the species apart from space. This is particularly frustrating with the genus Avicennia, where A. alba, A. marina, and A. officinalis grow in mixed stands and look nearly identical in standard satellite imagery. To solve this, we moved our workflow to Google Earth Engine and tried a different approach. Instead of relying on standard spectral indices (like NDVI), which often fail to separate these species, we integrated "satellite embeddings" into a Random Forest classifier. Essentially, this allowed our model to look at the spatial texture and pattern of the canopy, rather than just the pixel color. The difference in results was immediate. The embedding-based approach cleared up much of the "salt-and-pepper" noise typical of pixel-based maps and successfully separated the three species. We found a clear distributional pattern: Avicennia marina is by far the dominant species, covering vast stretches of the coastline, while A. alba and A. officinalis appear much less frequently and in more restricted pockets. These results suggest that to get accurate Blue Carbon numbers in the complex environment of the Pacific, we need to move beyond basic spectral bands and start utilizing spatial context.

Keywords: Google Earth Engine, Satellite Embeddings, Random Forest, Avicennia, Blue Carbon

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Uncovering Critical Nearshore Habitats: Multi-Platform Monitoring Of Endangered Humpback Dolphins Along The Kerala Coast.

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ABSTRACT

Assessing the abundance and behavioural ecology of coastal marine mammals is fundamental to tracking marine biodiversity and ecosystem health, particularly in human- impacted nearshore environments. The Indian Ocean humpback dolphin (Sousa plumbea), classified as Endangered by the IUCN, persists in shallow-water habitats that overlap with intense fishing, vessel traffic, and coastal development. Despite frequent nearshore sightings along Kerala, scientific data on population structure and behaviour remain scarce. This study uses dedicated Unmanned Aerial Vehicle (UAV) surveys in the nearshore waters of Munambam to quantify local abundance and document detailed behavioural patterns of S. plumbea, providing a high-resolution assessment of how these dolphins interact with a dynamic and human- dominated coastal ecosystem. Across a three-month observation period, repeated UAV flights produced high-quality imagery capturing 45 independent group sightings, with dolphin presence strongly concentrated nearshore of the Munambam bar mouth and tidal channels. A recurrent subpopulation of approximately 13 individuals (11 adults, 2 juveniles) consistently used the Munambam harbour corridor, suggesting strong site fidelity to this narrow, resource-rich yet heavily disturbed zone. Aerial imagery allowed precise identification of behavioural states that are typically missed from vessels, including coordinated travel, resting mills, tactile affiliative interactions, high-energy social displays, and mating behaviour. Foraging and social activities were closely associated with Chinese-net fishing sites, and fisher interviews indicated increased dolphin presence during high tide and squid peaks, highlighting trophic linkages between prey dynamics and artisanal fisheries. Overall, this UAV-based assessment highlights Munambam as a critical-use habitat for S. plumbea and demonstrates the value of aerial platforms for fine-scale ecological monitoring. The findings highlight the importance of nearshore habitat patches as critical-use zones for S. plumbea and underline the need for ecosystem-based management measures such as regulating gear types and safeguarding bar-mouth corridors to sustain marine mammal populations and maintain coastal ecosystem health along the Kerala coast.

Keywords: Behavioural ecology, Sousa plumbea, Coastal ecosystem, Abundance estimation, Habitat Use Dynamics.

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Length–Weight Relationship And Growth Pattern Of The Spineless Cuttlefish (Sepiella Inermis, Orbigny, 1835) From The Southwest Coast, India

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ABSTRACT

Understanding the length–weight relationship (LWR) in short-lived Cephalopods is fundamental for evaluating growth patterns, physiological condition, and population dynamics. This study investigates the LWR of the spineless cuttlefish, Sepiella inermis, a commercially important species that is not only widely consumed along the Indian coast but also contributes to seafood export markets. Specimens collected from the coastal waters of Kerala, India, were analyzed to characterize their growth pattern. Wild individuals displayed a clear negative allometric growth trend, indicating that mantle length increases at a faster rate than body weight. The estimated allometric exponent (b = 2.55) suggests that the species invests more energy in mantle elongation than in mass gain, a characteristic common among cephalopods, as a longer mantle improves hydrodynamic efficiency, enhances swimming performance, and supports predator avoidance during early and intermediate life stages. The strong coefficient of determination ($R^2 = 0.90$) underscores the reliability of the LWR model and its ability to reflect natural variability in growth arising from environmental changes and differences in food availability. Overall, this study provides essential baseline information on the growth biology of S. inermis, offering valuable insight for ecological evaluations and contributing to the sustainable management of this economically significant food and export species in regional fisheries.

Keywords: Cephalopod fisheries, Dorsal mantle length, Negative allometric growth Sepiella inermis, Southwest Coast.

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Age Determination Of The Pharaoh Cuttlefish (Sepia Pharaonis Ehrenberg, 1831) Using Cuttlebone Increments From Indian Coastal Waters

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ABSTRACT

Sepia pharaonis is an ecologically and economically important species inhabiting coastal waters up to 100 m depth across the Indo-Pacific region. It represents a key edible cephalopod species, widely consumed, contributing significantly to export revenues and supporting coastal fisheries. Accurate age determination is essential for understanding population dynamics, growth variability and stock productivity; yet validated ageing information for S. pharaonis from Indian waters remains limited. This study investigates age and growth patterns along the southwest coast of India using cuttlebone increment analysis from both reared and wild individuals. Cuttlebones from wild populations were extracted, cleaned, dried and examined to quantify daily growth increments, and increment periodicity was validated using known-age laboratory-reared hatchlings. Growth relationships between dorsal mantle length (DML), estimated age and increment counts were established using statistical functions in R, and differences between wild and reared specimens were assessed. Reared individuals displayed clear, consistent daily increments confirming a “one day = one ring” deposition pattern, while wild specimens showed greater variability, reflecting environmental and ecological influences. Model comparison showed that a second-order polynomial provided the best statistical fit for the DML–age relationship, effectively capturing the rapid early growth and gradual slowdown characteristic of the species. Variations observed in the wild population are likely driven by natural environmental conditions, including predator pressure, food availability, and fluctuating abiotic factors, all of which influence increment deposition and growth trajectories. The study provides the first integrated comparison of wild and reared S. pharaonis ageing profiles from Indian coastal waters and highlights the applicability of cuttlebone increment analysis for fisheries assessments. Findings contribute baseline information for life-history modelling, recruitment studies and sustainable management of this commercially important species.

Keywords: Age estimation, cuttlebone increment, increment validation, reared and wild populations, Sepia pharaonic

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Cell Line Development And Cryopreservation Of Deep Sea Edible Fishes Of Economic Value

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ABSTRACT

The development of marine fish cell lines plays a pivotal role in understanding immune mechanisms, advancing sustainable aquaculture, and marine biotechnology. This study outlines a comprehensive approach for establishing primary liver cell cultures from economically valuable deep-sea grouper species found along the coast of Goa.
In this project, The primary cells from Liver (hepatocytes) were isolated and characterized from Indian Groupers- Epinephelus sp, found off the coast of Goa, India. Tissue samples (Liver) were collected from fishes under sterile conditions and processed using optimized enzymatic digestion and trypsinization techniques to generate primary cultures. Media formulations were optimized to support cell attachment, proliferation, and maintenance for various tissue types. The resulting cultures were characterized morphologically, immunocytochemically, and through molecular markers to confirm cell identity and functionality.
Cryopreservation protocols were optimized using graded concentrations of dimethyl sulfoxide (DMSO) and fetal bovine serum (FBS) as cryoprotectants. Post-thaw assessments, including trypan blue dye exclusion, MTT assay, and flow cytometric analysis, were used to evaluate cell viability, proliferation, and metabolic activity.
The establishment of these protocols provided a standardized framework for developing stable cell lines from deep sea edible fishes, contributing to sustainable aquaculture practices, enhanced understanding of fish cellular physiology, and long-term conservation of marine genetic resources.

Keywords: Fish cell lines, Grouper, Epinephelus sp, Cryopreservation, deep sea fish, edible fish.

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Towards Sustainable Dolnet Fishery Along The Northwest Coast Of India: Evaluation Of Square Mesh Integration Through Cover Codend Experiments

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ABSTRACT

Dolnet fishery constitutes one of the most dominant marine fishing systems along the northwest coast of India, contributing significantly to regional fish landings and livelihoods. Despite its economic importance, the dolnet fishery faces a major ecological challenge due to the extensive capture of juvenile fishes, particularly of Harpadon nehereus and Coilia dussumieri, which adversely affects the long term sustainability of the stock. Based on this issue, we examined the effectiveness of a modified dolnet fitted with a 40 mm square mesh cover codend for improving size selectivity and reducing juvenile bycatch. Field trials were conducted at Karanja creack, Raigad, India, from April 2024 to March 2025, involving standard experimental hauls using standardized 6 m LOA vessels (20 Hp diesel engine). Comparative analyses between inner (square mesh) and outer (traditional diamond mesh) codends revealed that H. nehereus dominated the catch (63.4% ± 6.4%), followed by C. dussumieri (13.7% ± 9.0%), while juveniles contributed up to 32.4% ± 4.7% of total biomass in traditional codends. The square mesh design demonstrated superior retention efficiency, with a mean selectivity ratio exceeding 2.5 and significant reduction in juvenile retention across all species ($p < 0.05$). Seasonal escape ratio (ER) analysis showed highest escapement during the monsoon (0.47) and lowest post-monsoon (0.39), reflecting hydrodynamic influences on fish behavior. The study concludes that the incorporation of a 40 mm square mesh cover codend enhances catch quality, reduces juvenile bycatch and supports sustainable dolnet operations. Large scale implementation of square mesh modifications, coupled with awareness and regulatory inclusion in coastal management policies, recommended to promote responsible fishing and resource conservation along the northwest coast of India.

Keywords: Catch composition, Juvenile escapement, Square mesh selectivity, Cover codend experiment

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How Climate Variability Shapes Red Bigeye Fisheries Across Taiwan's Coasts - Implications For Adaptive Fisheries Resource Management

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ABSTRACT

In recent decades, fluctuations in fishery catches have increasingly highlighted the role of environmental factors—particularly large-scale climate oscillations—in shaping the dynamics and sustainability of global fish stocks. Numerous studies have revealed strong associations between climate variability and the abundance, distribution, and catch patterns of commercially important species worldwide. The red bigeye (Priacanthus macracanthus), an important demersal species in Taiwanese coastal fisheries, has exhibited pronounced interannual fluctuations in catch during the past decade. This study investigates the relationship between large-scale oceanic climate oscillations and the catch dynamics of red bigeye from 2013 to 2023 across the northeastern and southwestern coasts of Taiwan.
Using bottom trawl fishery data and major climatic indices, including the North Pacific Gyre Oscillation (NPGO), El Niño–Southern Oscillation (ENSO), and Pacific Decadal Oscillation (PDO) and many more, we identified NPGO with a one-year lag (NPGO_1) exerted the most prominent influence on red bigeye catches. Specifically, higher NPGO values were associated with increased catches along both coasts, suggesting enhanced productivity linked to favorable oceanic conditions. Additionally, other climatic oscillations were found to contribute to regional variations in catch trends, as well as the influence on abundance and distribution, reflecting the complex oceanographic interactions surrounding Taiwan. These findings underscore the pivotal role of climate oscillations in shaping the spatiotemporal variability of red bigeye fisheries and emphasize the need for region-specific, adaptive management strategies to ensure sustainable fisheries under future climate uncertainty.

Keywords: Priacanthus macracanthus, Demersal fisheries, NPGO, climate variability, regional oceanography

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Sustainable Fabrication Of Biodegradable Fishing Gears From Polypropylene With Additives For Ghost Fishing Reduction

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ABSTRACT

The widespread use of non-biodegradable synthetic fishing materials like polypropylene (PP) and nylon 66 has created serious environmental issues including marine pollution, ghost fishing and long-term harm to aquatic ecosystems. Lost or abandoned synthetic nets continue to trap fish and other marine life for years, posing a major ecological concern. To address these challenges, the present study focuses on developing biodegradable gill nets and crab traps using polypropylene blended with biodegradable additives, achieved exhibiting a tensile strength of 19.61 ± 0.85 N and an elongation of 57.33 ± 5.77 %, which together promote faster environmental degradation. In this study, gill nets with a 45 mm mesh size designed for mackerel fisheries and crab traps with a 25 mm mesh size were fabricated using polypropylene (PP) yarns treated with biodegradable additive concentrations ranging from 0.25% to 0.75%. These biodegradable additives act as degradation enhancers, enabling the material to break down more quickly under natural conditions while still maintaining sufficient strength during active fishing operations. The fabrication process followed standard extrusion and twine formation techniques to ensure ease of handling and operational efficiency similar to traditional synthetic gear. The developed gear offers a sustainable alternative to conventional nets, reducing ghost fishing and contributing to healthier aquatic environments. Previous studies have demonstrated that the incorporation of biodegradable additives facilitates the gradual mineralization of PP over time. Therefore, the future investigations shall focus on assessing microplastic leaching to estimate the potential release and environmental impact of degradation by-products.

Keywords: Biodegradable fishing gear, Polypropylene blend, Gill net fabrication, Ghost fishing reduction, Sustainable fisheries

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Integrated Assessment Of Heavy Metal Contamination And Ecological Risk In Coastal Sediments And Fishes

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ABSTRACT

Metal pollution in coastal sediments poses a persistent ecological and public health threat due to its toxic, bioaccumulative, and non-biodegradable nature. Extensive global reports on metal pollution underscore the need for comprehensive monitoring and assessment along the Indian coastline. A post-monsoon reconnaissance survey (Dec 2023–Apr 2024) across eight Indian coastal locations—Kolkata, Paradeep, Visakhapatnam, Mangalore, Kerala, Mumbai, Gujarat, and Goa—quantified concentrations of nine toxic metals (Cr, Cu, Cd, Pb, Zn, Ni, Mn, As, Co) in sediments and assessed bioaccumulation in locally sourced fish. Manganese (Mn) showed the highest average sediment concentration, while cadmium (Cd) exhibited the highest geoaccumulation index (Igeo), likely due to low crustal abundance. Sediment quality indices revealed low ecological risk (PERI < 150) in West Bengal, Odisha, and Goa, but moderate to considerable risk (150 ≤ PERI ≤ 300) in Kochi, with isolated moderate-risk stations in Mangalore, Gujarat, and Mumbai Andhra Pradesh . The pollution load index (PLI) indicated baseline contamination (PLI = 1.0) in parts of Kochi and Maharashtra, while enrichment and contamination factors highlighted moderate to significant cadmium (Cd) contamination. Human health risk assessment showed elevated Target Hazard Quotient (THQ > 1) for chromium in several fish species, notably Lepturacanthus savala, Megalaspis cordyla, Sardinella longiceps, Rastrelliger kanagurta, Fenneropenaeus indicus, and Arius arius. The cumulative Hazard Index (HI > 1) across most sites suggests significant non-carcinogenic risk from combined metal exposure.
These findings underscore the importance of integrated risk assessments in evaluating the overall health risks associated with seafood consumption, as well as in monitoring and managing metal pollution risks.

Keywords: Metal pollution, Potential ecological risk index (PERI), Pollution load index (PLI), Targeet Hazard Quotient (THQ), Hazard Index (HI)

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Session Title: Coral reefs in a changing world: Bridging science, policy, and action for climate resilience

Session Convener: Dr Manikandan B

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Benthic Cyanobacterial Mats – As The Driver Of Reef Degradation Through DDAM Positive Feedback Loop In Lagoons Of Kavaratti Atoll, Lakshadweep

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ABSTRACT

Coral reefs are experiencing rapid ecological degradation driven by climate change, eutrophication, and overfishing, lead to DDAM positive feedback loop (DOC, Disease, Algae,microbialization)where copiotrophic, potentially pathogenic bacterial communities proliferate with the support of DOC released by ungrazed algae ultimately harming corals and influencing algal competitive dominance. We have found that among the key biological agents accelerating these transitions are benthic cyanobacteria (*Lyngbia* sp.), the major DOC producers in the lagoons in Kavaratti atoll, Lakshadweep. Insitu experiment on *Lyngbia* sp. for understanding the DOC production rate and composition has shown that DOC production rate is moderate around 103 *µmol*/gm with high abundance (~88%) of low molecular weight compounds (<500 Da).

Our study on Untargeted metabolite identification has found that Beyond direct allelopathic compounds such as Lyngbyabellin, Malyngamide, Tumonoic acid F; ethyl tumonoate A, methyl tumonoate A, Lyngbyapeptin B, Laingolide, Ulongamide C, Konbamide, Kahakamide- A,Yanucamide A,Decarbamoylgonyautoxin1,12βDeoxydecarbamoyloxygonyautoxin-3, Nocuolin A, Hapalocyclamide; having potential cytotoxicity on corals; *Lyngbia* sp. also produces lower aromatic and less Cram(carboxyl rich alicyclic molecules) like compounds which play significant biogeochemical role by contributing to the substantial quantities of labile dissolved organic carbon (DOC) into surrounding waters. Bioavailability of reduced carbon compounds with lower oxidation state provide ample substrate to stimulate heterotrophic bacterial growth resulting shift to microbialization. Thus, cyanobacteria-mediated DOC enrichment and microbialization represent a mechanistic pathway linking coastal nutrient pollution, microbial disturbance, and coral decline. Understanding the molecular and ecological interactions between major DOC producers in coral reef ecosystem, labile DOC dynamics, and associated microbiomes is essential for predicting reef responses to anthropogenic stressors and for designing targeted interventions to mitigate cyanobacterial blooms and preserve coral reef resilience.

Keywords: coral reef, benthic cyaobacteria, DDAM, dissolved organic carbon, microbialization, reef degradation

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In The Andaman Islands, Coral Reef Community Structure And Post-Bleaching Recovery Trajectories Are Influenced By Wave Action.

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ABSTRACT

The 2024 global mass bleaching event impacted coral reefs in the Andaman Islands. The post-bleaching recovery of these reefs largely depends on their benthic community structure, which is influenced by extrinsic drivers such as wave action.

Using a four-year dataset, we examine the coral reef community structure across four sites exposed to wave action and four sheltered sites inside the Mahatma Gandhi Marine National Park, South Andaman. We show that local-scale variation in wave action may underpin divergent post-disturbance recovery trajectories.

Replicate surveys were conducted between 2022 and 2025 using three 30m belt transects per site. Quadrat photographs (1m² every 10m; N=384) were analysed for benthic components, coral morphologies, and colony size classes.

Results indicate a significant influence of exposure to wave action on benthic composition and coral morphology (PERMANOVA: $R^2 = 0.54$, $F = 8.73$, $p = 0.003$). Temporal trends show that following bleaching, dominant coral morphologies and coral recruits recovered differently between exposed and sheltered sites. Overall, exposed sites had higher coral cover, dominated by encrusting and fast-growing *Acropora* morphologies, lower turf algae cover, and a higher number of recruits. In contrast, sheltered sites had lower coral cover, dominated by slow-growing massive *Porites* corals, higher turf algae cover, and fewer recruits.

Exposed reefs, typified by boom-and-bust corals, may be more vulnerable to bleaching but recover rapidly due to high recruitment and space availability. Sheltered reefs, while tolerant, may experience slow, protracted declines due to low recruitment and competition from turf algae. These patterns suggest that reefs across the same island can follow divergent recovery trajectories. Amid increasingly short recovery windows, integrating extrinsic drivers such as wave action into reef management frameworks could support adaptive, context-specific conservation strategies in the Andaman Islands.

Keywords: Coral Reefs, Bleaching, Recovery, Wave Action, Andaman

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A Review On Impacts Of Kappaphycus Alvarezii Mass Cultivation In The Gulf Of Mannar And Palk Bay.

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ABSTRACT

The commercial farming of the red algae *Kappaphycus alvarezii*, which is indigenous to the Philippines, was introduced to India in 1995 for the production of carrageenan. Since 2002, its cultivation has been successfully established along the coasts of the Gulf of Mannar and Palk Bay through the efforts of the CSIR - Central Salt and Marine Chemicals Research Institute (CSMCRI). The farming of *K. alvarezii* has provided a profitable source of income for coastal communities, averaging ₹15,000–₹16,000 per month, and has increased the supply of raw materials for the carrageenan industry (Periyasamy et al., 2014). From 2001 to 2013, production levels varied from 21 to 1,490 dry tonnes, resulting in the creation of 765,000 man-days of employment and an annual turnover of ₹2 billion (Mantri et al., 2016). The large-scale cultivation of *K. alvarezii* has yielded economic benefits; however, it can possess impacts on the surrounding environment and ecosystem. This review aims to analyse both the positive and negative effects of mass cultivation of *K. alvarezii* in the Palk Bay and Gulf of Mannar regions. In their research conducted in 2020, Veeragurunathan et al. reported no adverse impacts from *K. alvarezii* cultivation while surveying native seaweed diversity across 19 islands in the Gulf of Mannar. Abilash et al. (2019) found no significant changes in water quality linked to the long-term cultivation of seaweed. On the other hand, Chandrasekaran et al. (2008) observed that *K. alvarezii* cultivation results in smothering and shading effects on *Acropora* sp. corals. Additionally, Mandal et al. (2010) indicated a limited spread of *K. alvarezii*, accounting for less than 0.0035% of the reef area at Kurasadai Island. Conversely, Arasamuthu et al. (2023) documented coral mortality rates of 6 to 9% at Valai and Thalaiyari Islands, and stated that *K. alvarezii* cultivation could be one of the reason. This study assessed published literature to examine the physico-chemical, chemical, and biological changes by *K. alvarezii* cultivation in the Palk Bay and Gulf of Mannar areas.

Keywords :Kappaphycus alvarezii, Seaweed Cultivation, Gulf of Mannar, Palk Bay, Economic benefits, Coral Reef Ecosystem.

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Session Title: Plankton to fish: linking primary producers to fishery resources

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Demographic Parameters Of Important Live Feed Species, Acartia Bilobata (Abraham, 1970) As A Function Of Salinity And Temperature

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ABSTRACT

Calanoid copepods particularly Acartia with smaller nauplii, shorter generation time, higher fecundity and rich in DHA/EPA, constitute an ideal live feed organisms for mariculture industry. Additionally relatively higher carotenoid content, dependency on microalgal diet, nonpredatory and nonparasitic behaviour make them appropriate diet for growing fish larvae in larvae culture. The marine larviculture industry entails a steadfast and extensive supply of live feed and at weaning to fingerling stage, selected copepod is crucial. Knowing key environmental factors like temperature and salinity is essential for stable and successful culture. This study examined how these factors affect somatic, population growth and life table traits of the euryhaline copepod Acartia bilobata.Experiments were initiated with N1 nauplii cultured on the microalga, Isochrysis galbana and maintained under a 3×3 factorial design combining three temperatures (18°C, 25°C, and 32°C) with three salinities (10,20, and 30 psu) under controlled laboratory conditions. We estimated the key life table parameters, including developmental duration, longevity, age at first reproduction, fecundity, gross and net reproductive rates and generation time at each salinity temperature combination. Results revealed that the effect of temperature, salinity and their interaction were significant on age at first reproduction, and net reproductive rate. Temperature had a more pronounced effect than salinity on most life-history traits. Females reared at 32°C exhibited the fastest post-embryonic development, earliest maturity, highest clutch frequency, and shortest lifespan. However, the organisms realised lower fecundity at the highest salinity level tested. In contrast, individuals maintained at 18°C showed prolonged development, delayed reproduction, and the lowest reproductive rates. Salinity significantly influenced reproductive parameters at 18°C and 25°C, but its effect diminished at 32°C. Mean life expectancy at birth, longevity, and generation time decreased markedly at the highest temperature. Our results indicate the suitable temperature and salinity combination for optimal production of A. bilobaba is 25°C at 20 psu salinity level.

Keywords: Acartia bilobata, mariculture, temperature, salinity, demographic traits

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Estuarine Haven vs. Anthropogenic Pressure: Vertical Stratification and Seasonal Variability of Benthic Diatoms across Intertidal Gradients on India's West Coast

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ABSTRACT

Benthic diatoms are key primary producers in intertidal sandflats, yet their vertical distribution and tidal-height patterns remain poorly understood, particularly in tropical monsoon-dominated systems. This study examined the vertical (0–10 cm) and intertidal (low-, mid-, and high-tide) distribution of benthic diatoms at two adjacent beaches along India's west coast with contrasting hydrodynamic and anthropogenic settings: (i) Dias Beach (sheltered, Zuari estuary mouth; very fine sand to silt/clay; low disturbance), and (ii) Miramar Beach (exposed, Mandovi estuary mouth; fine to very fine sand; intense recreational use). Monthly replicate sediment cores (n=3) were collected during the lowest low tides from June 2023 to December 2024. Mean benthic diatom abundance was ~1.9× higher at Dias (329.7 cells g^{-1}) than at Miramar (173.7 cells g^{-1}). Surface layers (0–2 cm) dominated at both sites but were ~2× higher at Dias (691.7 cells g^{-1}) than at Miramar (335.7 cells g^{-1}). Vertical attenuation was steeper at Dias (surface: bottom = 10.8×) than at Miramar (7.4×). Seasonal variability was more pronounced at Dias, with maximum abundance during the pre-monsoon (564.3 cells g^{-1}) and marked declines during the monsoon (238.4 cells g^{-1}) and post-monsoon (303.8 cells g^{-1}) periods. Differences among tidal heights were weaker compared to between-site and vertical contrasts. Thalassiosira sp. and Navicula sp. occurred across a range of depths (up to 35 cm) and seasons, reflecting their tolerance to salinity fluctuations and physical disturbance. Bellerochea and Lithodesmium sp. were restricted to Dias, suggesting habitat specificity or local endemism, while Melosira sp. was more abundant in subsurface (2–5 cm) layers, indicating potential resting stages or shade-adapted persistence. Overall, the results highlight a strong contrast between "estuarine haven" and "anthropogenic pressure" over kilometre scales, with higher surface biomass at Dias indicating greater sediment stabilisation and trophic support potential compared to the disturbed, homogenised assemblages at Miramar.

Keywords: Benthic diatoms; Intertidal flats; Monsoon; Vertical distribution; Anthropogenic disturbance; West coast of India

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Oxygen Minimum Zones As Hotspots Of Zooplankton Ecological Reorganization: Insights From The Andaman Seamounts

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ABSTRACT

Seamounts within the Indian EEZ serve as biodiversity hotspots, fostering unique pelagic and benthic communities by enhancing vertical mixing, nutrient upwelling, and habitat heterogeneity across depth gradients. The Andaman Basin, in the northeastern Indian Ocean, features one of the strongest Oxygen Minimum Zones (OMZs) in tropical waters, shaping midwater ecosystem structure around its seamounts. To evaluate the influence of hypoxia on zooplankton vertical distribution, samples were collected from nine Andaman Seamounts during the FORV Sagar Sampada cruise (December 2024) using Multiple Plankton Net stratified hauls (0–200, 200–500,>500 m), along with CTD-based profiles of temperature, salinity, and dissolved oxygen. Hydrographic data revealed a sharp thermohaline gradient (100–300 m) and an OMZ core (0.4– 1.5 ml l^{-1}) extending from ~200 to 900 m. Within this layer, oxygen depletion compressed zooplankton habitats and triggered clear community reorganization. Zooplankton abundance exhibited a marked decline with increasing depth, while dominance patterns intensified, suggesting strong ecological filtering under hypoxic conditions. Peak abundance was recorded in the epipelagic zone (0–200 m), primarily composed of calanoid (Candacia, Temora sp.) and cyclopoid copepods (Oithona, Oncaea sp.). In the upper mesopelagic layer (200–500 m), abundance dropped sharply, coinciding with the onset of the oxygen minimum zone (OMZ), which appeared to inhibit diel vertical migration. Taxa inhabiting this zone (Corycaeus, Farranula sp.) were characterized by smaller body sizes and reduced pigmentation—traits likely adaptive to low-oxygen stress and limited mobility. The deepest layer (>500 m) showed the lowest abundance, with assemblages dominated by foraminifera and larval stages of bivalves and gastropods, indicating a shift toward taxa tolerant of extreme environmental conditions.The coincidence of OMZ intensity with maximum community turnover demonstrates that oxygen availability is the primary structuring force in the Andaman Seamount ecosystem. Hypoxia acts as an ecological selector, reducing richness yet promoting dominance of tolerant and opportunistic forms that sustain mid-water trophic fluxes. These results identify the Andaman OMZ as a natural observatory for studying deoxygenation-driven reorganization of zooplankton communities, offering a baseline for predicting ecosystem responses to expanding OMZs under future ocean-warming scenarios.

Keywords: Oxygen Minimum Zone, Seamount Ecosystem, Andaman Sea, Community Reorganization, Zooplankton Communities

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Copepod Size Spectra In Marine Ecosystems: A Review Of Patterns, Drivers, And Research Gaps

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ABSTRACT

Zooplankton size is a key ecological trait shaping trophic interactions, energy transfer, and nutrient cycling in marine and estuarine systems. However, size-based studies remain limited, especially for copepods, the dominant mesozooplankton group. This review synthesizes current knowledge on how copepod size spectra respond to hydrographic forcing across depths, seasons, and developmental stages, and outlines priorities for future research. Advances in microscopy and imaging now enable consistent characterization of size distributions, revealing depth gradients in which smaller copepods (<2 mm) dominate shallow waters (≤150 m), while larger prevail at greater depths. In the southeastern Arabian Sea, warm, stratified pre-monsoon waters with low chlorophyll-a support larger copepods (avg. 718 ± 169 × 10^5 µm³ ind^{-1}), whereas cooler, nutrient-rich southwest monsoon waters with upwelling-driven blooms favour smaller forms. In the Bay of Bengal, deep chlorophyll maxima (~40 m) during pre-eddy phases support smaller copepods, whereas shoaling in cold-core eddies enhances food availability, larger copepod abundance, and fish catches. Warm-core eddies instead suppress nutrient supply and productivity. At smaller spatial scales, estuaries are dominated by small omnivorous copepods, with their contribution declining toward coastal and oceanic waters. Ontogeny further structures size spectra, with body size increasing from 0.5–3.4 mm across naupliar to copepodite stages. Although copepod size is shaped by hydrography, biogeography, and development, limited long- term datasets and poor understanding of developmental responses to environmental change constrain predictive capacity. Targeted long-term and size-resolved observations are needed to refine future assessments.

Keywords: Copepod size spectra, hydrographic-biological coupling, ontogenetic scaling, Arabian sea, Bay of Bengal

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Dynamics Of Microzooplankton Community In The Tropical Estuaries Of The Southwest Coast Of India

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ABSTRACT

The present study investigates the spatio-temporal variability of microzooplankton (MZP) community composition and numerical abundance in two major estuarine systems of Kerala, Ashtamudi Estuary (AE) and Cochin Estuary (CE), located along the southwest coast of India. Microzooplankton, comprising heterotrophic and mixotrophic planktonic organisms (20– 200 µm), include protozoans (ciliates, heterotrophic dinoflagellates, and foraminifera) and metazoans (crustacean larvae and rotifers). Functioning as crucial intermediaries in marine food webs, MZP consume a broad spectrum of autotrophic prey ranging from cyanobacteria to chain- forming diatoms, exhibit growth rates comparable to those of their prey, and facilitate the efficient transfer of organic biomass to higher trophic levels. Field observations were conducted during the pre-monsoon (PrM, April 2018) and post-monsoon (PM, November 2018) seasons across seven stations in each estuary, selected based on salinity gradients from coastal waters to riverine sections. The physico-chemical parameters revealed pronounced spatial and seasonal variability, with the pre-monsoon period characterized by warmer waters and elevated salinity in both estuaries. CE consistently exhibited 2-3 times higher phytoplankton biomass (chlorophyll *a*) than AE irrespective of season. Correspondingly, MZP abundance was also higher in CE (4,929 ind. L^{-1}) than in AE (2,886 ind. L^{-1}) during the PrM period. Distinct differences in MZP community composition were observed between the estuaries. Protozoans (ciliates and heterotrophic dinoflagellates) dominated (>81%) the MZP community in CE during both seasons, whereas metazoans (crustacean larvae and rotifers) comprised the majority (>80%) in AE irrespective of season. These contrasting patterns reflect the strong influence of hydrological gradients shaped by seasonal freshwater discharge (PM) and seawater intrusion (PrM), which in turn support unique estuarine planktonic assemblages. As the first comparative assessment of MZP communities from these tropical estuaries, particularly the relatively unexplored Ashtamudi Estuary, this study provides essential baseline information on MZP dynamics along the southwest coast of India.

Keywords: Microzooplankton, Cochin Estuary, Ashtamudi Estuary, Protozons, Metazoans

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A Comprehensive Review Of Mesozooplankton In The Oxygen Minimum Zone: Biomass And Size Structure In The Arabian Sea

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ABSTRACT

Oxygen Minimum Zones (OMZs) are midwater layers (200-1000 m) characterized by severely reduced oxygen concentrations that constrain marine biodiversity, biogeochemical cycling, and ecosystem functioning. The Arabian Sea contains one of the thickest and intense OMZs globally, with oxygen levels reported below 0.1 ml l^{-1}. Copepods, the dominant component of the mesozooplankton community, exhibit diverse ecological, behavioural, and physiological strategies that enable persistence within these extreme low-oxygen waters. This review synthesises current understanding of mesozooplankton distribution across the northern (>15°N) and southern (<15°N) Arabian Sea, with emphasis on their role in organic-matter transport to the deep sea and in sustaining regional food webs. It also examines the physiological adaptations of zooplankton to different oxygen levels. Seasonal physical forcing produces marked north-south contrasts in primary productivity and zooplankton biomass. In the northern Arabian Sea, wind- driven and convective mixing enhance primary productivity and supports elevated mesozooplankton production, whereas the stratified southern basin remains comparatively oligotrophic. These regional differences strengthen carbon export and oxygen consumption in the north, supporting a thick, persistent OMZ, while weaker in the south. OMZ conditions substantially alter the vertical distribution and size structure of mesozooplankton, particularly copepods. Size spectra become compressed within the OMZ, with reduced abundance of large- bodied taxa and dominance of small to mid-sized forms (e.g., Oncaea sp., Oithona sp., Corycaeus sp.), whereas well-oxygenated layers support larger calanoid genera such as Calanus sp., Metridia sp., and Pleuromamma sp. Despite persistent OMZ, seasonal variability in zooplankton biomass, size structure, and metabolic adaptations across oxygen gradients remains insufficiently resolved. This review identifies key ecological drivers shaping mesozooplankton communities and highlights critical gaps for future research.

Keywords: Mesozooplankton, oxygen minimum zones, Arabian sea, upwelling, winter convection

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Ecological Responses Of Diatoms To The Seasonal Hydrographical Changes In The Central- And South-Eastern Arabian Sea

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ABSTRACT

Among the phytoplankton, diatoms play a vital role in marine food webs and biogeochemical processes. The seasonal hydrographical variations strongly influence their abundance, size and composition in coastal waters, yet these dynamics remain poorly studied in the eastern Arabian Sea. This study was conducted along the central (off Goa) and south (off Kochi) eastern Arabian Sea (coastal) to understand the occurrence and dominance of diatom communities during the southwest (SWM-2022), northeast (NEM-2022) and spring inter-monsoon (SIM-2023). The cooler, nutrient-rich, and oxygen-depleted waters with low photosynthetically active radiation during the SWM supported the highest concentrations of chlorophyll-a and abundant diatom populations both off Goa (avg. 3885 ± 4769 ind./L) and Kochi (avg. 17924 ± 15935 ind./L). Among the diatom communities, centric forms (e.g., *Chaetoceros* spp., *Thalassiosira* spp., *Rhizosolenia* spp.) were dominant during the nutrient-depleted NEM and SIM, whereas pennate forms (e.g. *Nitzschia* spp., *Navicula* spp., *Fragilaria* spp.) dominated during the nutrient-rich SWM, particularly in the deeper (≤50 m) and offshore waters (~10-35 km) influenced by coastal upwelling. This suggests that pennate diatoms effectively utilize upwelled nutrients under low PAR and oxygen-depleted conditions during the SWM, contributing the highest biovolume to the total diatom biomass. Fragilariopsis spp., one of the dominant large pennate diatoms, is frequently reported along the southwest coast of India during the SWM and is known to attract sardine fish populations. These findings demonstrate the key role of monsoon-driven upwelling in shaping diatom community dynamics and biovolume, particularly the dominance of pennate forms that contribute substantially to coastal primary production and fishery resources in the eastern Arabian Sea.

Keywords: Phytoplankton; diatom community; coastal upwelling; Pennate diatoms; Arabian Sea

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Analysis Of Biochemical Contents Of Some Commercially Important Bivalve Molluscs From Bhatye Estuary, Ratnagiri Coast Of Maharashtra, India

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ABSTRACT

Bivalve molluscs are having commercial value so they are economically significant. Various varieties of shellfishes such as oysters, clam and mussels are widely dispersed along the coast of Maharashtra, specifically in the coastal regions of Ratnagiri district. The bivalves include shell fishes like oysters, mussels and clams which are helping to achieve the nutritional requirements of the people living near the coastal habitat. They are principled and plentiful source of proteins, minerals and carbohydrates. They are simply digestible compared to other dietary compounds isolated from animal sources. In this study we analysed biochemical contents of some commercially important bivalve molluscs, we found highest protein percentage in *Paphia malabarica*, highest lipid percentage in *Meretrix meretrix* highest Carbohydrate percentage was found in *Paphia malabarica*. bivalve molluscs species present in this region are good source of proteins, lipids and carbohydrates, so we recommend all the four species included in this study *Meretrix meretrix* (Linnaeus, 1758), *Paphia textile* (Gmelin, 1791), *Paphia malabarica* (Dillwyn, 1817) and *Perna viridis* (Linnaeus, 1758) as a good alternative food source for coastal as well as general public consumption.

Keywords: Bivalve molluscs, shellfishes, commercial value, digestible, consumption

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Hydrographic Controls on Mesozooplankton Community Structure During the Fall Intermonsoon in the Bay of Bengal

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ABSTRACT

The present study emphasizes the significant impact of hydrography—subsurface eddies, distinct vertical and horizontal salinity gradients, and oxygen distribution—on spatial patterns in mesozooplankton assemblages in the Bay of Bengal (BOB) during the fall intermonsoon of 2019. The impact of subsurface warm-core (18°N, 89°E) and cold-core eddies (17°N, 83°E) on the mesozooplankton assemblage is evident in both Central Bay (CB) and Western Bay (WB) transects. Extensive field sampling showed that over 90% of mesozooplankton biomass and abundance were confined to the upper 200 m of the water column, i.e. above the thermocline. There was a clear vertical separation in feeding habits with respect to the depth, with herbivores dominating above the thermocline and carnivores dominating below the thermocline. Copepods dominated the assemblage, constituting about 90% of total abundance; with 79 species from 27 families, including several new taxa like Copilia hendorfii, C. quadrata, and Sapphirina intestinata recorded from BoB. The common copepods dominant species were Acrocalanus sp., Paracalanus sp., Temora turbinata, and Pleuromamma indica. The presence of species like T. turbinata, P. indica, and Distioculus sp. acted as biological markers of upwelling regions, oxygen minimum layers, and oceanic influence, respectively. Regional differences in community composition were also apparent, with coastal stations influenced by riverine input supporting higher phytoplankton biomass and herbivore densities, while offshore eddy-rich zones were marked by greater copepod abundance and predatory taxa. The findings emphasize the interaction between mesoscale hydrographic features and mesozooplankton community structure, underscoring the importance of integrated ecosystem approaches for effective management and conservation in the Bay of Bengal.

Keywords: Mesozooplankton, Hydrography, Copepoda, Subsurface eddies, Bay of Bengal

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2. **Building coastal resilience to cyclones, tsunamis, sea level rise, erosion, marine heatwaves, and seawater intrusion in India**

3. **Changing coastlines due to natural and anthropogenic influences**

4. **Enhancing Coastal Risk Resilience: Integrating Science, Nature, and Innovation for Safer Shores**

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Session Title: Advancing Marine Heatwave Science: Mechanisms, Impacts, Interactions, And Societal Consequences

Session Convener: Dr Saurabh Rathore

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2.	Biogeochemical Impacts Of The Record-Breaking 2023-24 Indian Ocean Marine Heat Wave
3.	Changing Baseline And Future Marine Heatwaves
4.	Short Term Forecasting Of Marine Heat Waves Using Machine Learning Based Algorithm
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Vertical Structure of Marine Heatwaves in the North Indian Ocean

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ABSTRACT

Oceans are vital regulators of global climate and biodiversity, yet increasing anthropogenic pressures have intensified warming and triggered extreme events such as marine heatwaves (MHWs). The North Indian Ocean, recognized as one of the fastest-warming tropical basins, remains comparatively understudied despite its vulnerability. This study examines the spatiotemporal evolution, frequency, and intensity of MHWs from 1993–2024 using NOAA OISST data, with emphasis on the Arabian Sea and Bay of Bengal. Results reveal a significant rise in both intensity and occurrence of extreme warming events, reflecting distinct basin-specific thermal responses. Further assessment of vertical thermal structures using GLORYS12V2 reanalysis shows that MHW warming is not restricted to the surface; many events extend deep into subsurface layers. Three MHW types are identified: mixed-layer, deep, and full-depth events with surface signatures, as well as submerged and benthic types lacking surface expression. Subsurface MHWs are found to be more frequent and often longer-lasting, with stronger intensities compared to surface events. Several heatwaves originate at the surface and propagate downward, while others emerge within deeper layers and later influence surface waters. These contrasting developmental modes underscore the complex physical drivers shaping MHW evolution. Findings highlight the urgent need for expanded subsurface observations and sustained monitoring to improve prediction and support adaptive management for rapidly warming regions of the North Indian Ocean.

Keywords: Marine heatwaves, North Indian Ocean, subsurface warming, vertical structure,
MHW propagation

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Biogeochemical Impacts Of The Record-Breaking 2023-24 Indian Ocean Marine Heat Wave

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ABSTRACT

The year 2023-24 was the warmest on record, driven by anthropogenic climate change. This resulted in unprecedented ocean warming and widespread marine heat waves (MHWs) over the oceans. The North Indian Ocean (NIO) also experienced one such record-breaking MHW event during this period. However, studies on this event remain limited, with the only existing work focusing primarily on its physical drivers. The current study examined this event, which is the most prolonged and intense MHW in the NIO in the last 44 years, and attempted to investigate the associated biogeochemical changes. This severe category MHW event occurred in the western Arabian Sea, evolving at a rate of 0.0045 °C/day and lasted 290 days (12 August 2023 to 27 May 2024). The event reached a maximum intensity of 1.43 °C, and dissipated at a rate of 0.007 °C/day. Significant declines in the biogeochemical parameters, such as Chlorophyll-a, Net Primary Productivity, Nitrate, and Dissolved Oxygen, were observed, with deviations of -0.084 mg/m^3, -5.16 mg/m^3/day, -0.185 mmol/m^3, and -3.25 mmol/m^3 from the respective climatological values. A decrease in climatological wind speeds by 1.3 m/s and shoaling of the mixed layer depth by up to 6.8 m compared to the climatology were also observed, coinciding with the event. The reduced vertical ocean mixing and enhanced surface stratification owing to decreased wind speeds could have contributed to elevated sea surface temperatures (SSTs), resulting in enhanced stratification and hence limiting the surface biogeochemical parameters during the MHW. The study highlights the implications of a severe category MHW event in altering the marine biogeochemistry of the Arabian Sea.

Keywords: Marine Heat Wave, Ocean Biogeochemistry, North Indian Ocean, Arabian Sea

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Changing Baseline and Future Marine Heatwaves

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ABSTRACT

The tropical Indian Ocean (TIO) has emerged as a major global warming hotspot and recently experienced a near-permanent marine heatwave (MHW) state during 2023–2024, raising major challenges about ecosystem resilience and climate feedbacks. This study investigates the characteristics of MHWs in the TIO during 1982–2100 using observations and CMIP historical and SSP5-8.5 simulations. Based on present-day MHW intensity distributions, five hotspot regions were identified, among which the Arabian Sea, western equatorial, and southwestern Indian Ocean show the strongest intensification and highest mean values of MHW intensity, duration, and frequency. The CMIP6 models were evaluated and ranked based on grid-scale bias and interannual variability skill of key MHW statistics, using a multi-criteria decision-making framework to identify a skilful subset of models for future projections. To address the saturation of MHW metrics associated with the elevated baseline, shifting-baseline approach was adopted to identify future MHW events more robustly. Future projections indicate 0.8–1 °C increase in mean MHW intensity in the Arabian Sea and substantial rise in MHW frequency in the Bay of Bengal by the mid to late 21st century. The western equatorial and southern Indian Ocean regions are also projected to experience more frequent extreme MHW events. These findings highlight the increasing oceanic heat stress and potential ecological implications in the TIO, underscoring the importance of bias corrected and baseline- adjusted frameworks for assessments of future ocean heat extremes.

Keywords: tropical Indian Ocean, Marine heatwave, CMIP6, SSP5-8.5, Arabian Sea

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Short Term Forecasting Of Marine Heat Waves Using Machine Learning Based Algorithm

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ABSTRACT

Marine heatwaves (MHWs) are prolonged periods of abnormally high sea surface temperature. MHWs can have significant ecological and climatic impacts, such as influencing coral bleaching, fisheries, and regional weather patterns. This study investigates the detection and short-term forecasting of MHWs using deep learning algorithms. ERA5 reanalysis data over Arabian Sea was used to train the machine learning model. Sea surface temperature (SST) anomalies were computed following the Hobday et al. (2016) definition, using a 90th percentile threshold based on a multi-year climatology. Auxiliary variables including 2 m air temperature, surface wind components, and mean sea-level pressure were integrated to provide atmospheric context. A convolutional-recurrent neural network was trained to forecast 5 day sequences of MHW occurrences from the preceding 5 days of ocean-atmosphere fields. The model effectively captures spatial evolution and persistence of MHWs, demonstrating potential for operational forecasting in coastal and open-ocean regions. The approach highlights the usefulness of AI- driven methods in marine climate monitoring and early warning systems.

Keywords: Marine Heat Wave, Machine Learning, Convolutional Neural Networks, Recurrent Neural Networks, Short-Term Forecasting

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Assesment of WRF Model in Simulating Heat Wave Events over India: A Comparative Case Study

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ABSTRACT

There is a challenge to understand how severe heatwaves in the Indian continent are growing and affecting the global climate. The North West (NW) and South East (SE) parts of India experience high temperatures and extreme Heat waves (HW) during summer. In this paper, the episodic HW events of 2015 and 2016 over Indian regions have been simulated using Weather Research and Forecasting (WRF) model. Simulations are carried out over three sub-domains of Indian region with varied horizontal resolutions of 27km (d01), 9km (d02) and 9km (d03). Six experiments (Exp1- Exp6) with different combination of physical parameterization schemes were performed using WRF model. The model results indicate an overestimation of Tmax by +1°C to +2°C. This suggests that the regional temperature is influenced by the location and the complex orography. Overall, the statistical analysis (correlation, RMSE, FB) results reveal that best performance is achieved with Exp2 which is the combination of WSM6 microphysics (MP) together with radiation parameterization CAM, Yonsei (PBL), NOAH land surface and Grell- 3D convective schemes. Moreover, to understand the dynamics of rising HW intensity, two case studies of HW days i.e. (22nd-30th May, 2015) and (14th-23rd May 2016) along with influencing parameters like Tmax, RH and prevailing wind distribution have been analysed over India. Model simulated multiday Tmax during 2015 HW event reaches up to 44°C in NW and SE part of India which reveal that it is the combination of the both temperature and RH that created a rare and deadly event during 2015. Strong El Nino effects, anthropogenic climate change, etc. might be possible causes of the temperature rise on those days. Also, those high temperature days have unusual atmospheric conditions with strong warm, gusty dry winds blowing over the NW region of India. In 2016, HW is more prevailing towards NW while in SE region temperature range around 34-38°C but high RH (60%-85%) is likely one of the dominating factor giving rise to HW phenomena. The comparative research made it abundantly evident that these episodic events were unique in terms of duration, intensity and geographical spread

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which can be used to assess WRF performance and extreme HW events for future projections and to comprehend the scenario of extreme weather occurrences.

Keywords: WRF, Extreme temperature, Heat Wave, Relative Humidity, regional model

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Sea Surface Temperature Rise and Marine Heatwave Intensification Over Coral Reefs in the Indian Ocean

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ABSTRACT

Coral reefs are among the most diverse yet vulnerable ecosystems, increasingly threatened by ocean warming and prolonged thermal stress. This study focuses on the Lakshadweep Islands and the Andaman & Nicobar Islands in the North Indian Ocean—two vital but understudied coral reef regions. Using three complementary sea surface temperature (SST) datasets—HadISST (reconstructed), ERA5 (reanalysis), and OISST (satellite observations)—we examined long-term SST variability and marine heatwave (MHW) trends to assess regional ocean warming.Results show that HadISST and ERA5 exhibit slower warming while OISST reveal progressively higher SST rises, in the range of 0.13ºC to 0.22ºC/decade across the datasets and varying across all locations. Our analysis also reveals that the Andaman & Nicobar Islands show an increase of 36.99 (ERA5) and 53.61 (OISST) MHW days per decade, closely followed by Lakshadweep with 35.94 (ERA5) and 50.37 (OISST).During 2015–2024, both reef systems experienced over 200 MHW days annually, indicating near year-round thermal stress. The accelerating rise in SST and MHW frequency highlights that these coral ecosystems are approaching survival thresholds, posing severe risks to biodiversity, reef resilience, and dependent coastal livelihoods

Keywords: Marine Heatwaves, Coral reefs, Thermal stress, Semi-permanent MHW, north Indian Ocean

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Impact Of Marine Heatwaves On The Primary Productivity Across Climate Sensitive Regions Of The Tropical Indian Ocean

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ABSTRACT

Marine heatwaves (MHWs) are prolonged periods of anomalous high sea surface temperatures (SSTs) that exceed the thresholds of seasonal climatology of a region. Globally, MHWs occur due to long-term ocean warming, weakened wind-driven mixing, reduced vertical heat transport causing ocean stratification . In the Indian Ocean, these events are also influenced by large-scale climatic phenomena such as the Indian Ocean Dipole (IOD), Madden-Julian Oscillation (MJO), El Niño–Southern Oscillation (ENSO), and the Indian Monsoon, which modify wind patterns, ocean circulation, and ocean heat fluxes. The basin's rapid warming enhances the MHW events by increasing heat retention and reducing horizontal heat exchange from the land-locked northern Indian Ocean to the surrounding open-ocean regions. These extreme warming events have significant biological consequences, as high SSTs can enhance stratification and decrease nutrient availability in the tropical region, which can disrupt the metabolic functioning and distribution of marine organisms. As a result, it leads to widespread biological damage like mass mortality events, coral bleaching, and the loss of habitats.This study examines the influence of MHWs on chlorophyll-a concentration, used as a proxy for primary productivity, across multiple climate sensitive regions of the Northern and Southern Bay of Bengal and Arabian Sea, Southwest Indian Ocean, South Java Coast and Somalia Coast. Using daily SST and chlorophyll-a datasets from 1998 to 2022, the study analyzes regional MHW intensity, duration, and frequency, and evaluates chlorophyll anomalies before, during, and after prolonged and the extreme MHW events. The study also highlights seasonal alterations in phytoplankton blooms in several regions. By examining the MHW characteristics, long-term SST variability, and the changes in chlorophyll-a concentration, this study evaluates the impact of extreme warming events on primary productivity across the tropical Indian Ocean.

Keywords: Primary Productivity Anomalies, Ocean Warming Effects, Climate Change

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Coastal Upwelling Zones Responses To Recent Extreme Warming Events Of The Arabian Sea

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ABSTRACT

Anomalous ocean warming driven by climate change has resulted in significant increases in both sea surface temperature (SST) and subsurface ocean temperatures. The rate of anomalous surface and subsurface warming is rising most rapidly in the Indian Ocean compared with other major basins such as the Atlantic, Pacific, and Arctic Oceans. The presence of an anomalously warm upper-ocean water column is a growing concern, with profound implications for primary producers and the broader marine ecosystem.Upwelling, an oceanic process in which cool, nutrient-rich subsurface water rises to the surface, enhances regional biological productivity during June to September (the Indian summer monsoon season) in the Indian Ocean. This study focuses on three prominent coastal upwelling zones in the Arabian Sea. Chlorophyll-a (chl-a) concentration—used as a proxy for phytoplankton biomass and an indicator of ecosystem health—responds sensitively to changes in ocean temperature.In this investigation, satellite-merged and reanalysis datasets are used to examine and compare chlorophyll-a variability in these upwelling regions of the Indian Ocean over a 27-year period (1998–2024) under the influence of ongoing ocean warming.Interannual time-series analyses of anomalous SST and chl-a reveal a significant increase in warming across all zones, accompanied by a corresponding anomalous decline in chlorophyll-a during the study period.During major warming events—specifically 2015–2016, 2019–2020, and 2023–2024—the anomalous SST increase is associated with varying responses in chlorophyll-a concentration and Ekman transport during JJAS across the three upwelling zones. The 2019–2020 warming event is characterized by more intense and spatially consistent negative chl-a anomalies, in contrast to the more asymmetric chl-a response observed during the 2015–2016 event. These uncertainties and inconsistent ecosystem responses across warming events appear to be linked to the differential roles and interactions of natural climate variability modes, including the El Niño– Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), and the Indian Ocean Basin Mode (IOBM).

Keywords: ENSO, Marine Heatwaves, Upwelling, Chlorophyll

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Analysis Of Record Low & High Sla Events: Links To Marine Heatwaves Over Central Indian Ocean Basin

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ABSTRACT

This study examines the occurrence and drivers of record low and high Sea Level Anomaly (SLA) events in the Central Indian Ocean Basin (CIOB). Using SLA data anomalies spanning 1993–2024, 2011 is identified as the year exhibiting the strongest negative SLA anomaly over the CIOB, while 2024 showed the most pronounced positive SLA anomaly during December to February. The contrasting ocean states represented by these anomalous events provide a valuable framework to investigate the underlying physical mechanisms. Both anomalous SLA episodes exhibit strong connections to basin-scale climate mode, El-Niño and Southern Oscillation (ENSO) as both events has occurred during peak phase of ENSO. ENSO has emerged as a dominant forcing mechanism modulating regional wind stress patterns and thermocline variability. The record low episode of SLA was a La-Niña where as the record high episode of SLA was a El-Niño. The 2024 El Niño, in particular, appears to have played a critical role in amplifying downwelling conditions and intensifying heat build-up in the CIOB. These warm anomalies created a favourable background state for the onset and persistence of marine heatwaves, reflecting the sensitivity of CIOB thermal structure to remote equatorial Pacific forcing.Our findings highlight the importance of understanding SLA extremes as indicators of dynamic ocean processes that regulate heat storage, vertical mixing, and ecological stress in the CIOB. By elucidating the coupled impacts of wind stress curl, Rossby wave dynamics, and El Niño forcing, this study provides new insights into the mechanisms that significantly impact the sea level anomalies of CIOB region. The increasing stress of marine heatwaves in a rapidly warming Indian Ocean is also found to be significantly contributing to the record high SLA event. Such knowledge is essential for improving predictions of extreme thermal events and assessing their potential consequences for marine ecosystems in this vulnerable region.

Keywords: Sea Level Anomaly, El-Niño, Sea Surface Temperature, Marine Heat Wave, Rossby wave

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Session Convener: Dr Sudheer Joseph

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Assessing Coastal Erosion–Accretion Dynamics and Morphodynamic States along the Visakhapatnam Coast through Beach Profile Studies (2023–2024)

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ABSTRACT

The Visakhapatnam coastline has been undergoing persistent erosion and seasonal morphological reshaping driven by monsoonal waves, shifting sediment budgets, storm events, and human influences. Understanding these drivers is critical, as erosion threatens coastal communities, recreation, and sustainable tourism. This study examines beach profile dynamics across four representative sectors Rushikonda in the north, Ramakrishna (RK) in the centre, and South and North Yarada in the south, using fortnightly field profiles collected between April 2023 and August 2024 along with littoral observations. Beach morphodynamic states derived from the Dean number (Ω), together with high-resolution satellite imagery, were used to validate the identified morphological signatures. RK Beach shows clear seasonal variability with berm building during the pre-monsoon and summer and pronounced erosion across 50–70 m during the monsoon. The upper 0–20 m remains stable, and profiles converge near a reduced level of 2–3 m at a closure depth of 80–100 m. Rushikonda exhibits a similar pattern with stability over 0–10 m and a dynamic 20–50 m zone shaped by monsoon erosion and pre-monsoon accretion. South Yarada is the most active sector, stable over 0–18 m but highly variable between 30 and 70 m due to strong monsoonal erosion and post-monsoon lowering, with profile convergence near a reduced level of about 2 m beyond 90 m and consistent pre-monsoon recovery. North Yarada has a gentler slope with stability from 0 to 20 m and seasonal changes across 30–60 m, and closure occurs around 64–70 m where reduced levels stabilise near 3 m. Morphodynamic state analysis shows South Yarada as the most dynamic, followed by RK Beach, North Yarada, and the more balanced Rushikonda, with conditions ranging across reflective, intermediate, and dissipative states, as validated by high-resolution satellite imagery. Erosional hotspots along these beaches are driven by monsoonal wave energy, reduced sediment supply, nearshore circulation cells, headland control, cyclone impacts, and human interventions, including altered longshore transport near Visakhapatnam and Gangavaram ports, with critical erosion mainly during the monsoon, heightened by cyclones, and extending into the early post-monsoon. These hotspots have resulted in beach narrowing, dune loss, and recurrent damage to coastal infrastructure. The findings emphasise the need for sustained monitoring, sediment budget assessments, and targeted actions such as dune restoration, controlled nourishment, backshore stabilisation, and strengthening of natural buffers to support sustainable coastal management along this high-energy littoral environment.

Keywords: Erosional hotspots, beach profile analysis, beach morphodynamic states, coastal zone management, Visakhapatnam.

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Sequencing of tsunami waves through the prism of the forerunners – an analytical approach.

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ABSTRACT

Wave sequencing within tsunami trains remains a persistent problem in long-wave hydrodynamics, bearing significant implications for hazard prediction and coastal risk assessment. Observations and theoretical developments increasingly demonstrate that the first tsunami wave to arrive at the shore is not necessarily the most destructive. Murty et al. (2006) noted that the third to fifth waves often exhibit the highest amplitudes, although this trend is not universally consistent. Studies by Okal and Synolakis (2016) attribute this phenomenon to frequency dispersion, which causes long-wavelength, low-amplitude components to arrive earlier than shorter, higher-amplitude waves. Consequently, while the largest wave may occur near the source in the near field, far-field regions often experience delayed arrival of the most energetic crest. This evolution is governed by complex interactions involving the source characteristics, bathymetry, water depth, and coastline geometry.

The hydrodynamics controlling such processes remain intricate. Although the propagation of long waves under one-dimensional and two-dimensional nonlinear shallow-water (SW) conditions is well established, uncertainties persist due to coupling between seabed deformation and free-surface dynamics (Synolakis & Bernard, 2006). The classical hodograph transform fails to provide analytical solutions for SW waves in oceans with variable bathymetry. Grimshaw and Yuan (2016) further showed that even minor initial sea-surface disturbances—such as a depression followed by an elevation—can intensify the leading wave, producing amplitudes far exceeding those of simple perturbations.

Here, in our study, non-linear bathymetric effects are incorporated in the generation of SW waves. The analytical solution derived by us allows for the separation of small-amplitude forerunner waves, revealing that the larger, more destructive waves reach the coast after the forerunners' instantaneous arrival. These insights offer a qualitative framework for understanding tsunami wave sequencing and may improve early-warning protocols by signalling the potential arrival of subsequent, higher-impact waves.

Keywords: Shallow water waves, Tsunami wave sequence, Forerunners, non-linear Ocean bathymetry

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Impact Of Extreme Water Levels Along The Mumbai Coast On Building Coastal Resilience Planning

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ABSTRACT

Global sea level rise is a need of the hour to discuss. India having more than 7500 km coastal regions are impacted by the long-term sea-level rise and short-term extreme events along with environmental and socioeconomic impacts. In this study we are focusing on Mumbai, a rapidly growing mega city and one of the major ports in the country. The citie's coastal exposure and regular flooding in the monsoon season make it more vulnerable to the extreme events as well as sea level rise. Our analysis primerly covers Mumbai urban, suburban and Tanne. The sea level rise and extreme water level rise of 25 years and 100 years were predicted using long term tide gauze data. These cumulative water level (sea level rise and extreme water levels)were used to identify the coastal exposure with the help of high-resolution DEM. The resulting exposure depicts the flood line that can inundate due to inundation from oceanogenic hazards such as tsunamis, storm surges, erosion, and coastal floods. The exposure extent was calculated for short term 25 years return period which represent the frequently occurring small amplitude events. Whereas the 100 years return period exposure depict the major events that occur on long-term recurrence. Further, various geospatial data depicting the vulnerable elements with in this exposure zones were analyzed, to understand vulnerability scenario and to estimate the impact under both scenarios. This assessment can be helpful for providing the urban planners and policies makers to give early warning and make strategies accordingly and developing resilient communities/infrastructure against the oceanogenic hazards.

Keywords: Sea level rise, Extreme water level rise, Coastal exposure, Coastal Inundation,
Geospatial analyisis

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Swell Propagation From the Tropical Cyclone Freddy and Its Impacts Along the Indian Coast

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ABSTRACT

The unstructured WAVEWATCHIII (WW3) model is used to examine the swells generated by Tropical Cyclone (TC) Freddy, an unusually long-lived system that moved westward across the entire Southern Indian Ocean in February 2023. Three experiments were performed: (1) a control run with full wind fields across the Indian Ocean, (2) track-forced run incorporating winds only along TC Freddy's path to isolate swell propagation, and (3) a run forced with winds exclusively over the Extra-Tropical Southern Indian Ocean (ETSIO) region to quantify ETSIO swell contributions. Analysis of the results shows that swells from TC Freddy were able to reach distant coastlines, including India, the Gulf countries, and eastern Africa. Spectral evolution along the cyclone track revealed a transition from cyclone-driven wind seas to dominant long- period swells, with nonlinear interactions amplifying low-frequency energy during the cyclone's peak intensity. Wave power density analysis further highlighted that regions such as the southern coast of India, Sri Lanka, Lakshadweep, and the Maldives are particularly vulnerable under similar scenarios.Although swells are less energetic compared to local wind waves, their low-frequency nature can drive substantial coastal impacts, including erosion and flooding. With the expected increase in the intensity and duration of severe TCs under future climate scenarios, the associated coastal risks are likely to become more significant. Understanding the behaviour of such cyclones and their implications for coastal vulnerability is therefore essential. This study highlights the extensive reach of long-lived cyclones on distant coastlines and provides critical insights for assessing coastal risks and designing effective protection strategies under future climate scenarios.

Keywords: unstructured WW3, Wave power density, nonlinear interaction

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Atmospheric Pathways of Marine Microplastics to a Protected Mangrove Ecosystem in the Northern Bay of Bengal

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ABSTRACT

Marine microplastic (MP) pollution has traditionally been assessed through oceanic and sediment pathways, yet emerging evidence suggests that the atmosphere acts as an overlooked but highly efficient vector linking terrestrial and marine systems. This study presents the first atmospheric investigation of PM_{10}-bound microplastics over a pristine, human-habitation-free island within the Sundarbans Mangrove Ecosystem (SME), a globally critical coastal-marine biosphere in the northern Bay of Bengal. Using an 8-day high- resolution sampling strategy aligned with land–sea breeze circulations and fog–non-fog episodes, we identify distinct marine and terrestrial contributions to airborne MPs. Mean MP abundance (10 ± 6 MPs/100 m^3) substantially exceeded previously reported values for remote marine environments, underscoring the SME's role as both a sink and a secondary source for marine MPs.Sea-breeze episodes revealed strong marine signatures, dominated by low-density polymers such as polypropylene (PP) and polyethylene (PE), characteristic of fishing nets, aquaculture materials, and ocean-surface microplastic reservoirs uplifted through bubble-burst sea- spray aerosolization. Fog-free marine conditions showed particularly enhanced MP entrainment, linking wind-driven wave activity to atmospheric export of marine plastics toward inland forest zones. Conversely, land-breeze regimes transported textile- and waste- derived MPs, highlighting the bidirectional exchange between coastal waters and the atmosphere.The results indicate that atmospheric transport is a critical yet underappreciated pathway for redistribution of marine MPs, with potential implications for mangrove health, estuarine biogeochemistry, and the coastal marine food web. By demonstrating how mesoscale meteorology mediates the atmospheric export of sea-derived plastics, this study strengthens the emerging paradigm that marine microplastic pollution must be addressed through an integrated land–ocean–atmosphere framework. These findings have strong relevance for coastal conservation policy, marine pollution mitigation, and global assessments of microplastic fluxes into sensitive coastal ecosystems.

Key Words: PM10 bound Microplastics, Atmospheric Dynamics, Mangrove Ecosystem, Land Ocean Pollutant Exchange

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Temporal Evolution of Cyclone Biparjoy Wind Structure Using Doppler Radar–Derived Radial Velocity

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ABSTRACT

Doppler Weather Radar (DWR) provides high-resolution, real-time observations of the wind field and structural evolution of landfalling tropical cyclones. This study uses radar-derived radial velocity to assess structural changes, intensity variations, and landfall impacts of Extremely Severe Cyclonic Storm Biparjoy during 15–16 June 2023 along the Gujarat coast. Early scans on 15 June show a well-organized cyclonic circulation with symmetric inbound (negative) and outbound (positive) velocities around the eyewall, indicating strong low-level convergence and a mature rotational core. As the cyclone moved closer to the radar site, successive scans captured increasing magnitudes of radial velocities on both sides of the storm, reflecting intensifying rotational winds and the approach of the cyclone center. By around 15:30 IST, just before landfall, a compact circulation interacting with the coastline was observed, marked by sharp velocity gradients corresponding to peak intensity. After landfall, weakening of the radial velocity field and increased asymmetry became evident due to frictional effects and disruption of the vortex structure. Throughout 16 June, the velocity signatures progressively lost organization, with fragmented patterns and diminished gradients consistent with a decaying system over land. The analysis highlights the capability of DWR radial velocity in distinguishing an approaching, intensifying cyclone from a weakening post-landfall circulation. These results demonstrate the value of radar observations for real-time monitoring, operational forecasting, and high-resolution wind hazard assessment in vulnerable coastal regions.

Keywords: Doppler Weather Radar, Radial Velocity, Cyclone Biparjoy, Landfall, Wind Structure .

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Characterization Of Tsunami Wave Behaviour In Oceans With Varying Seafloor Topography.

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ABSTRACT

The analytical investigation of tsunami waves generated by general seabed disturbances has long attracted the interest of mathematicians and theoretical oceanographers. Yet, progress in this field has been limited due to the intrinsic mathematical complexity of the governing equations. This article presents an exact solution to the forced long linear wave equation in an ocean characterized by a non-uniform bathymetry defined as $y = -qx^r$, where $q > 0$ and $0 < r < 2$. Even within the linear framework, analyses involving such non-planar seabed profiles are uncommon. The solution derived here generalizes the well-known plane beach case ($r = 1$) to a broader class of bathymetric forms. The work builds upon and extends previous studies by Kanoglu and Synolakis [JFM, 1998, doi:10.1007/BF00162789] and Bandyopadhyay [IJG, 2013, doi:10.4236/ijg.2013.42042], through a detailed analysis of the wave integral solution incorporating double Hankel integral expressions - a mathematically challenging task successfully addressed in this study.

The analysis reveals five key findings:

(i) The generated waves propagate as a quartet;
(ii) one member of this quartet, termed the "forerunner," precedes the main tsunami waves and offers potential value for early forecasting [Journal of Ocean Dyn, 2021, doi:10.1007/s10236-021-01454-z];
(iii) another component governs the wave runup behavior;
(iv) the slope of the seabed strongly affects wave dynamics and evolution; and
(v) the amplitude of the forerunner waves decreases with changes in seabed curvature, represented by the parameter r.

In conclusion, several visual illustrations are provided to depict wave behaviour across different spatial and temporal domains. Last but not the least, comparative analyses of depth profiles from various regions in the Indian and Pacific Oceans confirm that the general parabolic seabed structure assumed here is representative of natural oceanic topographies at least qualitatively in a local domain.

Keywords: Tsunami waves, Tsunami forerunners, Hankel transform, Hankel function, Tsunami wave run-up.

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Future Projections of Tropical Cyclone Genesis Frequency and Characteristics in the North Indian Ocean up to 2100 Using CMIP6

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ABSTRACT

Global warming in the wake of climate change would influence tropical cyclone activity for the decades to come. Although the future projections remain uncertain, potential shifts in the frequency, spatial distribution, and genesis and intensity characteristics of the tropical cyclones possess substantial implications to vulnerable populations and socio-economic systems. In the present study, we analyse multi-model climate projections and the future changes in the characteristics and frequency of the tropical cyclone genesis over the Northern Indian Ocean (NIO) upto the year 2100 are studied using the genesis potential index. It was found that these changes are potentially governed by an increase in mid-level relative humidity and lower-to- mid level cyclonic vorticity, as well as a decrease in the vertical wind shear and moisture loading, which also play a significant role. Projected changes in the tropical cyclone genesis frequency over the NIO shows pronounced seasonality, characterised by a substantial and statistically robust decline during the pre-monsoon period and an enhancement during the post- monsoon season. It is also re-affirmed that there exists a strong positive relationship between GPI and humidity; GPI and vorticity, but a negative relationship exists for GPI with the wind shear.

Key words: Tropical Cyclone, Future projection, Genesis Potential Index, Northern Indian Ocean, TC genesis

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Assessment Of Saltwater Intrusion In Coastal Odisha Using Hydrochemical Indicators And Machine Learning Approach

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ABSTRACT

Freshwater resources in coastal aquifers is increasingly threatened by salinization driven by seawater intrusion, undermining long-term resource sustainability. In this study, a structured methodological framework is developed to delineate vulnerable zones using an integrated hydrogeochemical, spatial, and machine learning approach. Groundwater samples from 33 tubewells in the Ersama block, Odisha, were collected during the pre- and post-monsoon seasons of 2023, and major ions including Cl^-, HCO_3^-, and Na^+ were analysed. Two key diagnostic ratios—Cl^-/HCO_3^- for assessing salinization intensity and Na^+/Cl^- for identifying salinity sources—were computed. Contamination severity was initially classified into six categories based on established thresholds. These were further refined by integrating salinity origin information, resulting in 11 hybrid classes that served as labelled inputs for Random Forest (RF) classification. The spatial distribution of contamination classes was mapped in ArcGIS, enabling clear visualization of affected zones. During the pre-monsoon period, areas exhibiting high to extreme contamination linked to seawater intrusion covered 19.1% of the region, while non- marine sources contributed 31% under similar severity levels. Post-monsoon analysis revealed a substantial reduction in seawater-related contamination (6.4%), whereas contamination from other sources surged to 43%. These seasonal variations indicate a dilution-driven reversal of hydraulic gradients following monsoon recharge, which temporarily suppresses seawater intrusion but enhances contributions from terrestrial sources. Overall, the integrated framework demonstrated here provides an effective and scalable tool for assessing and monitoring saltwater intrusion dynamics in coastal aquifer systems.

Keywords: Groundwater chemistry, salinity, Random Forest, coastal aquifers, Odisha

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Role Of Upper Ocean In Increase In Extreme Events In A Warming Climate: A Case Study

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ABSTRACT

The Indian Ocean (IO) has warmed significantly in recent decades, and this warming is linked to more frequent and intense extreme events, including tropical cyclones, marine heatwaves, and heavy rainfall. This study investigates the critical role of upper-ocean processes in intensifying these extremes under a warming climate. Recently, an extremely severe cyclonic storm Biparjoy formed over the Arabian Sea (AS) and lasted for over 13 days (6^{th} - 19^{th} June 2023) which is highly unusual for small basins of the north Indian Ocean. It is interesting to note that Biparjoy developed in a low vertical shear environment, but the shear increased abruptly after the genesis. To elaborate the response of upper-ocean to the passage of cyclone Biparjoy, we analyzed the upper-ocean features such as SST, marine heat waves (MHW), mixed layer depths (MLDs), tropical cyclone heat potential (TCHP), Brunt–Väisälä frequency (N^2), and vertical shear of ocean currents (S^2) in the pre-, during-, and post-storm period. It is found that pre-storm background conditions of low-winds, shallow MLDs, stronger sub-surface stratification, low S^2 values, presence of warm-core anticyclonic eddies, deeper 28°C isotherms, and high TCHPs contributed to the strong resistance of subsurface stratification to the cyclone-induced mixing. The freshening of upper-ocean layers further contributed to development of stably stratified near- surface layers. The results highlight the role of near-surface and subsurface stratification in sustaining the high intensity of cyclone Biparjoy over long duration. This study establishes the role of ocean in characterizing the unique development of Biparjoy in observations and numerical model.

Keywords: Tropical Cyclone, TCHP, MHW, stratification, Arabian Sea

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Understanding the Tropical Cyclone Intensification over North Indian Ocean

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ABSTRACT

Tropical cyclones (TCs) peak intensity, potential for destruction, and related socioeconomic effects are all significantly influenced by their rate of intensification. Long-term changes in TC intensification have not been systematically evaluated, despite the North Indian Ocean (NIO) being one of the most active cyclone basins in the world. This research examines the temporal progression of tropical cyclone intensification rates across the North Indian Ocean from 1981 to 2023, analyzing interannual, seasonal, and decadal scales, with an emphasis on both Rapidly Intensifying (RI) and Non-Rapidly Intensifying (NRI) storms.Over the course of the study, the mean intensification rates in the basin were 5.68 ± 1.64 knots (6-hourly), 10.16 ± 2.95 knots (12-hourly), and 17.83 ± 5.33 knots (24-hourly). In both the Arabian Sea and the Bay of Bengal, RI TCs show significantly greater intensification than NRI TCs, whereas NRI TCs typically show only slight intensity changes of 0–5 knots. With little variation between the two sub-basins, 0-, 5-, and 10-knot changes predominate for all TCs combined. Interannual analysis reveals a positive but statistically insignificant trend in raw intensification rates; however, applying a 3-point moving average highlights a statistically significant increasing trend across all intensification windows. Seasonal analysis shows a clear distinction between pre- and post-monsoon periods. The post-monsoon season (October– December) exhibits a significant upward trend in intensification rates, whereas no significant trend is detected in the pre-monsoon season (April–June). These changes are further highlighted by decadal variability. Between the 1980s and the 1990s, intensification rates significantly increased; on average, they went from 4.27 to 14.57 knots to 6.31 to 19.55 knots over 6-, 12-, and 24-hour periods. Intensification rates from 2010 to 2023 are still high, but they fall short of the 1990s peak values. Overall, the study shows that TC intensification is strengthening over the long term, especially in the post-monsoon season. This emphasizes the need for better prediction systems and increased readiness in all countries that border NIO.

Keywords: Tropical cyclone, Intensification, North Indian Ocean, Rapid Intensification, Postmonsoon

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Assessment of WRF Model Performance in Simulating Cyclone Nivar (2020) Over the Bay of Bengal

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ABSTRACT

This study evaluates the performance of the advanced research-based Weather Research and Forecasting (WRF-ARW) model in simulating Very Severe Cyclonic Storm (VSCS) Nivar over the Bay of Bengal using Final Analysis (FNL) datasets. This work advances earlier efforts by examining a single-domain, high-resolution simulation of Nivar using updated GRIB2-based FNL fields and a streamlined workflow suited for short-duration experiments and limited computational resources.The model setup followed a full WPS (WRF Preprocessing System) – WRF Model pipeline, beginning with geophysical and meteorological preprocessing and followed by ARW integration from 21 to 26 November 2020 during the cyclone Nivar. Post-processing was conducted through ARWpost and GrADS to extract position, estimated central pressure (ECP), and maximum sustained surface wind (MSSW). Model-simulated track and intensity were compared with India Meteorological Department (IMD) cyclone best-track data using correlation and RMSE metrics.Results show that WRF successfully captured the formation of the low-pressure system and the overall evolution of Nivar, including its intensification phase and landfall timing. The simulated landfall location deviated by only 22 km from IMD observations. Track correlation exceeded 0.99 for both latitude and longitude. RMSE was low for longitude (0.25) and moderately higher for latitude (1.17), reflecting minor displacement errors. The model reproduced intensity parameters with good agreement: MSSW correlation was 0.93 (RMSE = 9.01 knots) and ECP correlation was 0.96 (RMSE = 2.49 hPa). These results indicate that the updated FNL data provide a reliable initial and boundary condition set for cyclone simulation, supporting earlier findings that high-quality analyses reduce track and intensity errors. The study demonstrates the usefulness of a compact, replicable WRF workflow for cyclone simulation, especially where computational constraints limit multi-domain or ensemble approaches. By validating the model against Nivar, this work contributes to improving short range prediction experiments and highlights the potential of operational NWP setups to support regional hazard assessment and early-warning strategies.

Keywords: WPS–WRF, FNL datasets, ECP, MSSW, Cyclone best-track data

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Building Coastal Resilience through Morphological Monitoring: A Periodic Assessment of the Visakhapatnam Coast

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ABSTRACT

Coastal degradation poses a growing threat in India, affecting infrastructure and the livelihoods of coastal communities. Along the 48 km Visakhapatnam coast (Bheemili to Yarada), seasonal beach changes are driven by waves, tides, currents, and human interventions like dredging and jetty construction. Bimonthly beach profilings are conducted at ten sites for three years i.e. during 2023,2024 and 2025 Pre-Monsoon, Monsoon, and Post-Monsoon seasons, combined with littoral data, revealed significant morphological shifts. The southern coast (Yarada to Submarine) saw major erosion in the year 2023, especially during the months of July–August and sediment deposition occurred in the year 2024. The northern stretch (Rushikonda to INS Kalinga) gained sediment in the year 2023 but eroded in the year 2024. Bheemili consistently showed erosion, likely due to its embayed nature. These findings identify key erosion and deposition zones, aiding future coastal planning and management.

Keywords: Shoreline dynamics, Sediment loss, Sediment gain, Coastal surveys, Visakhapatnam shoreline.

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Subsurface Thermal Refugia During the 2024 Marine Heatwave in Lakshadweep Archipelago: Implications for Coral Reef Resilience

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ABSTRACT

Marine heatwaves (MHWs) are emerging as one of the most severe climate-driven disturbances to coral reef ecosystems in the Indian Ocean. However, the vertical thermal structure associated with these events remains poorly resolved in the Lakshadweep Archipelago, limiting our understanding of potential subsurface thermal refugia. This study characterizes three- dimensional temperature patterns during the April 2024 MHW to assess depth zones that may buffer corals from extreme surface warming. CTD observations were collected across three atolls; Kavaratti, Agatti, and Kadmat, during the peak of the event, complemented by satellite- derived SST data indicating sustained and intense surface warming throughout early April to early May.Vertical temperature profiles revealed clear thermal stratification across all sites, with warm surface layers overlying significantly cooler subsurface waters. A well-defined thermocline was consistently observed, separating upper layers that exceeded regional bleaching thresholds from deeper waters that remained comparatively cooler. This depth-dependent thermal structure suggests the presence of subsurface refugia capable of moderating heat stress during acute warming events. Inter-island comparisons showed broadly similar stratification patterns, although local oceanographic conditions influenced the strength and depth of the thermocline.Overall, the persistence of cooler temperatures below the shallow mixed layer indicates that deeper reef habitats may provide temporary physiological relief for coral communities during MHWs. These potential refugia hold substantial ecological importance, functioning as reservoirs for surviving coral populations and contributing to post-bleaching recovery through larval replenishment. The findings underscore the need for management strategies that incorporate depth-stratified monitoring, targeted protection of deeper reefs, and climate-informed restoration planning. As MHWs intensify under continued climate change, understanding and safeguarding such thermal refugia will be essential for sustaining coral reef resilience in the Lakshadweep Archipelago and similar atoll systems.

Keywords: Marine heatwaves, Thermal stratification, Subsurface refugia, Coral bleaching, Lakshadweep Archipelago

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A Case Study On The Impact Of Tropical Cyclone Biparjoy On Aviation Weather Serices Within The Delhi Fir

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ABSTRACT

Tropical Cyclone Biparjoy, which developed over the Arabian Sea in June 2023, had a significant indirect impact on aviation weather conditions within the Delhi Flight Information Region (FIR). Although the cyclone's core circulation remained far from northern India, its extensive peripheral influence resulted in enhanced convective activity and widespread thunderstorms over northwestern and central India between 18–20 June 2023. The Meteorological Watch Office (MWO), Palam, closely monitored the evolving synoptic situation using satellite imagery, numerical models, and tropical cyclone advisories issued by the Regional Specialized Meteorological Centre (RSMC), New Delhi. Under the influence of Biparjoy, severe embedded thunderstorms were observed across multiple sectors of the Delhi FIR. In response, MWO Palam issued a series of WS SIGMETs to ensure the safety of en-route aircraft operations, each valid for four hours, describing areas of convective activity.These timely SIGMETs provided critical situational awareness to pilots, air traffic controllers, and flight dispatchers, minimizing operational disruptions and enhancing flight safety. The coordinated dissemination of warnings and communication with the Airports Authority of India demonstrated effective inter-agency collaboration. In addition, a detailed analysis was carried out on various meteorological parameters, including rainfall distribution, associated gusty winds, and aerodrome warnings issued across multiple airports within the Delhi FIR. The case of Cyclone Biparjoy underscores the importance of continuous monitoring, accurate tropical cyclone advisories, and proactive SIGMET issuance by MWOs to mitigate the adverse impacts of remote tropical systems on aviation operations over inland FIRs such as Delhi.

Keywords: Tropical Cyclone Biparjoy, Aviation Meteorology, SIGMET, Thunderstorm, Delhi FIR

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Seawater intrusion assessment in coastal aquifers in North Goa, Goa, India.

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ABSTRACT

Sea water intrusion is a rising concern in the coastal regions of India, where the invasion of seawater into freshwater aquifers is affecting water quality. Sea water intrusion can affect agricultural productivity due to increased salinity in soil and water used for irrigation. Uncontrolled urbanization and land-use changes reduce groundwater recharge, further increasing vulnerability.In this study, the concentrations of major cations and anions in the coastal aquifers of Pernem and Bardez taluka in North Goa, Goa, were assessed to detect seawater intrusion in the aquifers. Twenty-eight wells were selected, and samples were analyzed for cations, including calcium, magnesium, sodium, and potassium, as well as anions, including bicarbonate, chloride, nitrate, and sulfate. The analyses were conducted using ICP-OES, UV- spectrophotometer, and titration methods. The data obtained were then compared with drinking water standards (BIS, 2012).The results revealed that 10 out of the 28 water samples (36%) exceeded the concentration of one or more elements with respect to BIS (2012) drinking water standards. The results also showed high levels of sodium, calcium, chloride, and nitrate in wells located near the coast and estuary. The most probable cause of the contamination is primarily due to the interaction with saline water. Other causes include anthropogenic activities such as a flawed septic tank system, the use of fertilizers, and landfills. The spatial distribution of element concentrations is also plotted on a map, which provides an indication of saline water intrusion in the northwestern and southern regions of the study area. To mitigate seawater intrusion, measures can be implemented, such as controlling the abstraction rate of groundwater, implementing rainwater harvesting, and enhancing the groundwater infiltration rate.

Keywords: Groundwater, Coastal aquifers, Contaminant, seawater intrusion, rainwater harvesting.

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Distinct Air–Sea Interaction Pathways Driving Pre- and Post-Monsoon Cyclone Intensification in the Bay of Bengal

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ABSTRACT

The Bay of Bengal (BoB) exhibits contrasting oceanic thermal conditions between the pre- and post-monsoon which can significantly impact the intensification processes of developing tropical cyclones (TCs). To investigate this effect, we have implemented a coupled atmosphere-ocean- wave model and simulated two TCs, Mocha (2023, pre-monsoon) and Phailin (2014, post- monsoon), with a lead time of up to 96 hours. The simulated TC intensity agrees well with the observations. During the pre-monsoon, the BoB shows higher Tropical Cyclone Heat Potential (TCHP) compared to post-monsoon, indicating a larger reservoir of heat. Despite that, both the TCs reached a comparable peak intensity. The intensification of Mocha was slowed down due to its passage over a cold eddy (TCHP < 70 kJ.cm^{-2}), whereas Phailin intensified steadily with a continuous support of latent heat flux (LHF). During initial intensification, larger bulk kinetic energy growth for Mocha (>150%) is noticed than for Phailin (117%), linked to rapid moisture consumption. Despite a reduced LHF, a second intensification phase was noticed in Mocha due to an increased lateral moisture flux followed by increased cross-isobaric flow, regulated by a high TCHP (>120 kJ·cm^{-2}) area located far away (~300 km) from the core region, counteracting the negative effect of ocean surface cooling. In contrast, Phailin's intensification was supported by favorable atmospheric conditions (low vertical shear) and a steady supply of heat fluxes from the ocean. Despite having a lower TCHP, the presence of a thick barrier layer reduced the negative impact of the ocean surface cooling from TC-induced vertical mixing, allowing post- monsoon TCs to maintain steady intensification. The absence of a barrier layer increases the sea surface cooling during the TC passage in the pre-monsoon, therefore negatively impacting its intensification. The pre-monsoon TCs thus exhibit a stronger dependency on ocean subsurface variability compared to post-monsoon.

Keywords: Tropical cyclone, barrier layer, coupled model, air-sea interaction, Mocha, Phailin

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Automated Shoreline Extraction And Change Analysis Using Deep Learning And Dsas: A Case Study Of Mousuni Island, India

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ABSTRACT

Shoreline retreat poses a critical challenge to coastal resilience in monsoon-dominated marine environments, where shoreline evolution is controlled by complex interactions among wave climate, sediment transport, and coastal morphology. Mousuni Island in the western Indian Sundarbans is particularly vulnerable due to strong tidal currents, wave–tide interactions, and reduced sediment supply, resulting in enhanced hydrodynamic stress and accelerated shoreline instability. This study presents a comprehensive 35-year (1990–2025) assessment of shoreline change along Mousuni Island using an integrated framework combining geoinformatics, deep learning–based shoreline extraction, and the Digital Shoreline Analysis System (DSAS). Multi- temporal Landsat imagery was employed to implement and evaluate two semantic segmentation models, U-Net and DeepLabV3+, for automated shoreline delineation, with U-Net demonstrating superior boundary precision and spatial consistency across diverse coastal settings. Quantitative shoreline change analysis using DSAS-derived metrics, including Net Shoreline Movement (NSM), Shoreline Change Envelope (SCE), and Linear Regression Rate (LRR), reveals pronounced spatial variability in erosion and accretion patterns driven by monsoon-induced wave energy, sediment redistribution, and localized anthropogenic influences. The analysis revealed erosion as the dominant process, affecting nearly 90% of the island's perimeter. The mean shoreline retreat rate was −4.36 m yr^{-1}, with extreme erosion rates of up to −23.55 m yr^{-1} observed in the southern and northwestern high-risk zones. In contrast, limited accretion was identified in localized northeastern sectors, with a maximum shoreline advance of +2.81 m yr^{-1}.The study introduces a replicable framework that integrates historical erosion patterns with future risk projections to assess deltaic island vulnerability, providing actionable insights for nature-based solutions, strategic embankment design, and climate-resilient coastal management.

Keywords: Shoreline change, Coastal erosion, Monsoon dynamics, Deep learning, DSAS

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Towards Predictive Coastal Intelligence: A Geoai Perspective On Shoreline Dynamics And Hazards

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ABSTRACT

Accelerated sea-level rise, intensification of tropical cyclones, storm surges, and human interventions have rendered shoreline dynamics increasingly non-linear, non-stationary, and difficult to predict using conventional approaches. Classical remote sensing and GIS-based shoreline change analyses largely dependent on deterministic, linear, or rule-based statistical methods and have proven effective for historical trend assessment but remain limited in capturing complex spatio-temporal interactions, compound hazards, and extreme-event-driven transformations under a changing climate. Recent advances in GeoAI, encompassing machine learning and deep learning integrated with remote sensing and GIS, offer transformative opportunities for coastal hazard assessment and shoreline dynamics modeling. This work presents a critical synthesis of emerging GeoAI-enabled frameworks for coastal studies, highlighting their potential to move beyond descriptive change detection toward predictive and anticipatory coastal intelligence. GeoAI techniques enable automated feature extraction from multi-sensor satellite data, learning of non-linear shoreline responses to hydro-meteorological forcings, integration of diverse drivers including geomorphology and human activity, and improved short- to long-term hazard projections under extreme weather and climate change scenarios. The work further identifies key scientific and operational challenges hindering large-scale adoption of GeoAI in shoreline dynamics, including data sparsity and bias, model generalizability across diverse coastal settings, and integration with physics-based coastal process understanding. By consolidating current knowledge and outlining a future research agenda, this work aims to position GeoAI as a critical enabler for next-generation coastal monitoring, hazard assessment, and climate adaptation strategies across multiple spatio-temporal scales.

Keywords: Coastal Morphodynamics, GeoAI, Shoreline dynamics, Remote sensing and GIS, Extreme weather events, climate change impacts

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Seasonal Variability Of Suspended Sediment Concentration And Particle Size Distribution In The Estuarine And Nearshore Waters Of The Central West Coast Of India

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ABSTRACT

The suspended sediment dynamics in coastal regions and estuaries play a crucial role in influencing various coastal processes and sediment budgeting. The sediment budget, vital for coastal stability, faces risks such as coastal erosion, sediment influx from rivers along the shore, and the cross-shore transport of sediments. The Suspended Sediment Concentration (SSC) is highly dynamic and affected by diverse hydro-meteorological parameters. In-situ measurements struggle to effectively estimate SSC in the dynamic coastal waters and estuaries, inadequately capturing the entire system's variations. Ocean colour sensors have greatly improved SSC mapping in open waters and coastal regions, yet their coarser spatial resolution limits their utility in nearshore waters and estuarine environments. The emergence of high spatial resolution multispectral sensors offers enhanced performance with specific algorithms to derive precise water reflectance in coastal waters. Operational Land Imager (OLI) from Landsat-8 and MultiSpectral Instrument (MSI) from Sentinel-2 are widely adopted sensors for mapping SSC in coastal and estuarine waters. This study employs these sensors to estimate SSC in the Goa coastal waters from 2014 to 2020 and the Zuari estuary from 2016 to 2022. Satellite-derived suspended sediment concentration (SSC) was validated using approximately seven satellite in-situ match-up samples collected within ±30 minutes of satellite overpass. Validation against LISST-derived SSC yielded good agreement, with a coefficient of determination of $R^2 \approx 0.941$ and a root mean square error of RMSE ≈ 2.19 mg L^{-1}, consistent with accuracies reported for optically complex estuarine waters. The six-year analysis captures SSC variations and associated processes, revealing the dynamics of suspended sediments in coastal waters, estuaries, and rivers. The study observes a reasonable variation in SSC from the upstream (15 - 18 mg/l) of the river to the estuary (8 - 12 mg/l) and extending into coastal waters (5 - 10 mg/l). The variations of SSC in the coastal waters give a wider picture of the sediment budget in the region to the sediment cells and the interaction of the sediments from the river discharge with the adjacent coastal parts. This integrated long-term observations of multispectral satellite data offers finer resolution SSC estimates in the estuarine and coastal environments.

Keywords: In-Situ Observations, Particle Size Distribution, LISST-200x, Suspended sediment dynamics, central west coast.

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Monthly And Seasonal Evaluation Of Wave Spectra Along The West Coast Of India

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ABSTRACT

The west coast of India, bounded by the Arabian Sea is subject to highly dynamic wave regimes shaped by monsoonal winds, long-period swells originating from distant sources, and locally generated wind seas. The region exhibits distinct seasonal variability: the southwest monsoon produces strong winds and high-energy waves, whereas the northeast monsoon shows comparatively weaker conditions. The wave parameters from global reanalysis datasets perform well in deep waters, their reliability in shallow and intermediate waters requires validation against *insitu* measurements. 2D wave spectra provides the most comprehensive means to evaluate the distribution of wave energy across frequencies and directions for any coastal region. This work evaluates 2D wave spectra against buoy measurements off Honnavar for 2014–2015, at daily, monthly, and seasonal timescales. On the daily scale, ERA5 successfully reproduced dominant swell directions and broad spectral trends, though it consistently underestimated energy and showed slight directional shifts relative to observations. Monthly comparisons showed better match than daily analyses. Seasonally, ERA5 performed well during the southwest, accurately representing the unimodal, swell-dominated wave field and associated high-energy levels, although with a tendency to broaden the frequency–direction spread. On the contrary, during the pre- and post-monsoon transition periods, measured spectra frequently exhibited a bimodal structure representing the coexistence of locally generated wind-seas and long-period swells. ERA5 was able to capture the general energy trends but underestimated the distinct separation between spectral peaks, instead of producing a smoother energy distribution. These findings highlight the value of spectral-scale validation in coastal regions and highlight ERA5's effectiveness for applications ranging from coastal hazard mitigation and port operations to long-term wave climate assessments under changing climatic conditions.

Keywords: 2D wave spectra, ERA5, moored buoy, ocean waves, spectral analysis

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Assessing The Morphodynamic Response Of Embayed Beaches To Climate Change Along The Central West Coast Of India.

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ABSTRACT

This study examines the morphodynamic behavior and climatic influences affecting twenty- seven embayed beaches along the central west coast of India through an integrated approach combining in-situ field observations and remote sensing analyses. For the first time, these embayments were classified using an embayment morphometric parameter (γe), derived from embayment area (Ae) and indentation (a), enabling categorization into three distinct types: Class 1 (open/exposed), Class 2 (semi-exposed), and Class 3 (semi-closed/sheltered). Field-based beach profile measurements were carried out for sixteen accessible embayments to assess seasonal and annual volumetric variations. The results revealed a marked decline in beach volume from February to September, primarily attributed to intense monsoonal wave activity, followed by partial recovery between September and February.Long-term shoreline dynamics were evaluated using satellite imagery from 1990 to 2023, which indicated maximum erosion of 81.72 m at Mirya and maximum accretion of 62.5 m at Undi. Net Shoreline Movement (NSM) analysis further identified critical retreat trends in eight embayments, including Palshet, Hedavi, and Vengurla. To understand the underlying drivers, climate-related parameters: sea-level rise, cyclone frequency, wave power, and swell activity were analyzed. The results demonstrated an increase in regional sea levels, intensified cyclone occurrences, and higher wave power, correlating strongly with observed erosion patterns. Additionally, anthropogenic activities such as breakwater and jetty construction were found to significantly alter local morphodynamics. Overall, this study emphasizes that embayed beaches, often perceived as morphologically stable over seasonal or annual timescales, exhibit substantial dynamism and instability when examined over decadal periods. These findings underscore the compounded impacts of climatic and human-induced factors on coastal evolution along the central west coast of India.

Keywords: Coastal erosion, anthropogenic pressure, shoreline change, Bay morphometry,Sea level rise,Monsoonal waves

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Assessment Of Wave–Current Interaction And Morphodynamic Response Under Cyclone Fengal (2024)

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ABSTRACT

Cyclone-induced morphodynamic changes play a vital role in shaping coastal morphology and influencing long-term shoreline evolution. Understanding these changes is essential for improving predictions of coastal hazards and resilience planning in cyclone-prone regions. This study investigates the relationship between cyclone-induced wind waves and the associated morphodynamic responses along the eastern Indian coast, focusing on the Kattupalli region near Chennai. A coupled TELEMAC-TOMAWAC modeling framework was employed to simulate local hydrodynamic and wave conditions during Cyclone Fengal (2024). The model incorporated detailed bathymetry, coastline geometry, and high-resolution atmospheric forcing to represent the cyclone's wind and pressure fields. Simulated parameters, including surge height and significant wave height, were validated against field measurements, showing reasonable agreement in spatial and temporal trends. Pre- and post-cyclone field surveys were conducted to document shoreline change and bathymetric variations. The measured seabed elevation changes provide valuable insights into the scale and nature of cyclone-driven morphological responses. Preliminary interpretation indicates that regions exposed to intense wave activity and strong hydrodynamic forcing experienced noticeable seabed adjustments. Integrating numerical simulations with field observations offers a comprehensive understanding of nearshore processes during extreme events. The study demonstrates the effectiveness of the TELEMAC- TOMAWAC system in reproducing cyclone-induced wave dynamics and highlights the importance of high-resolution morphodynamic observations in post-storm assessments. These findings enhance the understanding of storm-induced coastal processes and support improved management strategies for vulnerable coastal regions.

Keywords: Cyclone Fengal (2024), Morphodynamic response, Wave–current interaction, Sediment transport, Coastal resilience

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Assessment of Manual and CoastSat-Based Shoreline Using DSAS along the Machilipatnam Coast, India

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ABSTRACT

The Machilipatnam coast, situated along the Krishna River delta in Andhra Pradesh, experiences dynamic shoreline changes driven by monsoonal waves, tidal currents, and sediment transport. This study focuses on a 16 km coastal stretch of the Machilipatnam shoreline and compares two geospatial approaches, (1) automated extraction using CoastSat and (2) manual digitisation in GIS, to evaluate their effectiveness in assessing shoreline change for the year 2024 using LISS- IV and Landsat data. A total of 25 CoastSat-derived satellite images and 6 high-resolution LISS-
IV datasets from 2024 were analysed for shoreline change. Shorelines were extracted automatically using CoastSat and manually digitised in a GIS environment. Both shoreline datasets were statistically analysed in DSAS using the Weighted Linear Regression (WLR) method to quantify erosion and accretion rates. CoastSat, an automated Python-based tool, delineates shorelines from multispectral imagery through spectral thresholding and the Modified Normalised Difference Water Index (MNDWI) technique. Both approaches showed strong agreement in the central and northern sectors of the Machilipatnam coast, consistently identifying high erosion exceeding 1 m per year. However, deviations occurred in the southern estuarine and port regions, where CoastSat indicated localised accretion not detected through manual digitisation. However, deviations occurred in the southern estuarine and port regions, where CoastSat indicated localised accretion was not detected through manual digitisation. These discrepancies primarily arise from anthropogenic influences such as port construction, dredging, and sediment dumping, which modify nearshore sediment dynamics and spectral reflectance patterns.CoastSat offers advantages in automation, reproducibility, and high temporal frequency, whereas the manual GIS-based method ensures higher positional accuracy. The comparison demonstrates that integrating both techniques enhances shoreline change analysis by combining the efficiency of automated extraction with the reliability of manual validation and statistical modelling. Future work will incorporate tidal correction and field surveys for validation to further improve the accuracy and applicability of shoreline monitoring in dynamic deltaic environments.

Keywords: Shoreline, CoastSat, DSAS, Python, GIS, Coast

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Challenges Of Climate Change, Sea Level Rise And Fluvial Sediments Shortage For The River Don Delta And The Sea Of Azov

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ABSTRACT

The Sea of Azov is the shallow semi-enclosed sea situated in the Southern European Russia. The Sea is one of the most productive water bodies of Russia and has significant stock of valuable fishes. Because the Sea is shallow, it is sensitive to regional climate change, anthropogenic activities and (possibly) to sea level rise. Most importan coastal area of the Sea is The River Don, which is unique in provision of economic services (fishing and shipping, tourism) and ecological services (carbon sequestration, conservation of habitats for plants and animals). Flourishing and rapidly growing city of Rostov-on-Don, capital of Southern Europen Russia, borders the Delta. However, the Sea of Azov, River Don Delta and human population of coastal areas are gradually becoming more and more vulnerable since the start of the Anthropocene (since 1950th). Indeed, we found by application of simulation modelling, statistical analysis and analysis of remote sensing images that significant geomorphological and biophysical changes are happening both in the Sea and the Delta. So, the Don Delta has changed its functional type recently from river dominated over centuries to a wave dominated and that marine forcings in form of interaction between waves and surges now determine the geomorphological stability of the Delta. This happens, because the amount of runoff and sediment delivery to the Sea of Azov and the Delta and their seasonal distribution has significantly changed due to the river engineering upstream in the last sixty years. This combines with never before observed increase in sea water temperature and in salinity posed by regional climate change in the last two decades. We are now making an assessment how these radical changes will affect the Sea and the Delta in the nearest future and which measures should be undertaken for sustainable development of our Sea and our coastal areas. This work was supported by the Russian State Assignment of SSC RAS № 125011200143-4.

Keywords: Shallow sea, river delta, climate change, coastal area risks, sediments shortage

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Hydrodynamic Processes Behind Kallakadal Induced Coastal Flooding Along the Southwest Coast of India

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ABSTRACT

Kallakadal events—sudden episodes of coastal flooding occurring along the southwest coast of India—often arise without any noticeable local meteorological disturbances, making them difficult to anticipate. This study examines the ocean–atmosphere interactions responsible for three such events, tracing their origins to synoptic-scale disturbances in the Southern Hemisphere. Cut-Off Low (COL) systems developing south of 30°S were found to generate persistent, high-energy winds over large fetch regions, producing long-period swell waves that traverse the Indian Ocean and reach the Indian coastline. Using a coupled modelling framework involving WAVEWATCH III for basin-scale swell propagation and XBeach for nearshore transformation, we demonstrate how these remote swells evolve into energetic infragravity waves within the surf zone. The amplification and breaking of these IGWs, especially over gently sloping coastal profiles, significantly enhance wave setup and contribute to coastal inundation. By integrating atmospheric diagnostics with hydrodynamic simulations, this study provides a comprehensive understanding of the physical processes driving Kallakadal events and highlights the offshore precursors that can improve early warning capabilities.

Keywords: Kallakadal, infragravity waves, Cut-Off Low, coastal flooding

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Assessment And Mitigation Of Estuary Bank Erosion Through Numerical Modelling And Field Observations: A Case Study Of Purna River, Gujarat

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ABSTRACT

Globally, nearly two-thirds of beaches are experiencing erosion, the erosion rates vary significantly across different regions are influenced by a multitude of factors, including climate change and human activities. This study focuses on the ecologically sensitive Purna River estuary in Navsari, Gujarat, which is undergoing severe erosion and inundation during extreme events. This erosion is actively cutting off the riverbank road and threatens residential properties, farms, and local livelihoods. As the area spans CRZ-IA, CRZ-IB, and CRZ-IVB, protection measures must mitigate erosion without adverse impacts on the adjacent coast. Extensive field measurements (beach profile, bathymetry, currents, sediment properties), multi-temporal satellite analysis, and coupled spectral wave, sediment transport, and hydrodynamic modelling were carried out to understand historical and baseline shoreline changes and to design effective long-term protection measures. Satellite imagery shows that the southern side is erosion-prone (min: 1.5 m/yr, mean: 9.5 m/yr, max: 17 m/yr), whereas the northern portion remains relatively stable. Numerical modelling shows a similar pattern of bed-level change. The erosion pattern is linked to higher current speeds (up to 1 m/s) in the south compared to the north. The region is tide-dominant, with a tidal range of ~7 m. A groyne field system is found effective, reducing current velocities by about two-thirds near the bank. Locations previously showing severe erosion now demonstrate accretion or stable bed levels. This indicates that the proposed structures can reduce estuary-bank erosion without adverse impacts on overall river flow characteristics

Keywords: Estuary dynamics, Shoreline change, Numerical modelling, Groynes, Coastal protection

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Shoreline Dynamics and Monsoon-Driven Wave Climate Influences on the Central Kerala Coast (2015-2025)

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ABSTRACT

The Chandhapalam–Arattuvazhy sector of the Thrissur coast in central Kerala is a sandy, monsoon-dominated shoreline with high seasonal variability. This study quantifies decadal shoreline change along a 2.5-km stretch from 2015 to 2025 using Sentinel-2 multispectral imagery, with shoreline positions extracted via the CoastSat framework. Only post-monsoon shorelines were analysed to isolate interannual recovery trends. Interannual shoreline variability was evaluated against ERA5-derived wave parameters to assess the influence of southwest monsoon wave forcing. The results indicate a consistent net erosional trend across the entire sector. Puthiya Beach and Cheraman Beach exhibit the highest rates of shoreline retreat, emerging as persistent erosion hotspots. Despite the presence of seawalls prior to 2015, shoreline recession has continued, indicating diminished structural effectiveness and sediment deficits linked to altered longshore transport pathways. Years characterised by higher monsoon significant wave heights correspond to greater post-monsoon shoreline recession, underscoring the role of energetic monsoon wave climates and wave approach angles in modulating shoreline response. Progressive shoreline retreat has reduced beach width, posing risks to fringing coastal vegetation and nearshore benthic habitats that support intertidal organisms and juvenile fish. Overall, this study highlights the coupled influence of monsoon wave dynamics and coastal structures on shoreline evolution in central Kerala and underscores the need for sustained, site-specific coastal erosion management interventions.

Keywords: Shoreline dynamics, Monsoon wave climate, Sentinel-2, Erosion hotspot, Longshore sediment transport.

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Assessing Deformation Processes In A Complex Coastal Setting: A Geodetic–Hydrologic Perspective From Visakhapatnam

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ABSTRACT

Visakhapatnam, a major industrial and port-driven city on India's eastern coastline, shows a complex pattern of land deformation influenced by groundwater depletion, rapid urbanization, heavy industrial loading, and coastal reclamation. The Line of Sight (LOS) deformation rates for the Vizag city was derived from the Sentinel-1 data SBAS time series method (2016–2024), GRACE-FO terrestrial water storage anomalies (2002–2025), and CGWB groundwater records (2000–2025), this study examines the combined hydro-geological and anthropogenic controls on subsidence.

Time-series analysis reveals substantial subsidence in several regions of Vizag, including the areas surrounding the Visakhapatnam International Airport, the port zone, and the steel and thermal power plants, with subsidence rates ranging from ~ –21 to –37 mm/yr. A subsidence rate of ~–35 mm/yr is also recorded near the Kanithi Balancing Reservoir (KBR), the primary water source for the Visakhapatnam Steel Plant and its associated township, where groundwater fluctuations induces aquifer compaction. In contrast, significant uplift of +37.3 mm/yr occurs over slag-dump sites, where progressive accumulation of slag and fill material produces reclamation-induced heave. These patterns indicate that groundwater-induced aquifer compaction is further intensified by load-induced settlement in rapidly urbanizing inland settlements, industrial areas, and major port zones. GRACE observations reveal a terrestrial water storage decline of –2.3 cm yr^{-1}, consistent with deep CGWB wells in Akkireddipalem and Anakapalli (42 m), indicating extraction from stressed semi-confined aquifers. The study highlights how integrated geodetic–hydrological monitoring is critical for anticipating deformation hazards and guiding resilient land-use and groundwater management strategies in rapidly expanding coastal cities like Visakhapatnam.

Keywords: InSAR, Coastal Subsidence, Groundwater, Vizag, Urbanization

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Gis Analysis Of Anthropogenic Impact On Shorelines Of The Sea

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ABSTRACT

Anthropogenic activity has a major effect on shoreline environments in several different ways, including coastal development, pollution, and climate change. Together, these actions alter the balance of shoreline environments, underscoring the need for sustainable management and conservation efforts, with GIS playing a crucial role. GIS analysis helps track the ongoing process of coastal sediment erosion and deposition, which is a natural phenomenon involving features that form and disappear as sea levels and other conditions change. From our viewpoint, the changing nature of the coast is often seen as a threat to our activities, so we have developed GIS techniques to monitor the influence of shoreline erosion, usually through hard stabilisation or the building of structures to stop the movement of sand. Tourism also brings challenges to coastal areas. Pollution is a sad consequence of increased human activity in many shoreline areas. Coastal construction alters natural shorelines. Construction can destroy key niches. When a shoreline is "hardened" in this way, valuable marine habitats are lost, sediment production is reduced, and this can affect beaches in other areas. This article focuses on the importance of coastal ecosystems and examines, using GIS techniques, how human impact affects them. It will look at key threats like pollution, overfishing, and construction while discussing solutions through conservation efforts. The combination of Remote Sensing (RS) and Geographic Information Systems (GIS) has been vital in assessing and monitoring changes along coastlines, especially in response to human activities. These methods allow for the detection and measurement of shoreline shifts, offering important insights into how coastal landforms behave and how anthropogenic factors affect them. Gaining a better understanding of these dynamics helps us support a healthier and more sustainable marine environment.

Keywords: Seashore line, Population, Ecosystem, Natural Habitat, Management

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Linking Coastal Urbanization To Thermal Comfort: A Geospatial Evaluation Of LULC Related Seasonal LST Shift In India's Emerging Coastal Smart Cities .

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ABSTRACT

With increased population pressure, economic development, changing land-use patterns, and climate variability, the Indian coastal regions have undergone a rapid transformation. Changes due to rapid urban land expansion have drawn wide attention to their effect on the urban thermal environment, to which LULC plays vital role. Enhanced UHI effect by global warming increases the level of public health hazard and socioeconomic losses. The aforementioned drivers interact to influence local environmental conditions, resulting in changes in land surface temperature, vegetation health, humidity, and the extent of UHIs. Understanding these interrelated processes across diverse yet comparable coastal settings is crucial for developing efficient and climate-resilient urban approaches.This work presents an overall multi-decadal spatio-temporal analysis of major coastal cities-Panjim, Mangalore, Kochi, and Thiruvananthapuram- from 1991 to 2023. By integrating multi-decadal climate records with satellite-derived land-use and land-cover maps, NDVI/NDBI indices, and surface temperature data, this study demonstrates long-term environmental transformations due to urbanization and climatic fluctuations. The findings present both shared trajectories and city-specific patterns, revealing the complex vulnerabilities of India's coastal urban ecosystems. The evaluation across these cities reveals apparent seasonality and a decrease in urban thermal comfort throughout both UHI and non-UHI zones, indicating the broad influence of urban surface modifications. The increase in impervious surfaces heightens the absorption of heat, adding to these increasing trends of LST.Vegetation health assessments using NDVI highlight the healthy vegetations in eastern Kochi and northern Thiruvananthapuram, while reduced NDVI characterizes their urban cores due to construction activities and loss of vegetation cover. The NDBI patterns confirmed intensified urbanization, while the strong positive correlation with LST for both cities expresses the contribution of expanding built-up surfaces to surface heating. In contrast, for Panjim and Mangalore, the correlations between LST–NDVI and LST–NDBI weakened, indicating a reduction in thermal contrasts between built-up and vegetated surfaces. While the UHI zones persisted, they became more localized and less intense due to monsoon-driven cooling. Cumulatively, the present study highlights how land-use shifts, climatic variability, and rapid urban expansions have exerted far-reaching impacts on India's coastal cities and, in this respect, brought forward urgent needs for response through climate-responsive urban planning, expanded green-blue infrastructure, ecological buffer restoration, use of reflectant materials, and controlled urban sprawl to increase resilience and thermal comfort across rapidly urbanizing coastal regions.

Keywords: Coastal Cities, Urban Sprawl, Climate Variability, Urban Heat Island, Satellite

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Morphodynamic Shifts in the Indian Sundarban Delta: Tracing the Impact of Natural Processes and Human Interventions (1972–2025)

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ABSTRACT

The Indian Sundarban Delta (ISD), situated at the confluence of the Ganga–Brahmaputra– Meghna river system along India's eastern coast, represents one of the most geomorphologically dynamic and environmentally fragile deltaic environments in the world. Over the past five decades, the region has experienced pronounced morphodynamic alterations driven by both natural processes, such as relative sea-level rise, coastal wave activity, and variations in sediment flux, and anthropogenic interventions, including upstream flow regulation through dams and barrages. This study investigates the long-term shoreline and island morphological evolution of the ISD from 1972 to 2025 using multi-temporal Landsat imagery acquired under consistent tidal conditions. Shorelines were manually delineated and analyzed using the Digital Shoreline Analysis System (DSAS) in ArcGIS. A total of 45,356 transects were generated at 50 m intervals across eight coastal zones, encompassing approximately 2980 km of shoreline. Shoreline change metrics, Net Shoreline Movement (NSM) and End Point Rate (EPR), varied between –3286 m to +4510 m and –62.97 m/yr to +125.75 m/yr, respectively. Areal analysis of 92 tidal islands revealed a net land loss of 72 km², resulting from 256.31 km² of erosion partially offset by 183.88 km² of accretion. Ocean-facing island margins exhibited the highest morphodynamic instability and erosion intensity. The formation of new sand patches in certain regions indicates localized depositional activity that may evolve into stable landforms under favorable hydrodynamic conditions. The observed spatio-temporal trends reflect the synergistic influence of sea-level rise, sediment retention upstream, swell wave dominance, and increasing cyclone frequency, emphasizing the urgency for adopting integrated and adaptive coastal management strategies to sustain the delta's fragile ecosystem and human livelihoods.

Keywords: Coastal morphodynamics, Shoreline dynamics, Climate change, Sundarbans, Sea- level rise (SLR), DSAS

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Shoreline Change Assessment Of North Andaman & Great Nicobar Islands: A Remote Sensing Perspective.

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ABSTRACT

The Andaman and Nicobar Islands host unique and diverse coastal ecosystems which are vulnerable to multi hazard impacts. There is a major Knowledge gap in long-term shoreline change monitoring after the 2004 Indian Ocean Tsunami. The current study aims to quantify and analyses multi-decadal shoreline dynamics pre and post tsunami for the North Andaman and Great Nicobar Islands using geospatial techniques. The key objective is to assess the impacts of disasters and natural process on shoreline dynamics of the islands.

Shorelines from 1990-2024 were extracted through modified Normalized Difference Water Index (mNDWI) on Landsat Imagery from Google Earth Engine. They were analyzed using DSAS v6.0 and ArcGIS Pro. Different DSAS metrics (EPR, NSM, SCE) were derived from the analysis and the change rates were compared across time intervals to identify trends among the islands. The Great Nicobar Islands showed high erosion while the North Andaman Island exhibited widespread accretion, likely linked to tectonic upliftment and subsidence followed by the 2004 Earthquake and Tsunami. Interval-based analysis revealed rapid shoreline changes during the post-Tsunami period. Shoreline and ecological recovery were observed in the subsequent years, with stabilization occurring in recent years.

This research underscores the dynamic nature of island coastlines along seismically active zones
and emphasize the necessity for continuous monitoring and management programs for Disaster Risk Reduction initiatives for coastal zone management like inclusive land use planning and coastal ecosystem management.

Keywords: Shoreline change rates, DSAS, Erosion, Accretion, Andaman and Nicobar Islands

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Spatio-Aware Temporal Convolutional Network For Probabilistic Shoreline Prediction In Data-Scarce Coasts

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ABSTRACT

Prediction of shoreline evolution is critical for sustainable coastal management. Yet, traditional process-based models demand extensive field data and computational resources, making them impractical for data-scarce coasts like Kerala. This study proposes a lightweight spatio-aware Temporal Convolutional Network (TCN) for probabilistic shoreline prediction using entirely open-source datasets. The framework integrates natural and anthropogenic drivers of shoreline change, aiming to achieve spatial generalizability across contrasting coastal settings. Shoreline timeseries were derived from multi-decadal Landsat imagery using the CoastSat toolkit, while environmental forcings were obtained from ERA5 (winds and waves) and TPXO10 (tides). Anthropogenic features such as groynes and breakwaters, along with natural features like tidal inlets, were encoded as spatial conditioning inputs through Feature-wise Linear Modulation (FiLM). The TCN employs dilated convolutions to capture both short- and long-term dependencies efficiently, preceded by an initial convolutional layer to embed spatial context. A heteroscedastic Gaussian likelihood formulation enables explicit modelling of predictive uncertainty, with training based on a negative log-likelihood (NLL) loss. Model performance is assessed using satellite-derived and field-surveyed GPS shorelines from three representative coastal domains—southern, central, and northern Kerala—to test cross-regional transferability. Evaluation metrics include RMSE, MAE, correlation coefficient, coefficient of determination (R^2), and the continuous ranked probability score (CRPS) to quantify probabilistic accuracy. Preliminary results indicate promising spatial generalisability, suggesting that the proposed framework could serve as an efficient, data-light alternative to conventional numerical models, enabling accurate shoreline forecasting in resource-limited coastal regions.

Keywords: Shoreline prediction, Temporal convolutional networks, Kerala Coast, Coastal management

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A Food Security Perspective on Microplastic Contamination in an Economically Important Freshwater Teleost

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Microplastics, which are plastic fragments less than 5mm, are increasingly an environmental concern, particularly in large riverine ecosystems such as the Mahanadi, one of peninsular India's major rivers. Rivers serve as conduits for transferring terrestrial contaminants to marine environments. Small Indigenous Fish Species (SIS), owing to their nutrient-rich nature, are important for nutrition and livelihoods across eastern and northeastern India. These fish experience ecological disruption due to the buildup of microplastics in aquatic environments and their accumulation in various organs, such as the gonads and brain. Our research highlights the presence of numerous microplastics within tissues of common and economically important SIS such as *Puntius sophore*, *Amblypharyngodon mola*, *Chanda nama*, and *Mystus nigriceps*. The presence of microplastics has been demonstrated in all of these fish species, with concentrations ranging from 70 to 90 particles (0.1 µm to 5,000 µm) per fish. The fragments were the most abundant morphotype as depicted by the Co-efficient of Microplastic Impact (CMPI) analysis. Particle size analysis indicated that particles <50µm accounted for ~80% total contamination, which suggests extensive invasion into fishes' tissues.
Environmental monitoring via water sampling at various riverine locations revealed microplastic bundance of various size fractions (0.1-1000µm) to be positively related to factors such as Total Dissolved Solids (TDS) and Conductivity ($r > 0.9$). On the other hand, pH, hardness, and Total suspended solids (TSS) show a strong negative correlation ($r < -0.7$). Concentrations of microplastics were mployed to calculate several hazard indices, such as the Pollution Load Index (PLI), Average Dietary Intake (ADI), and Polymer Hazard Index (PHI), all of which indicated high levels of threat. The extensive microplastic contamination reported in these nutritionally relevant fish species raises concerns about food safety for consumers and the sustainable long-term maintenance of SIS populations. It underscores the need for rigorous research and effective mitigation measures to safeguard both SIS populations and human health.

Keywords: Pollution Load Indices, SIS, Fish health, Environmental monitoring, Freshwater

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Shoreline retreat of the Jambu Dwip of Indian Sundarban and its impact on eco-tourism

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ABSTRACT

Jambu Dwip, an isolated eviction island, in the south-west corner of Sundarbans, well known for transient fishing communities' homeland since 1955. The aim was study the impact of shoreline changes on tourism initiative of Jambu Dwip.The study, comprising ground survey and geo-spatial techniques to understand the dynamism of the shoreline and its subsequent impact on eco-tourism. The island came into existence after a cyclone in 1970. The rate of erosion in Jambu Dwip is 0.187 sq.km yr. ^{1} between 1985 to 2010 , has been part of the buffer zone of the Indian Sundarbans, where ecologically sound practices with fishing permitted (1980). This uninhabited island lost forest cover from 6.095 sq.km in 1986 to 5.003 sq.km in 2012 or about 10% where land cover 5.24 sq.km in 2011 to 4.79 sq.km in 2024. Repetitive cyclones are affecting the loss of mangrove forest and destruction of coastal resources where extending rate of erosion is 49.08m/yr. and accretion 122.4m/yr. The changes in the islands and coastal regions are due to various oceanographic and riparian forces and anthropogenic interventions. Jambu Dwip , a biodiversity hotspot which attracted a vast number of local tourist. Over the period tourism has declined due to progressive shoreline shifting and degradation of biodiversity. Jambu Dwip is currently reserved forest under the Govt. of India. In recent years State Govt. is striving to revamp eco-tourism initiatives which may benefits of local boat operators, guide mans, local community, local vendors and local guest house.

Keywords: Coastal erosion, Mangrove, Tourism, biodiversity hotspot, local community

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Bharati – An Ai-Based Rip Current Detection Framework For Beach Safety

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ABSTRACT

Rip currents remain a leading cause of beach-related drowning incidents along the Indian coastline, underscoring the urgent need for advanced technological solutions capable of detecting hazardous nearshore circulation in real time. BHARATI (Beach Hazard Assessment and Rip Avoidance Tracking Interface) is an indigenous AI-based rip current detection framework currently under development at Space Applications Centre (ISRO) with the long-term goal of supporting operational beach safety and decision-support systems. The present work discusses the development of a comprehensive training pipeline leveraging high-resolution satellite imagery, beach video footage, and manually annotated datasets representing both human presence and rip-current signatures. A suite of state-of-the-art deep learning architectures— including YOLOv8, YOLOv11, EfficientDet, RT-DETR, and Faster R-CNN—have been trained and benchmarked to evaluate their suitability for detecting rip currents and identifying swimmers within dynamically evolving nearshore environments. Preliminary evaluation results indicate that YOLO-based models provide an optimal balance of detection accuracy and inference speed, while transformer-based architectures demonstrate notable strengths in capturing complex rip patterns despite higher computational demands. Current efforts are focused on expanding training datasets, improving model generalization, and conducting validation experiments using controlled video scenarios. Optimization for edge deployment and testing on embedded computing platforms such as NVIDIA Jetson computing boards constitute the next stage of development, prior to pilot-scale real-time assessments at selected Indian beaches. This ongoing research highlights the potential of integrating artificial intelligence, coastal observations, and smart sensor technologies to create a scalable and cost-effective rip current monitoring solution that may significantly enhance beach safety and support risk-informed coastal management.

Keywords: Rip currents, Beach safety, Artificial intelligence, Deep learning, Coastal hazards

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Safe Beach: Leveraging Ai/Ml-Powered Rip Current Forecasting To Improve Coastal Safety Measures

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ABSTRACT

Rip currents are a leading cause of coastal drownings worldwide, yet predicting them remains a significant challenge. Traditional empirical models often fall short because they struggle to account for the complex, non-linear interactions between different oceanographic factors. To address this gap, we developed **"Safe Beach"**, a machine learning-based forecasting system now operational at the Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC), Indian Space Research Organization (ISRO).The system is built on a two-stage approach: detection followed by prediction. First, we use a YOLO-V11 computer vision model to spot rip current signatures in Timex imagery from public video feeds and Video Beach Monitoring Stations (VBMS). This detection phase achieves 90% precision, creating a verified database that trains our primary prediction engine. This engine uses a stacked ensemble framework—combining Random Forest, Gradient Boosting, XGBoost, and Support Vector Machines—capped by a meta-learner to synthesize the final forecast. The model relies on key inputs including significant wave height, wave period, wave direction, and spectral directional spread derived from the satellite-assimilated WaveWatch III model, along with tidal elevation data. Currently, Safe Beach is monitoring 175 locations along the Indian coast. Built in Python, it runs autonomously, processing daily data to produce five-day forecasts at six-hour intervals. During the testing phase, the ensemble model demonstrated over 85% accuracy, significantly reducing the false positives common in traditional methods. Safe Beach is accessible via the MOSDAC portal at: **https://www.mosdac.gov.in/safebeach.** The system offers lifeguards and coastal authorities a reliable, operational tool for managing beach safety.

Keywords: Rip currents, Beach safety, Artificial Intelligence, Machine Learning, Coastal hazards

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Spectral and Thermal Characterization of Andaman Mud Volcanoes Using Landsat 8 Imagery

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ABSTRACT

This study examines the characteristics of mud volcanoes in the tectonically active Andaman Islands using Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) data. Landsat 8's multispectral capabilities were applied to map mud volcano locations and analyze their spectral behavior through surface reflectance and thermal emissivity. Land Surface Temperature (LST) was estimated from TIRS bands and converted to degrees Celsius, while OLI bands spanning the visible, near-infrared, and shortwave infrared regions were used to infer the mineralogical composition of the extruded materials. The analysis identified seven mud volcanoes—two in Diglipur and five in the Baratang region—with LST values ranging from approximately 27.3 °C to 29.6 °C. Spectral reflectance patterns indicated the presence of minerals such as pyrophyllite, quartz, nontronite, chlorite, and illite, supported by secondary geochemical information. Overall, Landsat 8's moderate-resolution multispectral and thermal data provide an efficient and cost-effective tool for monitoring mud volcanic activity and assessing surface mineralogy across the Andaman Islands.

Keywords: : Landsat 8, Mud volcanoes, Land Surface Temperature (LST), Spectral reflectance

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Dynamic Triggering Of Micro Earthquakes By The Mw 7.6 Tsunamigenic Philippine Trench Earthquake (02 December 2023) Observed From OBS Data In The Andaman- Nicobar Region

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ABSTRACT

The studies on dynamic triggering of earthquakes and tremors by distant large earthquakes has grown significantly in recent years. Such remote triggering is commonly observed in subduction zones, where regional stress conditions are already complex. Geothermal and volcanic regions, in particular, are highly susceptible to local earthquake triggering by both regional and remote seismic events. The transient stresses carried by the surface waves of distant earthquakes can activate faults that are close to failure. A passive OBS experiment was carried out in the eastern offshore area of the Nicobar Islands, Andaman Sea, between 10 October 2023 and 20 January 2024. During this period, a Mw 7.6 teleseismic earthquake occurred on 02 December 2023 along the Philippine Trench and was clearly recorded by the OBS network. Following this event, we carried out a systematic search for remotely triggered earthquakes and tremors in the Andaman-Nicobar region. We analyzed the waveform data for a 6-hour window before and after the teleseismic event to examine local earthquakes potentially triggered in the Andaman-Nicobar region. The computed dynamic stress is 3.914 kPa, which exceeds the commonly cited 1 kPa threshold for dynamic triggering and is therefore sufficient to enhance local seismicity. To identify triggered events, we used power spectral density analysis, manual waveform inspection, STA/LTA detection, beta statistics, and matched-filtering techniques. The triggering begins during the passage of the high- amplitude Love waves and continues through the arrival of the Rayleigh waves. Based on our initial analysis of the OBS01 waveforms, we identified two local earthquakes triggered during the passage of the surface waves, including the largest event of M_L 2.4 and a smaller event of M_L 1.9.

Keywords: Dynamic triggering, Philippine earthquake, Andaman-Nicobar, Micro earthquakes

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Tectonic controls on rupture velocity along the Andaman-Sumatra accretionary wedge during the 2004 megathrust earthquake

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ABSTRACT

The megathrust Sumatra earthquake, 9.1 M_w of 26 December 2004 nucleated off northern Sumatra and propagated northward along ~1300 km of the Andaman–Nicobar-Sumatra accretionary wedge. The rupture propagation was not uniform along strike of the accretionary prism. In this study, we use a newly compiled high-resolution multibeam bathymetry dataset (~197,500 km²), integrated with seismic reflection profiles, and compare with the rupture propagation to understand how along-strike forearc structure influenced rupture velocity during the event. The rupture began off northern Sumatra at a relatively low velocity of ~1.5 km/s within a broad, low-taper accretionary wedge characterized by long-wavelength folding and a shallow, weak decollement. Rupture velocity increased up to 2.6 km/s towards north Sumatra to Nicobar segment, where thick Bengal and Nicobar fan sediments present, shows moderate wedge taper, and longer fold wavelengths that create a mechanically weak and laterally continuous wedge that allows faster rupture propagation. A distinct reduction in velocity ~1.8 km/s occurred near the Andaman-Nicobar Transition segment, where wedge taper increases, fold wavelengths shorten, and structural heterogeneity associated with the subducting Ninety-East Ridge disrupts the wedge continuity. In the northern Andaman segment, the wedge becomes narrower, steeper, and more strongly coupled, with short wavelength folding. Here the rupture velocity slightly increased compared to the Andaman-Nicobar Transition segment to ~2.1 km/s and eventually terminated. The observed variations in rupture velocity show a consistent relationship with wedge taper, fold wavelength and sediment thickness. These results indicate that morphotectonic segmentation of the Andaman-Nicobar-Sumatra accretionary wedge exert significant control on rupture propagation during the 2004 megathrust earthquake.

Keywords: Subduction zone, accretionary prism, megathrust earthquake, rupture zone, morphotectonics

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Seismicity and Tectonic Stress Redistribution at the Alcock Rise Seamount: Insights from OBS Data in the Andaman Sea

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ABSTRACT

This study explores the seismicity of the Alcock Rise seamount in the Andaman Sea using data from a passive Ocean Bottom Seismometer (OBS) network deployed by CSIR-NIO between 25 December 2013 and 10 May 2014. Of the twelve OBS units, OBS09 was positioned on the Alcock Rise, enabling focused monitoring of local earthquake activity. Visual analysis of continuous waveform data using SEISAN software identified 298 events, of which 248 were accurately located using the HYPOCENTER program. A prominent cluster of earthquakes was observed near the boundary of the Alcock Rise, adjacent to the Andaman backarc basin. The clustering of events, with focal depths between 15–19 km and magnitudes ranging from 2.0 to 4.5, suggests a tectonic interaction between the extensional stresses of the backarc basin and the structural integrity of the Alcock Rise. It is inferred that lateral stresses generated by basin extension are transferred and accumulated along the seamount flanks, releasing as shallow, localized earthquakes when exceeding lithospheric strength. This spatial concentration of seismicity highlights the role of the Alcock Rise in accommodating and redistributing tectonic stress, offering new insights into crustal deformation and seismic hazard in the Andaman Sea.

Keywords: Alcock Rise, Ocean-Bottom Seismometers, Seismicity, Tectonic Extension, Stress Redistribution

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Soil liquefaction induced by the passage of cyclone Helen facilitated recent submarine slope failure in the Krishna-Godavari basin, Bay of Bengal

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ABSTRACT

A large-scale submarine slope failure has been identified in the shelfal region of the Krishna– Godavari (KG) Basin, Bay of Bengal, using multi-temporal geophysical datasets acquired over the past two decades. The failure, which occurred between 2009 and 2015, resulted in the removal of nearly 160 m of sedimentary strata and displaced an estimated 11 km³ of material. Cyclone Helen (November 2013) is considered a plausible external trigger; however, the event was primarily governed by preconditioning of gas-charged and mechanically weak sediments in the shelfal domain.Pre-failure 3D seismic reflection data from the Directorate General of Hydrocarbons (DGH) indicate that the failure surface coincides with a paleo-submarine canyon intersected by active faults, forming a structurally weak zone. Beneath this zone, high-amplitude reflections with reversed polarity point to gas-charged and overpressured sediments. The presence of mud volcanoes, pockmarks, low-frequency acoustic shadows, and post-failure gas flares observed in water-column data collectively confirm an active fluid-expulsion system. Overpressure buildup within these gas-saturated layers likely promoted soil liquefaction, reducing shear strength and preconditioning the slope for failure. The cyclic wave loading during the passage of cyclone Helen facilitated liquefaction-induced loss of sediment strength and may be considered as a compelling mechanism for the observed slope failure in the KG basin. These findings highlights the dynamic coupling between fluid migration, overpressured system, and weak external triggers in narrow-shelf basins in facilitating slope failure. Therefore, there is an urgent need for continuous monitoring of overpressured, hydrocarbon-bearing continental margins such as the KG Basin to better assess future geohazard risks.

Keywords: Soil liquefaction, mud volcanism, slope instability, overpressured system, KG Basin, geohazards, submarine landslide

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From Slope Failure to Seepage: Geohazard and Biogeochemical Impacts of Submarine Landslides in the Krishna-Godavari Basin, Bay of Bengal

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Submarine landslides are among the most significant geohazards in continental margins, posing risks to offshore infrastructure, submarine communication cables, and coastal populations through their potential to trigger tsunamis and destabilize seafloor environments.In the Krishna-Godavari (KG) basin, Bay of Bengal, integrated geophysical and field-based investigations reveal both large-scale and localized impacts of slope failure events. Time-lapse geophysical analysis indicates a major submarine slope failure between 2009 and 2015, involving ~160 m erosion of sedimentary strata with an estimated volume of ~11 km³ and a fan-shaped mass transport deposit (MTD) covering ~70 km² at depths of 950–1100 m. This represents one of the largest slope failures documented using repeated surveys. Potential external triggers include Cyclone Helen (2013), extreme flooding events (2010 and 2013), and a moderate earthquake (M 6.0, 2014), highlighting the interplay between sediment pre-conditioning and moderate external forcing in driving slope instability. Complementary ROV and sub-bottom profiler surveys in shallow waters of the basin identified an active landslide scar associated with methane seepage. The seepage sites were characterized by gas bubbling, white microbial mats, and sulfidic sediments, with dissolved methane concentrations (~172 nmol/L) near the seabed significantly exceeding background seawater levels. These seepages are likely induced by the reduction in lithostatic load following slope failure, independent of gas hydrate dissociation. Although no mature chemosynthetic communities were observed, localized microbial mats suggest the onset of nascent cold seep development. Collectively, these findings demonstrate that submarine landslides in the KG basin not only represent a geohazard to human activities but also act as catalysts for methane release and the initiation of new seep environments. This underscores the dual role of slope failures in both hazard generation and biogeochemical transformation of continental margin ecosystems.

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Integrated Remote Sensing and Hydrological Modelling for Long-Term Analysis of Discharge, Sediment Dynamics, and Morphological Changes in the Krishna–Godavari River Basins

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ABSTRACT

This study examines long-term hydrological and sediment dynamics of the Krishna–Godavari (KG) river basins through the lens of geohazards, focusing on how human-induced alterations and climate variability are reshaping flood, drought, erosion, and deltaic hazards in southern India. The Krishna and Godavari rivers, among the most heavily regulated and socio-economically critical systems in the region, have undergone major hydrological modification due to rapid land-use changes, reservoir construction, groundwater depletion, and shifting monsoon patterns. These transformations have substantially altered natural flow regimes, sediment transport, and river–delta–coastal interactions, thereby intensifying geohazard susceptibility. Using multi-decadal satellite observations (MODIS, Landsat 5/7/8, Sentinel-2, LISS IV), ground-based datasets (IMD, CWC, state irrigation departments), hydrological modelling, and cloud-based data analytics, the study reconstructs long-term hydro-sedimentary behaviour. Spectral indices (NDWI, MNDWI, NDTI) were used to map morphological changes and surface water dynamics from 1990–2024.Results show alternating phases of river expansion and contraction driven by monsoon variability, dam operations, and anthropogenic withdrawals. Significant contractions during 2000–2010 coincided with severe drought cycles and high irrigation demand, reflected in a decline in annual runoff from 112 mm to 63 mm in Krishna and from 215 mm to 148 mm in Godavari, enhancing drought hazard and altering sediment supply. A partial hydrological recovery after 2010 corresponds to improved rainfall and adjusted reservoir releases, with runoff increasing by 8–14% across several sub-basins. Overall, the Godavari Basin shows greater hydro-geomorphic stability than the Krishna, indicating relatively higher resilience to climatic stressors and geohazard triggers. Rainfall analysis (1970–2016) reveals basin-scale divergence: Krishna shows a +4.8% increase whereas Godavari displays a –6.2% decline. SWAT/ArcSWAT runoff modelling demonstrates strong performance, with calibration NSE = 0.74–0.84, validation NSE = 0.70–0.81, R^2 = 0.76–0.88, RMSE ranging from 8.4 to 19.2 m^3/s, and PBIAS between –5.3% and +7.8%. Rainfall–runoff coupling remains strong in forested upstream zones (correlation r = 0.72–0.86) but shows progressive hydrological decoupling (correlation dropping to r = 0.41–0.58) in highly irrigated and urbanizing sub-basins— conditions that elevate flash-flood and water scarcity haza

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Reservoir regulation significantly suppresses sediment delivery, with average sediment loads decreasing from 14.2–18.7 t/ha/yr in the 1990s to 7.6–11.3 t/ha/yr after 2010, and cumulative trapping efficiencies of 60–80% in reservoirs such as Srisailam, Nagarjuna Sagar, and Polavaram.Pixel-wise trend analysis in Google Earth Engine identifies geohazard hotspots where hydrological responses have shifted significantly, with negative water-spread slopes of –0.004 to –0.009 yr^{-1} and turbidity increases of 12–28%. Landsat-based LULC mapping confirms widespread conversion of forest to agriculture and built-up areas, altering infiltration, sediment connectivity, and runoff generation—key drivers of localized flood and erosion hazards. Remote-sensing-based surface water masks show strong agreement with SWAT-simulated runoff (R^2 = 0.67–0.82, RMSE = 9–17% in area–runoff relationships), demonstrating the effectiveness of remote sensing as a risk-monitoring tool in data-scarce regions. The integrated Earth observation–model fusion methodology offers a scalable approach for continuous geohazard monitoring in Indian river basins.Findings show that the Krishna–Godavari systems are transitioning into highly nonlinear hydrological regimes increasingly governed by human interventions, amplifying uncertainties in future flood, drought, sedimentation, and deltaic hazards. These quantified changes carry major implications, sediment load reductions of 32–48% in Krishna and 18–27% in Godavari have intensified delta erosion and reduced natural sediment supply; regulated flow patterns have altered flood peaks by 20–35% and long-term runoff decline rates of –0.9 mm/year (Krishna) and –0.4 mm/year (Godavari) indicate growing climatic vulnerability. By quantifying long-term hydro-geomorphic trends, identifying hazard-prone zones, and validating remote-sensing-based hydrological monitoring, this study contributes to national priorities in flood mitigation, delta protection, sustainable river restoration, and climate-adaptive water management in the Krishna–Godavari basins.

Keywords: Krishna–Godavari Basin, Remote Sensing, Hydrological Modelling, Rainfall– Runoff Dynamics, River Morphology

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Genesis of anomalous low acoustic backscatter pattern observed on the Central Western Continental Margin of India

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ABSTRACT

The analysis of high-resolution multibeam echosounder (MBES) data along the continental slopes of the central Western Continental Margin of India (WCMI) reveals a distinct and prominent occurrence of a band of low acoustic backscatter strength within 375 to 500 m water depths. This zone is sharply bounded by areas of high acoustic backscatter, both upslope at the shelf edge (< 375 m) and downslope at the foot of the continental slope (> 500 m). Generally, backscatter strength depends on the sediment distribution, surficial roughness of sea-bed and compactness of the sediments on the seafloor. We propose that the observed low backscatter strength is primarily due to the deposition of fine-grained sediments under low-energy conditions, while the high backscatter at the foot of the slope and shelf edge reflects the presence of coarse sediments and geomorphic bodies driven by stronger hydrodynamic forces. This pattern highlights the interplay between sedimentology, seafloor geomorphology, and oceanographic processes in shaping the acoustic signature of continental margins.

The region of interest is also well known for consistent prevalence of static Oxygen Minimum Zone (OMZ) throughout the year. In terms of water column depth, our observation coincides with the vertical extent of the documented OMZ. We found a strong correlation between the water depths and spatial impingement of OMZ onto the sloping seafloor, having core depth of lowest dissolved oxygen at 485 m.

In this presentation, we speculate some hypothesis which may explain the existence of a continuous band of low-backscatter strength along the slopes of the central WCMI to the OMZ.

Keywords: Acoustic, Backscatter, Geomorphology, WCMI, OMZ

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Integrated Geophysical and Geological Assessment of Sand Mining Impacts in Estuarine River Systems of Goa, India

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ABSTRACT

Sand mining is a vital global activity that supplies essential construction materials; however, when poorly regulated, it can cause profound environmental degradation. In Goa, where short and steep rivers such as the Mandovi, Zuari, Chapora, and Terekhol descend from the Western Ghats into the Arabian Sea, natural sediment supply is limited, making these systems highly sensitive to extraction pressure. Importantly, this study was supported by the Goa State Biodiversity Board (GSBB), Government of Goa, with additional support from the World Bank, representing one of the first comprehensive, government-funded scientific assessments of river health anywhere in the world. This pioneering initiative sets a global benchmark for science-driven river-basin management. To evaluate geomorphology, sediment dynamics, and the impacts of sand extraction, an integrated multi-platform geophysical and geological survey was conducted across four major rivers and thirteen additional minor river systems. Side Scan Sonar (SSS), Single Beam Echo Sounding (SBES), High-Resolution Seismic (HRS), and Multibeam Bathymetry (MBES) were employed to map riverbed morphology, subsurface structure, sediment thickness, and signatures of active and historical mining. Complementary grab-sediment sampling enabled grain-size, geochemical, and microscopic analyses. Comparative pre- and post-monsoon datasets revealed significant geomorphological adjustments, including deepened channels, eroding banks, shifting sediment bars, and partial replenishment or obliteration of mining pits. Results indicate that in several clusters, legally permitted extraction exceeds natural monsoonal replenishment, contributing to reduced water clarity, mangrove degradation, freshwater–saltwater imbalance, and declining fishery productivity. These findings underscore the need for stringent regulation, including depth limits, restricted tool usage, seasonal bans, and mandatory environmental assessments, to safeguard riverine ecosystems. Overall, the study demonstrates the critical role of continuous geophysical monitoring in ensuring sustainable sand-mining practices and in safeguarding the ecological and socio-economic stability of Goa's river systems.

Keywords: Sand Mining Impact; River Geomorphology; Geophysical Survey; Estuarine Dynamics; Sustainable River Management

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Estimating Submarine Landslide Volumes Using A Gis-Integrated Numerical Tool

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ABSTRACT

Submarine landslides are among the most significant mass-wasting processes shaping continental slopes and deep-sea environments. In these geomorphic settings, surface disturbances generate topographic voids or elevated features, and estimating their volumes is critical for understanding seafloor morphology, evaluating slope stability, and assessing geohazards such as tsunamigenic potential and infrastructure damage. This study used a GIS- based numerical tool that reconstructs the pre-failure surface from adjacent undisturbed morphology to calculate the evacuated volume of geomorphic disturbances. The method relies on the assumption that the adjacent terrain retains the original surface geometry prior to failure. The difference between the reconstructed presurface and the post-event bathymetry provides a quantitative estimate of material removed or displaced during the mass-wasting event. The accuracy of the technique was evaluated using synthetic DEMs having well-defined submarine slope failures.

Keywords: Bathymetry, Morphology, Submarine Landslides, GIS, Numerical Modelling.

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Rapid 21st century warming of subsurface north Indian Ocean

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ABSTRACT

Analysis of ocean mean temperature (OMT) derived from the Global Ocean Reanalysis and Simulations (GLORYS) product for the period 1993-2024 shows a marked increase in subsurface warming across the north Indian Ocean. The most pronounced temperature rise occurs below the mixed layer down to about 300 m. Based on the contrast between surface and subsurface trend patterns, three regions have been examined, including the northern Arabian Sea, the southern Arabian Sea, and the Bay of Bengal. The southern Arabian Sea exhibits the strongest signal, with a warming rate of about 0.07 °C/yr at 100 m, which is almost twice the rate observed at the surface. The northern Arabian Sea also shows rapid subsurface warming,
with rates of 0.05 °C/yr between 100-200 m, exceeding the surface trend, and in this region the subsurface layers below 150 m exceed the warming observed in the southern Arabian Sea. The Bay of Bengal shows the slowest increase in temperature in the upper layers compared to the Arabian Sea, although the depth range between 80-150 m warms at nearly double the surface rate, reaching about 0.04 °C/yr. The Arabian Sea shows a robust strengthening of subsurface warming during the last two decades, extending down to almost 500 m, while the Bay of Bengal shows a muted response in the upper 250 m and stronger warming only below this depth. These results highlight a clear contrast between surface and subsurface temperature changes and indicate that regional ocean dynamics play a major role in shaping the observed warming structure.

Keywords: OMT, Arabian Sea, Bay of Bengal, mixed layer, subsurface warming

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AUV-Based Multisensor Mapping Reveals Fluid-Flow Dynamics, Habitat Diversity, and Seep Evolution in the Krishna–Godavari Basin

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ABSTRACT

Autonomous Underwater Vehicles (AUVs) are advancing deep-sea geoscience by enabling highresolution, multi-sensor investigations of cold seeps, gas hydrates, and seafloor fluid flow. During a 2023 NIOT–CSIR-NIO–NCPOR expedition, an AUV surveyed the Krishna–Godavari (KG) Basin, building on the 2018 discovery of a major seep field. Operating at 30 m and 5 m altitudes, the AUV collected multibeam bathymetry at ~1 m and ~25 cm resolutions, watercolumn imaging (WCI), synthetic aperture sonar (HiSAS), sub-bottom profiling (SBP), and high-definition photographic imagery. Bathymetry mapped more than 100 pockmarks linked to focused fluid escape, while WCI detected ~303 gas flares, revealing clear spatial variability: fault-aligned active venting in the north, vigorous discharge and shallow hydrates in the southwest, and extensive but largely inactive carbonate beds in the southeast. SBP imaged subsurface faults beneath active pockmarks, confirming a fault-controlled seep system, and HiSAS backscatter distinguished microbial mats, carbonate crusts, soft sediments, and vent habitats. High-definition imagery revealed diverse chemosynthetic fauna including Bathymodiolus sp., Calyptogena sp., tubeworms, ampharetid worms, and bacterial mats. To refine habitat and faunal discrimination, pixel-based image classification using ilastik identified nearly ten biological and geological features like, Bathymodiolus sp., goose barnacles, bacterial mats, sea spiders, dead bivalves, Calyptogena sp., tube worms, faunal burrows, Siboglinidae tubes, and gas bubbles allowing clear separation of active and relict communities. Integrating geophysical signatures, fluid-flow characteristics, seafloor morphology, and faunal distributions reveals a natural progression from high-flux, microbially dominated sediments to zones hosting early colonizers and mature chemosynthetic communities, culminating in carbonate-capped terrains and relict mounds where venting has diminished. This multidisciplinary AUV-based framework provides a strong baseline for environmental monitoring, resource assessment, and improved understanding of deep-sea fluid flow and ecosystem dynamics.

Keywords: AUV, Krishna Godavari Basin, Cold Seep, Active Gas venting, Chemosynthetic Communities

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Evidence of Recent Submarine Slope Instability and Structurally Guided Gas Seepage in the KG Basin

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ABSTRACT

Time-lapse geophysical data from the Krishna–Godavari (KG) Basin, Bay of Bengal, reveal a major recent submarine landslide that occurred between 2009 and 2015. The event is characterized by significant head-scarp retreat, removing ~160 m of sediment and mobilizing an estimated ~11 km³ of material. The resulting fan-shaped mass-transport deposit (MTD), emplaced at 950–1100 m water depth, spans ~70 km² and attains a thickness of ~60 m, marking it as one of the largest slope-failure events documented from repeated geophysical surveys in the region. While several external triggers, including cyclonic activity, extreme riverine floods, and a regional Mw 6.0 earthquake, likely contributed to slope destabilization, the evidence strongly indicates that pre-conditioning of weak, unstable sediments was the dominant factor that ultimately enabled this large-scale failure. In response, high-resolution multibeam and water- column imaging surveys were undertaken to monitor ongoing seafloor instability. As part of Cruise SSK187 (May), detailed seafloor mapping was conducted to evaluate additional recent slumping and fluid-related deformation. Multibeam bathymetry, water-column backscatter, and sub-bottom profiler (SBP) data were acquired along systematic survey lines. Processed datasets reveal discrete gas flares along multiple transects, indicating active fluid escape. These seepage zones are spatially associated with local structural features such as faults and fractures, suggesting structurally controlled fluid migration. SBP integration is underway to delineate shallow stratigraphy and subsurface pathways. The combined time-lapse and cruise-based observations advance our understanding of sediment instability, fluid–sediment interactions, and the evolving geohazard potential of the KG Basin.

Keywords: Krishna – Godavari Basin, Multibeam Bathymetry+Water column Imaging, Active
gas venting, faults and fractures,

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Geomorphological degradation driven by unregulated sand mining in the Terekhol River, Goa: Evidence from integrated geophysical, geological and remote sensing

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ABSTRACT

Sand is a vital natural resource widely used in construction, infrastructure development, cement and glass manufacturing, and land reclamation, leading to increasing extraction pressure across India; however, unregulated sand mining severely threatens estuarine river systems, particularly in Goa, where rivers support rich ecosystems, maintain coastal environmental stability, and provide essential livelihood resources such as fishing, agriculture, and inland transport. The Terekhol River, a major fluvial system of North Goa, plays a crucial role in sustaining water availability, ecological balance, and socio-economic activities for several villages along its course, but has undergone rapid geomorphological deterioration due to uncontrolled sand extraction. To assess the extent and drivers of degradation, this study conducted detailed pre-monsoon (February 2021) and post-monsoon (January 2022) geophysical and geological surveys integrating single-beam echo sounding, Side-Scan Sonar (SSS), high-resolution shallow seismic profiling (HRS), geological sampling, and remote sensing analysis. Bathymetric mapping provided high-resolution riverbed elevations, while SSS mosaics revealed key geomorphological features including ripple marks, sand bars, consolidated sediment mounds, eroded banks, rock outcrops and numerous traditional and dredging type mining signatures several located dangerously close to riverbanks, roads, bridges, jetties, and other critical infrastructure. Post-monsoon SSS data further showed disappearance of ripple marks, reduction of sediment bars, step-like erosional features, and a marked increase in collapsed riverbank vegetation including uprooted coconut palms and associated debris, collectively indicating progressive bank instability linked to monsoonal scouring and active sand extraction. High-resolution shallow seismic profiles indicated predominant riverbed degradation and deepening down to bedrock in several stretches and minimal sediment replenishment, confirming insufficient upstream sediment supply. Geological analysis of 22 sediment samples revealed sand-dominated compositions with

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variable sorting, iron-oxide coatings, shell fragments, lithic grains, mud patches, and cohesive mud cakes produced by ongoing bank erosion, while integration with historical remote sensing records identified severe bank destabilisation and 5-8 m lateral erosion at multiple sites, along with clear evidence of hazardous and unregulated mining pits concentrated in downstream reaches. Overall, the combined results demonstrate that natural monsoonal processes, amplified by continuous and unregulated sand mining, are driving significant geomorphological instability, ecological degradation, and socio-economic risks along the Terekhol River, highlighting the urgent need for strict regulatory intervention, continuous monitoring, and sustainable management strategies to safeguard Goa's vulnerable estuarine river systems.

Keywords: Riverbed Geomorphology, Sand Mining, Geophysical surveys, Remote sensing monitoring and Vulnerability

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Evolution Of The Submarine Mud Volcano And Associated Geohazards In The Andaman Forearc Basin

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ABSTRACT

The Andaman–Nicobar Subduction Zone represents an active convergent plate margin marked by intense compressional deformation, focused fluid migration, and complex forearc basin evolution. We report a submarine mud volcano in the central Andaman forearc basin and investigate its surface morphology and subsurface seismic characteristics in relation to the compressional forearc structural regime shaped by the Diligent Fault Zone. High-resolution multibeam bathymetry reveals a circular edifice rising ~83 m above the surrounding seafloor at~1680 m water depth, with a basal radius of ~85 m. The distribution of adjacent ridges, linear structural highs, and localized depressions reflects deformation patterns consistent with the prevailing compressional stress field, indicating long-term tectonic modulation of seafloor morphology. The geophysical analysis integrates two seismic datasets multichannel seismic data and high-resolution seismic data. The multichannel dataset was subjected to detailed velocity analysis followed by post-stack and pre-stack time migration, enabling improved imaging of deeper subsurface architecture. In contrast, the high-resolution seismic profiles provide enhanced delineation of shallow structures and near-surface deformation around the mud volcano. The combined interpretation reveals a vertically oriented conduit-like feature, deformation of surrounding stratigraphy, and several steeply dipping faults spatially associated with the Diligent Fault Zone. With the present interpretation framework, the results indicate the potential role of fault-controlled fluid migration and over-pressured strata within the compressional regime in shaping the observed features. The presence of Bottom Simulating Reflectors (BSRs) in the surrounding basin suggests conditions favourable for gas hydrate presence and deeper free-gas accumulations that may interact with active fluid-migration pathways. Collectively, this integrated bathymetric and seismic investigation provides key constraints on the compressional and fluid-migration processes governing mud volcano development in the Andaman forearc basin. The study underscores the influence of compressional tectonics, structural pathways, and fluid–sediment dynamics in controlling submarine mud volcano activity and associated geohazards in active continental margin settings.

Keywords: Mud Volcanism, Andaman Forearc Basin, Compressional tectonics, Fluid migration, Geohazards, Gas Hydrates.

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Is the MTD Acting as a Seal, a Conduit, or a Trigger for Methane Venting in the Gas Hydrate Province?

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ABSTRACT

Time-lapse geophysical analyses from the Krishna–Godavari (KG) Basin, Bay of Bengal, reveal a major recent submarine slope failure that occurred between January 2009 and December 2015. The failure resulted in erosion of ~160 m of sedimentary strata at the head scarp and generated an estimated displaced volume of ~11 km³. The associated fan-shaped mass-transport deposit (MTD), situated at water depths of 950–1100 m, covers ~70 km² (volume ~2.2 km³) and attains a maximum thickness of ~60 m, making it one of the largest submarine slope failures documented from repeated geophysical surveys. To investigate its present-day geomorphic and fluid-flow dynamics, a high-resolution AUV survey was conducted in 2023 using multibeam bathymetry, HiSAS, sub-bottom profiling (SBP), camera imaging, and methane sensors. The multibeam and HiSAS data reveal intricate geomorphological features, including multi-episodic sediment flow pathways, frontal lobes, leveed channels, and depositional tongues that characterize the internal structure of the MTD. Water-column imaging (WCI) and methane sensor measurements indicate active gas venting across the deposit, suggesting focused fluid escape zones. SBP data exhibit strong internal reflections, vertically disrupted acoustic columns, chimney-like features, and a buried paleo-seafloor surface, pointing to ongoing subsurface fluid migration and potential stratigraphic disruption caused by the MTD emplacement. Together, these observations raise a critical question regarding the interaction between the recent MTD and the underlying gas hydrate system, including whether MTD-induced changes in overburden stress, pore-pressure redistribution, and sediment remobilization have altered the gas hydrate stability zone (GHSZ), modified the bottom-simulating reflector (BSR) depth, or facilitated methane release into the water column. This study integrates time-lapse geophysics and modern AUV-acoustic imaging to provide new insights into slope failure dynamics, sediment-gas interactions, and geohazard processes in one of India's most hydrate-rich offshore basins.

Keywords: Submarine Landslide, Krishna Godavari Basin, Active Gas Venting, Geomorphology, and Gas Hydrates

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Morphology, distribution and origin of submarine landslides in Southwestern Continental Margin of India

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ABSTRACT

This study reports for the first time, a large-scale submarine landslide com plex off Quilon, collectively named the Quilon Slide Complex (QSC), located on the Southwestern Continental Margin of India (SWCMI). Using high-resolution multibeam bathymetry and sub-bottom profiler data, we mapped the entire QSC slope along a 140 km stretch. Bathymetric analysis identifies slide scars up to 40 km wide with associated run-out deposits extending over 65 km. Sub-bottom profiler data indicate a diverse range of mass transport deposits covering an area of 4,400 km², ranging from large to smaller blocky deposits within the basin. A total of three submarine landslides (S1, S2 and S3) discernible in the QSC, occur along a prominent crack system in the upper slope region. Our investigation suggests that these cracks, extending over a 60 km stretch between the Alleppey Terrace in the north and the Trivandrum Terrace in the south, may serve as precursors to submarine landslides. We propose that sedimentation on steeply dipping slopes along fault-controlled weak zones, combined with factors such as sea- level fluctuations, bottom-current erosion, and slope angle variability, acted as the primary preconditioning and triggering factors, collectively contributing to the complex failure episodes observed in Slides S1, S2, and S3. This study provides valuable insights for modeling the propagation of large-scale submarine landslides in continental margins.

Keywords: Multibeam bathymetry, Sub-bottom profiler, Quilon Slide Complex,Mass wasting
processes, Mass Transport Deposits, Indian Continental Margin

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Seismic imaging of the gas hydrate deposits for geohazard assessment in the Krishna- Godavari basin, east coast of India

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ABSTRACT

The Krishna–Godavari (KG) offshore basin along India's eastern continental margin is a major pericratonic rift basin and an important region for gas-hydrate studies. The present study analyzes a 2D seismic profile from the KG-DWN-98/2 block in the KG basin acquired by ONGC, which spans the continental shelf–slope transition where water depths increase from about 100 m to nearly 1 km. Data is collected using a total of 906 shots with each shot gather containing 955 number of traces. The distance between the two consecutive shots is 50 m and between two traces is 6.25 m. The CDP interval is 3.125 m. The main objective is to map the Bottom Simulating Reflector (BSR), as its character and continuity provide insights into gas-hydrate distribution, subsurface fluid flow and potential geohazards. The seismic data has been processed using a standard processing workflow that included geometry merging, band-pass and FK filtering, top muting, WEMA (applied to shot gathers), CDP sorting, velocity analysis, NMO correction, Radon filtering, stacking, post-stack time migration and post-stack deconvolution. The processed seismic section reveals a seafloor having complex topography and several growth faults, suggesting rapid sedimentation and fault-controlled fluid pathways, and also indicates that Pre- stack Depth Migration (PSDM) would likely improve imaging in this complex setting. A strong, coherent BSR is recognized by its polarity reversal relative to the seafloor and its cross-cutting relationship with the underlying strata. Future study plans are to incorporate refraction tomography to better constrain the shallow velocity structure, followed by Full-waveform Inversion (FWI) for higher-resolution subsurface imaging. These advanced approaches are expected to enhance the understanding of gas-hydrate systems, help identify potential over- pressure zones and thus the slope-failure zones and support improved geohazard assessment across the continental slope region of the KG basin.

Keywords: K-G, BSR, Gas-hydrates, Geohazard, Seismic

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Evaluation of Seismic Hazard in the Makran Subduction Zone Using b-Value Variations

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ABSTRACT

This study investigates the b-value, the seismic parameter derived from the Gutenberg-Richter law, to understand the seismicity patterns and stress distribution across the Makran subduction region. Using ZMAP software, the area was divided into three distinct epicentral blocks, facilitating a detailed analysis of the heterogeneous seismicity and stress distribution. Spatial analysis revealed that regions with lower b-values, particularly near the Zendan-Minab and Chaman fault systems, correspond to high-stress zones prone to larger, potentially destructive earthquakes. Temporal analysis further indicated that declining b-values often precede significant seismic events, supporting the theory that b-value reductions serve as precursors to major earthquakes. Lower b-values in Blocks 2 and 3, compared to Block 1, suggest a higher potential for stress accumulation and larger magnitude events in the central and eastern regions. The connection between b-value analysis and historical seismicity emphasizes the usefulness of b-value as a predictive tool for evaluating seismic hazards, providing valuable insights for future seismic risk assessment in the Makran region.

Keywords: b-value,Makran, Gutenberg-Richter law

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Session Title: Wave-structure interaction

Session Convener: Prof. Trilochan Sahoo

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2	Flexural Gravity Wave Blockings And Energy Distribution In Marine And Polar Environments
3	Wave Structure Interaction And Performance Evaluation Of A Heaving Wave Energy Converter For Indian Coastal Conditions
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Wave Structure Intercation Problem Involving A Poro-Elastic Circular Plate With Varying Porosity

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ABSTRACT

This study investigates the interaction of surface waves with a flexible, porous circular plate within the framework of linear potential theory. The plate's permeability increases linearly along the radial direction, providing enhanced structural stability by reducing wave-induced forces and vibrations. To address the governing boundary value problem, a combination of hypersingular integral equations and modal analysis is employed. Both scattering and radiation problems are examined, incorporating multiple coupled natural frequencies of the plate to evaluate key hydrodynamic responses. The analysis highlights the effects of spatially varying permeability, plate depth, and stiffness on physical quantities such as added mass, damping coefficients and vertical exciting forces. Results are validated through comparison with existing studies, and the reciprocity relation is verified for the non-permeable case, offering an additional check on the numerical accuracy.

Keywords: Linear water wave, flexible circular plate, variable porosity, hypersingular integral equation, modal analysis

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Flexural Gravity Wave Blockings And Energy Distribution In Marine And Polar Environments

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ABSTRACT

The blocking of flexural gravity waves becomes increasingly significant under environmental extremes intensified by global warming, particularly when opposing currents, storm-driven flows, or rapidly evolving wave–structure interactions reduce the group velocity toward zero and drive the system toward a turning or saddle point on the hydroelastic dispersion curve. At such blocking points, wave energy ceases to propagate. It is instead reflected, locally amplified, or redistributed through enhanced scattering processes that strongly influence the stability of very large floating structures (VLFS) in open oceans and the dynamic response of sea ice under extreme forcing. Structural compressibility, arising from in-plane loads in VLFS or natural compressive stresses in sea ice, plays a crucial role by softening the effective stiffness, altering dispersion characteristics, and lowering the threshold for blocking; under higher compression, a propagating mode may vanish entirely, causing abrupt blocking, energy trapping, or mode conversion. Additional complexity arises from structural and seabed heterogeneity, which collectively modulate blocking behaviour through Bragg scattering, resonance shifts, and coupling between flexural–gravity waves and internal modes. These coupled processes have essential implications for wave attenuation, stress transmission, polar navigation channels, and the resilience of floating infrastructure in increasingly variable environments. This presentation synthesises recent advances in hydroelasticity, with an emphasis on wave blocking, scattering, and mode interactions, and highlights the extension of Fourier-based analytical frameworks to improve predictive modelling and design of coupled VLFS–ice-ocean systems under evolving climatic stresses.

Keywords: Flexural gravity waves, Very large floating structure, Floating ice sheet, Wave blocking, Wave scattering

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Wave–Structure Interaction and Performance Evaluation of a Heaving Wave Energy Converter for Indian Coastal Conditions

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ABSTRACT

Dependence on fossil fuels for energy production contributes to the harmful emission of greenhouse gases, triggering global warming. The necessity for environmental protection and sustainable development emphasized for generation of cleaner energy technologies. Ocean waves are a vast resource of renewable energy for the future. India has a long coastline and abundant wave energy resources. To utilize the advantage of heaving motion, wave energy converter (WEC) with a linear electric generator (LEG) which is a less complex mechanical system, is preferred.This study investigates the wave–structure interaction and performance characteristics of a heaving WEC in Indian coastal conditions. First, the analytical diffraction and radiation problems are carried out using the Fourier–Bessel series representation and the matched eigenfunction expansion technique. These formulations are developed within the framework of small-amplitude wave theory, assuming correspondingly small structural motions. Subsequently, the seasonal performance of the WEC is evaluated using in-situ nearshore wave measurements from two contrasting locations: off Gopalpur, Odisha, on the east coast of India (Bay of Bengal) and off Mormugao, Goa, on the west coast (Arabian Sea). These sites capture the distinct wave climates that characterize India's dual-coast environment, allowing a comprehensive evaluation of the device's performance across diverse sea states. The findings of the present study will be helpful in the design and development of various point absorber-type WEC buoy systems suitable for Indian wave conditions.

Keywords: Wave energy converter, Heaving motion, Fourier–Bessel series, Matched eigenfunction expansion technique, Indian Coastal Conditions

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Viscoelastic Membrane Dynamics: Influence of Bathymetry and Random Wave Conditions

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ABSTRACT

This work presents a dynamic analysis of viscoelastic floating membranes subjected to random wave conditions. To analyze the effect of random sea conditions, the JONSWAP wave spectrum, ideal for representing developing or rough seas with its sharper peak in wave energy distribution, is employed, while the Pierson-Moskowitz (PM) spectrum is applied as a special case when the JONSWAP shape parameter $\gamma = 1$, allowing for the study of both typical and extreme sea states. The mathematical model, developed within a framework under linear water wave theory, examines the interaction of water waves with a flexible, permeable viscoelastic membrane positioned over undulating seabed topography of varying shoal heights in finite water depth. A numerical approach coupling the finite difference method with the boundary element method is used to solve the problem, accurately handling the membrane's dynamic boundary conditions, including second-order derivatives. The analysis explores the effects of sinusoidal seabed variations, membrane damping properties, and the spectral characteristics of the incident waves on various hydrodynamic parameters such as wave reflection, transmission, scattering, and force. Key findings highlight the significant role of proportional material damping in wave dissipation, with local peaks in viscoelastic behavior observed at natural frequencies. The results also demonstrate how the membrane's viscoelastic properties enhance energy dissipation, particularly when interacting with complex bathymetry and realistic wave spectra, leading to the outward dispersion of incoming waves around finite membranes. The study concludes that viscoelastic floating membranes can extend their operational lifespan by improving durability while creating calm zones on the lee side, making them effective for coastal protection and wave energy dissipation. The adaptability of the membrane under varying bathymetric and wave conditions demonstrates its potential as a practical solution for managing coastal wave impacts. These findings offer valuable insights for optimizing the design of viscoelastic floating membranes in engineering applications.

Keywords: Viscoelastic Flexible Membrane, Boundary Element Method, JONSWAP Spectrum, Pierson-Moskowitz Spectrum, Random Waves

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Effect Of Submerged Flexible Porous Barrier On Flexural Gravity Waves

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ABSTRACT

Very large floating structures and breakwaters play a significant role in modern ocean engineering, which motivates the need for accurate mathematical models of wave-structure interaction. While numerical approaches dominate the literature, analytical solutions are more desirable in the deep water case. In this work an analytical study of flexural gravity wave scattering by submerged flexible porous barrier in deep water is carried out. By allowing wave incidence from both sides of the barrier and using the continuity of horizontal velocity, the original half-plane problem is reduced to a quarter-plane problem. Integral relations between the solution potentials and auxiliary potentials are then employed to simplify the higher order boundary conditions. Using some standard integral equations, the problem is converted to that of solving a system of linear equations, and with the help of integral relations, explicit formulae for the velocity potentials are found. Numerical results for the reflection coefficient and total energy are discussed. The effect of porosity and other barrier parameters is examined.

Keywords: Flexural gravity waves, Velocity potential, Flexible porous barrier, Deep water, Reflection coefficient.

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2.	AI Powered Underwater-Inspection System

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Deep-Sea Rescue Support: Human & Object Detection Using Sonar And AI Techniques

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ABSTRACT

Deep-sea rescue demands rapid interpretation of underwater sensing to locate, assess, and prioritize mission-critical human and object targets under low visibility and time pressure. This work presents an AI-assisted framework transforming multibeam sonar imagery into concise, actionable intelligence for mission support. The system automatically detects these targets in challenging acoustic images and augments each detection with approximate distance and direction relative to the sensing platform, enabling rapid transition from raw sonar data to informed tasking. Emphasis is on robustness to low contrast, noise, and small targets common at depth, while maintaining efficiency for near real-time use. A public multibeam sonar dataset is used for training and evaluation, providing credible benchmarking and performance assessment. Outputs are shown via an operator-centric interface overlaying labels, confidence, range, and bearing, summarizing likely candidates to support fast triage, navigation cues, and coordinated hand-offs to vehicle operators and dive teams. The study reports standard detection metrics along with accuracy of range and bearing estimates and includes qualitative examples illustrating faster localization of targets in representative scenarios. By coupling modern detection models with geometry-aware ranging on sonar frames, this work advances perception from simple object identification to integrated cues on identity, proximity, and orientation. This integrated view enhances situational awareness, reduces search time, and improves decision-making efficiency in deep-sea rescue. The contribution is converting complex sonar data into clear, prioritized guidance that operators can quickly interpret, supporting safer and timelier interventions when minutes matter. The framework aligns with practical mission workflows, emphasizes clear outputs for end users, and points toward scalable, data-driven support adaptable to diverse environments and evolving needs.

Keywords: Deep-Sea Rescue, Underwater Object Detection, Multibeam Sonar, Artificial Intelligence, Geometric Localization

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AI Powered Underwater-Inspection System

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ABSTRACT

The inspection and maintenance of underwater infrastructure, including subsea pipelines, oil rigs, bridges, and power or communication cables, are crucial for ensuring operational safety and environmental protection. However, traditional underwater inspection techniques largely rely on manual review of long video recordings captured by divers or remotely operated vehicles (ROVs). This process is extremely labor-intensive, time-consuming, and costly, and often suffers from human fatigue and subjective judgment errors, leading to missed or inconsistent detection of structural defects. To overcome these limitations, this project proposes an AI-powered software platform that automates the analysis of video data collected from ROV and AUV (Autonomous Underwater Vehicle) inspection missions. The system first ingests pre-recorded underwater videos and applies a sequence of advanced image enhancement algorithms to address common underwater imaging issues such as low contrast, color distortion, and turbidity caused by light scattering and absorption. Once the footage quality is improved, a Convolutional Neural Network (CNN)-based deep learning model is utilized to detect, classify, and localize structural anomalies, including cracks, corrosion, biofouling, and material degradation. The identified results are then presented through an interactive dashboard, enabling engineers to visualize detections, validate them, and generate detailed inspection summaries. This approach dramatically reduces inspection time and operational costs, while increasing the accuracy, consistency, and reliability of defect detection. Moreover, by providing data-driven insights and early warnings, the system facilitates predictive and preventive maintenance, minimizing downtime and extending the lifespan of underwater assets. Overall, this AI-driven solution represents a major step toward smarter, faster, and more reliable underwater infrastructure management.

Keywords: Artificial Intelligence, Computer Vision , Defect Detection , Image Enhancement ROV (Remotely Operated Vehicle) , Predictive Maintenance.

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Contrasting Microbial Response To Hydrothermal Methane In Two Vent Fields Of Southern Central Indian Ridge And Eastern Southwest Indian Ridge

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ABSTRACT

Hydrothermal systems along deep-sea mid-ocean ridges are key contributors to methane (CH_4) cycling, with ultramafic- and basalt-hosted settings producing distinct geochemical conditions that influence microbial activity. To evaluate microbial responses to hydrothermally derived CH_4, stratified water-column samples were collected from the southern Central Indian Ridge (sCIR) and the eastern Southwest Indian Ridge (eSWIR), including newly identified vent fields at 24°49′S (sCIR) and 67.67°E (eSWIR). Surface waters displayed low CH_4 concentrations (2.5–4.3 nmol kg^{-1}) and $\delta^{13}C$–CH_4 values of –51 to –45‰, indicative of atmospheric exchange, while mid-water samples with ≤1.63 nmol kg^{-1} CH_4 and isotopic enrichment to –37‰ suggested remineralization processes. Near-bottom waters showed ≤1.82 nmol kg^{-1} CH_4 with values up to –29‰. In the plume at 24°49′S (sCIR), methane levels exceeded background concentrations by >139-fold, with $\delta^{13}C$–CH_4 of –13.5‰, consistent with ultramafic–seawater interaction. Conversely, the basalt-hosted plume at 67.67°E (eSWIR) showed 18.1 nM CH_4 and $\delta^{13}C$–CH_4 of –24.7‰, together with a ~5-order magnitude increase in pmoA gene copies, demonstrating strong stimulation of methanotrophic communities. Comparison of the two systems underscores the contrasting geochemical signatures and associated microbial responses. These findings suggest that

subsurface processes at eSWIR may control methane isotopic composition and influence its availability for microbial oxidation.

Keywords: Hydrothermal, Ultramafic, Basalt, Methane, Methanotrophic communities.

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A Conceptual Ai-Based Whale-Inspired Robotic Miner For Deep- Sea Nodule Collection System

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ABSTRACT

This work presents a conceptual overview of an AI-based, whale-inspired robotic miner designed for deep-sea polymetallic nodule collection. The proposed system draws inspiration from the hydrodynamic efficiency, graceful motion, and suction-feeding mechanism of whales, integrating these biological principles into a futuristic underwater mining platform. The concept envisions a streamlined, whale-like robotic body coupled with an intelligent suction device mounted at the front, enabling smooth hover, controlled intake of nodules, and reduced sediment disturbance. Configured similarly to an autonomous underwater vehicle (AUV), the miner uses onboard artificial intelligence for adaptive navigation, terrain interpretation, plume avoidance, and resource identification. This conceptual design highlights how biomimetics and AI can combine to address challenges in deep-sea operations such as maneuvering in low-visibility, minimizing ecological impact, and improving system autonomy. The overview does not describe a finalized mechanical design; instead, it introduces a forward-looking model that sets the foundation for future detailed development, numerical studies, and experimental prototyping. The idea demonstrates the potential of combining whale-inspired biomechanics, AI-driven decision-making, and suction-based hydraulic collection to create a next-generation deep-sea mining system.

Keywords: deep sea mining, robotic miner system, polymetallic nodules, hydraulic collector, underwater robotic

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Fractal Roughness Assessment Of Polymetallic Nodule Field In The Central Indian Ocean Basin (CIOB) Using High-Resolution Autonomous Underwater Vehicle (AUV) Optical And Multibeam Backscatter Data

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ABSTRACT

Polymetallic manganese nodules (PMNs) are long-studied critical mineral deposits rich in manganese, nickel, cobalt and rare earth elements that occur in the deep ocean floor. To understand and estimate resource distribution, a detailed high-resolution seabed survey using an AUV was conducted in the CIOB at a depth of ~ 5270 m. High-resolution geophysical datasets, including 400 kHz multibeam data with backscatter and bathymetry, HISAS backscatter, and 4K resolution photographic results, revealed detailed morphological and nodule characteristics of the study area. The present investigation is carried out to compare the area seafloor roughness utilising optical and multibeam backscatter imagery data in the PMN area.

In the proposed methodology, self-similar methods are employed to estimate roughness parameters using camera-operated optical and multibeam backscatter imagery data from 50 blocks selected from the study area. Each block comprises 100x100m (100x100 pixels). A comparison between the Box and Information dimensions reveals that estimated roughness shows a 90% correlation between the values from the entire area. A statistical study carried out for the Box dimension results reveals three distinct clusters for the valley and two areas characterised by smooth and rough topography, which predominantly cover manganese nodules. The backscatter imagery mosaic (–4 dB to –26 dB) with radiometric corrections is used for areas where optical data are available. The estimated roughness parameter using Box dimension techniques was compared with the data obtained using optical data. Comparison between the estimated roughness parameters using optical and multibeam backscatter datasets is brought out in the article with a discussion on the influence of seabed characteristics.

Keywords: Polymetallic nodules, Seabed roughness, Fractal dimension, Multibeam backscatter, Optical imagery, Central Indian Ocean Basin

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Geochemical Fingerprints of Surface Sediments From Eastern Southwest Indian Ridge: Insights Into Hydrothermal, Basaltic, And Ultramafic Inputs.

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ABSTRACT

The ultra-slow-spreading Southwest Indian Ridge (SWIR) provides a distinctive tectonic environment for examining hydrothermal processes due to its low magma supply, extensive mantle rock exposure, and diffuse venting patterns. In this study, we integrate mineralogical data with major- and trace-element geochemistry and multivariate statistical analyses of surface sediments from the eastern SWIR (63°E–69°E). The sediments exhibit the presence of hydrothermal input, including enrichments in Fe, Mn, and chalcophile trace metals (e.g., Cu, Zn).

Factor analysis of the carbonate-free fraction identifies three principal endmembers: (1) an authigenic hydrothermal component comprising Fe–Mn (oxyhydr)oxides, birnessite, and hematite (62.3% of variance); (2) basaltic detritus represented by labradorite and alteration products such as montmorillonite, vermiculite, and illite (21.8%); and (3) ultramafic detritus dominated by antigorite (10.2%). These components are mixed in varying proportions across the sample set. Sample, C-GC-16 (0–1 cm) at 67.260°E, 26.574°S, displays elevated concentrations of conservative and redox-sensitive elements (U, Mo, V, As), alkali metals (K, Rb, Cs), and Cu, suggesting proximity to an active or recently active hydrothermal source.

Elemental ratio proxies further confirm the influence of seafloor venting on sediment composition, even at sites located away from the axial region. Overall, our results demonstrate that hydrothermal plumes and particulate fallout significantly contribute to sedimentation along this portion of the SWIR, with both basaltic and ultramafic sources supplying detrital material as well as hydrothermally altered clay minerals. These findings enhance understanding of sediment provenance, hydrothermal fluxes, seafloor alteration, and metal cycling in ultra-slow spreading ridge systems, with broader implications for ridge geochemistry and potential mineral resource formation.

Keywords: Eastern SWIR, MOR sediments, Geochemistry, Fe-Mn-(oxyhydr)oxides, Hydrothermal

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Ultramafic Hosted Seafloor Massive Sulfide (Sms) At Ultra-Slow Eastern South West Indian Ridge (Swir)

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ABSTRACT

Hydrothermal systems along the Mid-Oceanic-Ridges (MORs) play a key role in mass and volatile transfer to the ocean where metal enriched circulated seawater vented out and deposits at the ocean bottom to form seafloor massive sulfide (SMS). Among the global MOR network, the slow and ultraslow spreading ridges constitute half of the oceanic ridge systems (~65,000 km in length), exhibit diverse geological settings, enable different types of fluid-rock interactions as a consequence of their underneath litho-structural configuration. Thus, separate modes of sub- seafloor hydrothermal interactions and subsequent venting are observed at the seafloor, with distinct physico-chemical and mineralogical characteristics. These variations are usually interlinked with their styles of oceanic spreading and accretion, conversely defined as magmatic dominated or tectonic dominated spreading where lithospheric accretion resulted either by mafic volcanism or detachment faulting where large volume of ultramafic rocks are exposed along the spreading ridge. This study reports an Ultramafic hosted Seafloor Massive Sulfide site at 68°E;
26.5°S of SWIR. A combined qualitative and quantitative mi neralogical investigations are carried out to determine the sulfide mineralogy and lithological characterization of the associated host rock which suggest high temperature hydrothermal activity at magma poor eastern SWIR hosted by ultramafic substates.

Keywords: Indian Ocean, Mid-Oceanic-Ridge, Hydrothermal, Sulfide, SWIR

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Episodic Explosive Magmatic Degassing at 67.67°E, Eastern Southwest Indian Ridge

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ABSTRACT

Hydrothermal plumes are broadly classified into chronic (continuous) and event (episodic) types based on their physical and chemical characteristics. Chronic plumes are typically linked to active hydrothermal venting, whereas event plumes are associated with episodic disturbances such as seafloor earthquakes or magmatic intrusions. Recent observations of dissolved methane in deep waters along the eastern Southwest Indian Ridge (eSWIR) have revealed a hydrothermal field at 67.67°E, characterised by three vertically distinct plumes: Plume 1 (2300–3150 m), Plume 2 (3600–4100 m), and Plume 3 (4200–4500 m). Plume 1 is particularly noteworthy due to its unusual vertical thickness (~700 m), elevated turbidity (up to 0.09 NTU), and sharp decrease in oxidation–reduction potential (up to 20 mV), all of which point to an event-type hydrothermal plume. Exceptionally high helium-3 anomalies (112% above a 13% regional background) further indicate recent magmatic degassing. Although methane (6.64 nmol/kg) and manganese (19.53 nmol/L) concentrations are comparatively low, their helium-3 to heat (0.014 mol/J) and manganese to heat (0.04 nmol/J) ratios align with values reported for other event plumes. These results collectively suggest that recent and potentially short-lived magmatic activity has occurred beneath this segment of the ridge.

Keywords: Southwest Indian Ridge, Magmatic degassing, event-type plume, helium

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Biomineralization And Skeletal Coloration In Mg-Rich Calcitic Deep-Sea Octocorals

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ABSTRACT

Deep-sea corals play a vital role in marine ecosystems and serve as an important archive for reconstructing past ocean chemistry, circulation, and climate. While most corals form aragonitic skeletons, certain deep-sea species produce calcite or mixed polymorphs. Additionally, their skeletons exhibit striking colour variations, which have been linked to organic pigments such as carotenoids incorporated during biomineralization. However, the mechanisms controlling polymorph selection (aragonite vs. calcite vs high Mg calcite) and skeletal coloration remain enigmatic.

This study examines the biomineralization and pigmentation of a deep-sea octocoral from the Central Indian Ridge (Indian Ocean) that displays distinct pink and white skeletal regions. Using X-ray diffraction (XRD) and Raman spectroscopy, we analyzed the mineral composition and organic pigments in both regions. XRD data confirmed a Mg-rich calcite structure in both pink and white zones, with no polymorphic differences. Raman spectroscopy further validated the Mg-rich calcite composition, with the white region displaying characteristic Mg-rich calcite spectra. In contrast, the pink region exhibited additional Raman spectral peaks corresponding to organic pigments, likely □carotenoids, a type of polyene incorporated during skeletal formation, producing distinct pink colouration. Coral skeleton contains around 2 wt. % Mg which has been confirmed by XRD, Raman, SEM-EDS, EPMA and ICP-OES analysis. Our results demonstrate that while polymorph selection (exclusive calcite precipitation) remains consistent, organic pigments directly influence skeletal colour, crystal morphology and aggregation without altering the overall mineralogy. This study will improve our understanding of deep-sea coral biomineralization, particularly the roles of biological and environmental factors in shaping skeletal properties.

Keywords: Deep sea coral, biomineralization, skeletal colouration, high Mg calcite, CIR

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An Assessment On Nodule Collection Technologies Employed For Deep-Sea Mining

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ABSTRACT

The rising global demand for strategic minerals, coupled with the depletion of terrestrial reserves and growing environmental constraints, has positioned the deep seabed as a promising alternative resource frontier. Among the available deep-sea deposits, polymetallic nodules are the most abundant, occurring across vast abyssal plains at deep seas. Their rich metal content has driven decades of research in deep-sea mining, progressing from exploration to prototype-scale field trials. However, developing an efficient, low-impact, and reliable nodule collection system remains a major challenge. Existing technologies can be broadly categorized into hydraulic, Coanda effect, hybrid, and mechanical systems. Early hydraulic suction collectors enable continuous operation but are limited by high power requirements, sediment plume generation, and clogging issues. Coanda effect systems use fluid jets along curved surfaces to lift nodules with reduced sediment disturbance, yet suffer from lower lifting efficiency, complex control, and limited field validation. Hybrid collectors integrate both methods, offering partial gains in efficiency but still facing challenges in fluid control and maintenance. In contrast, the deep sea mining department of NIOT has developed mechanical based collectors represent a new generation of seabed mining tools emphasizing selective recovery, energy efficiency, and terrain adaptability. The State-of-the-Art mechanical nodule collector developed in this study features an arc-type tooth mechanism mounted on a chain-sprocket-driven blade assembly, integrated with a crawler-based mining vehicle. Prior to finalizing this configuration, various tooth geometries were designed and experimentally tested for their ability to dislodge and lift nodules under controlled conditions. Among these, the arc-type teeth demonstrated superior scooping performance, providing smoother sediment engagement, reduced slippage, higher nodule capture efficiency and ensures adaptability across irregular seabed terrains. Moreover, the system operates at moderate towing velocities and optimized rotation speeds, minimizing both resistance forces and actuator load while maintaining high collection rates. Based on the experimental results the proposed system is implemented in the existing mining machine and its performance during field trials in the deep Seas demonstrated stable operation under rough terrain conditions, confirming its suitability for deployment in mid-depth mining environments. This study thus proposes the arc-type mechanical collector as a promising, scalable, and eco-efficient solution for the next generation of deep-sea polymetallic nodule mining systems.

Keywords: Deep Sea Mining, Polymetallic nodules, Nodule collection system, mechanical based collector, Rough Terrain

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Near-Bottom Magnetic Observations As A Tool For Deep-Sea Hydrothermal Exploration: A Case Study From A Segment Of The Central Indian Ridge

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ABSTRACT

Hydrothermal systems at divergent plate boundaries are fundamental to seafloor construction, fluid–rock interaction, and submarine mineralisation. The seafloor massive sulphide (SMS) deposits generated by such systems are considered modern analogues of volcanic-hosted massive sulphide deposits on land, linking mid-ocean ridge magmatism to metal enrichment and long- term resource formation. Advances in near-seafloor surveying—using autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), and human-occupied vehicles (HOVs)— have transformed our ability to identify and characterise hydrothermal systems with high spatial resolution.

Near-bottom magnetic measurements are particularly effective for hydrothermal exploration, as both reduced and enhanced magnetic signatures may provide useful information on hydrothermal deposits; their formation, alteration and oxidation in a range of host rock substrates ranging from mafic to ultramafic systems. Consequently, active and fossil hydrothermal fields commonly exhibit magnetic anomalies reflecting alteration intensity and host-rock composition. For example, global studies across the Mid-Atlantic Ridge, Juan de Fuca Ridge, Southwest Indian Ridge, and Mariana arc demonstrate that basalt-hosted systems typically produce magnetic lows, whereas ultramafic-hosted systems tend to yield positive anomalies due to serpentinization.

Along the Central Indian Ridge, recent investigations have revealed one of the oldest and most distal fossil hydrothermal systems identified to date, supported by mineralogical, geochemical and chronological estimations of dredged samples. AUV magnetic surveys conducted over this off-axis region show a prominent circular magnetic low, suggestive of demagnetisation associated with pipe-like hydrothermal upflow zones. This reduced-magnetisation signature indicates a broad zone of hydrothermal alteration underlying this region, characterized by the circular magnetic anomaly low. These findings underscore the importance of magnetic investigations, particularly in off-axis settings, for locating fossil hydrothermal systems and assessing their mineralisation potential.

Keywords: Hydrothermal Exploration, Near-bottom Magnetic Survey, Central Indian Ridge, Seafloor Massive Sulphides

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Assessment of Beach Placer Minerals Along Coastal Belts Of Arjyapalli, Ganjam District, Southern Odisha, East Coast Of India

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ABSTRACT

An area of 07 sq. km. in the SW off Rushikulya River mouth from Arjyapalli to Nugaon, Ganjam district, Southern Odisha (UNFC G4 Stage) has been assessed by systematic pit sampling in 200m (across the coast) X 800m (along the coast) grid for resource potential of heavy minerals, to search for onshore economic placer minerals in the Quaternary sediments (beaches) and to formulate the operation methodologies for beach placer exploration. Coastal geomorphological land forms like beach, beach ridges, older coastal plain, younger coastal plain, stabilized dunes, etc., of Holocene age coupled with litho-units of the Eastern Ghat Complex consisting of dominantly charnockite, quartzite, Khondalite and younger granitic rocks characterize the hinterland geology of the area.

Systematic pit sampling in 200 m (across the coast) X 800 m (along the coast) grid was undertaken by digging 1 cu. m. of sample from 32 pits. There is a lateral variation of black sand concentration as observed form the different pit sections. Incidentally, the sample line which is most proximal to the sea along the beach shore contains the highest concentration of heavy minerals. Presence of the six economic heavy minerals viz. ilmenite, garnet, sillimanite, monazite, zircon and rutile are identified, in order of abundance. Down depth observed an increase in Total Economic Heavy Mineral (TEHM wt %) concentration from 33.07% to 38.09%. The TEHM wt % upto 1m depth in the pits varies from 6.07%to 82.04%, having an average value of 30.86% (TEHM), mainly all area concentrated in medium size sand only. The subsurface persistence of sandy sediment hosting these placer minerals has been successfully probed upto a depth of 1 meter establishing a significant resource potential in Arjyapalli area, which can be taken up further for detailed explorationin order to augment the beach placer resources of India. The geology and exploration models will definitely help in future mineral prognostications in this part and its extended areas around North Central East Coast of India.

Keywords: Beach Placer, Eastern Ghat Complex, UNFC G4 Stage, Arjapalli , ODISHA

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A Convolutional Neural Network Approach For Quantifying Polymetallic Nodules From Backscatter Imagery.

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ABSTRACT

Quantifying polymetallic nodule(PMN) abundance in deep-sea region is vital for resource assessment to plan the exploratory mining in potential target regions. While optical imagery provides highly accurate estimates of nodule coverage, it is limited in terms of spatial coverage because of the camera-based outputs at closer altitude. Acoustic backscatter from SONAR, in contrast, maps wide regions rapidly, but exhibits complex spatial variability driven by factors such as sediment type, incidence angle, and instrument parameters. To bridge this gap, we develop a data-driven framework based on Convolutional Neural Networks (CNNs) to infer nodule coverage from backscatter intensity maps, using an optical nodule coverage map as ground-truth supervision. Backscatter and optical images are obtained from the PMN site in the Central Indian Ocean at a depth of 5270 m using the deep-water AUV(Ocean Mineral Explorer – OMe 6000).

Backscatter intensity is pre-processed through radiometric normalisation, angular gain and beam pattern correction, and removal of nadir artefacts. The nodule coverage map is converted into different classes representing varying coverage, with thresholds chosen based on optical segmentation outputs. Overlapping patches of 64×64 to 256×256 pixels are extracted from the backscatter map, matched with corresponding class labels.

Different CNN architectures, including custom shallow networks and transfer-learning models such as ResNet-18 and EfficientNet-B0, adapted for single-channel acoustic inputs are evaluated. The models are trained using cross-entropy loss with Adam optimisation, and learning-rate scheduling. Performance is assessed through accuracy, recall, F1-score and confusion matrices. An accuracy score of 87 and a recall of 88 are achieved. The classification yielded an F1 score of 83.

The resulting CNN-based model demonstrates capability in identifying acoustic texture signatures associated with varying nodule densities. This integrated optical–acoustic methodology reduces reliance on dense camera surveys, significantly increases mapped area coverage, and provides a scalable approach for future deep-sea PMN resource assessment.

Keywords: Polymetallic Nodule, Deep Learning, Mineral Resource Assessment, CNN, AUV, Multibeam Backscatter.

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Alteration Mineralogy Of Mor-Basalts From Southern Cir (22– 26°S) : Indicator Of Hydrothermal Processes

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ABSTRACT

The Southern Central Indian Ridge (sCIR) (22-26 ºS) is an intermediate spreading ridge (47mm/year) that lies within a tectonically dynamic region. The region experiences variable magma supply along the ridge-axis. The segmentations between major fracture zones create conditions favourable for hydrothermal circulation. This region remains one of the least understood in terms of its mineralization potential, largely due to limited vent discoveries and sparse direct evidence of hydrothermal activity. In such settings, the alteration mineralogy of mid-ocean ridge basalts (MORBs) plays a powerful proxy for the identification of inactive and active hydrothermal systems and an indirect indicator of potential subseafloor metal enrichment and SMS-style deposits. The altered minerals mainly record the degree of alteration and the temperature of formation, and provide a mineral-based evidence of hydrothermal alteration. The study of altered minerals and their spatial distribution, allow to understand, the low or high-temperature alteration of the oceanic crust in the tectonically dynamic region and hydrothermal pathways for transporting fluid in the subseafloor. Further, the effect of alteration in the rock from core to rim reflects evolving fluid–rock interaction, and help in identifying regions where hydrothermal circulation was more intense. These alteration signatures effectively capture the thermal and chemical history of circulating fluids long after active venting has ceased. In this study alteration effects on MORBs were studied to identify the degree of alteration and formation temperature of altered minerals to establish the zones of hydrothermal activity in the southern CIR. Such an approach is particularly valuable for ridge regions where direct vent observations are rare, enabling a more predictive strategy for assessing marine mineral resources in the Indian Ocean.

Keywords: Hydrothermal alteration, Alteration zoning, MOR Basalt, Central Indian Ridge

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Exploring Hydrothermal Signature In The Southern Central Indian Ridge: Insights From Clay Mineralogy Of Mafic-Ultramafic Rocks And Sulphide Precipitates

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ABSTRACT

X-ray diffraction (XRD) analyses of whole-rock and sulphide mineralised samples were peformed to investigate the weathering/hydrothermal signatures in southern Central Indian Ridge (CIR). Unaltered/non-weathered basalt samples are consistent with pristine mineralogical assemblage of plagioclase, pyroxene and olivine. Mineralised samples are comprised of pyrite and goethite dominantly. Glass samples are not completely amorphous but also comprise small amount of crystallised plagioclase, pyroxene and olivine. In comparison to unaltered/non- weathered basalts, ultramafics and altered/weathered basalts are comprised of montmorillonite/vermiculite/chlorite along with plagioclase and pyroxene. Further, these samples were subjected to clay mineral separation using gravity settling and centrifuge methods. To characterise the clay mineralogy, the separated clay fractions were analysed for their XRD patterns in three steps (1) air-dried, (2) ethylene glycol vaporised and (3) heated at 400°C for 1 hour. The significant variation (14.6 Å, 16.9 Å and 10.2 Å) in d-spacing from these three steps respectively represented presence of montmorillonite whereas slight variation (14.5 Å, 15.3 Å and 12.3 Å) represented dioctahedral vermiculite. Combining the characterisation of clay minerals from southern CIR, its geological environment (weathering and hydrothermal alteration) of formation and geographical location of samples will be helpful to discover the locations of hydrothermal activity.

Keywords: Mid Ocean Ridge setting, Central Indian Ridge, X-ray diffraction, Clay Mineralogy, Hydrothermal Signature

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Vertical Variability Of Porewater Nutrients In Deep-Sea Ridge Sediments Of The Indian Ocean: Implications For Early Diagenesis

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ABSTRACT

Porewater nutrient profiles offer critical insights into early diagenetic processes and biogeochemical dynamics within sedimentary environments, particularly along tectonically active regions such as the Indian Ocean ridge system. This study investigates vertical variations in dissolved inorganic nutrients within two gravity cores (GC-8 and GC-22) sampled at 26˚36.172S 67˚55.773E and 27˚44.224S 63˚59.047E respectively from 5 to 250 cm sediment depth, aiming to elucidate remineralization patterns and sediment–water interactions in deep-marine ridge settings. Subsamples at 5 cm resolution were analyzed for nitrate+nitrite, nitrite, phosphate, silicate, and ammonia following standard porewater extraction and colorimetric procedures. Results from GC 8 indicate consistently elevated nitrate+nitrite concentrations (25.11–58.18 µM), with peaks at mid-depths, suggesting sustained nitrification within oxygenated pore spaces. Silicate concentrations ranged from 141 to 281 µM, reflecting active dissolution of biogenic silica. Ammonia exhibited pronounced variability (0–10.43 µM), increasing with depth, indicative of intensified organic matter degradation in deeper anoxic layers. Phosphate ranged from (3.54–11.93 µM), with localized enrichment at 105–115 cm. GC 22 showed similar patterns, though with lower silicate values in the upper 30 cm (84–137 µM) and elevated phosphate (up to 8.59 µM) and ammonia (up to 11.35 µM) at deeper strata, highlighting enhanced mineralization and sediment reactivity. Both cores demonstrate strong coupling between organic matter degradation and nutrient regeneration, with depth-dependent shifts influenced by redox gradients and sediment composition. These findings provide essential baseline information on nutrient cycling within ridge-associated sediments and contribute to broader understanding of Indian Ocean biogeochemistry.

Keywords: Porewater nutrients, Sediment biogeochemistry, Indian Ocean ridge system, Early diagenesis, Gravity core analysis

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Metals from The Seawater

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ABSTRACT

Metals have been proven to be an invaluable asset to social development for ages. Metals are primarily exploited from ores and minerals available in the Earth's crust (land-based mining) and processed suitably for further use. Among all, critical metals like Ni, Co, Cu, Cd are of significant interest due to their essential applications in advanced technology, renewable energy systems, electric vehicles, and biomedical devices. However, the progressive depletion of suitable grades of metallic ore bodies as well as the associated environmental impact of the extraction processes requires the consideration of their alternative source/s. The vast reserve of poly-metallic nodules on the sea-floor, hydrothermal deposits and the enormous ocean water reserve have created great interest among scientists and engineers due to their various important non-ferrous metals content. The metal extraction from the deep oceanic nodules and hydrothermal deposits faces challenges in terms of extraction feasibility and economic aspects. Present study aims to develop a novel methodology to extract trace metals from seawater in for commercial uses. Mn-coated acrylic fiber has been used to extract trace metals from surface and intermediate depth seawater. The adsorbed metals are extracted from the coated fibre. The individual metals are then separated from the bulk fraction using various organic solvents like Cyanex-272 (Co), Cyanex-301 (Ni) and Lix-984 (Cu). The separated metal fractions solution, subjected to their concentrations, further undergo electroplating technique for extraction of respective native metals.

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Mbd-Based Traction Modelling Of Deep-Sea Track Systems: Influence Of Grouser Geometry On Terrain Specific

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ABSTRACT

Deep-sea mining vehicles must operate across highly variable seabed environments ranging from rough, compacted sediment zones to extremely soft cohesive beds. The mobility and tractive efficiency of such systems depend predominantly on the interaction between their track grousers and the underlying soil. This study investigates the performance of two contrasting grouser configurations a flat grouser designed for rough, firm seabed conditions and a pin-type grouser intended for ultra-soft deep-sea sediments. The objective is to evaluate their respective abilities to provide adequate traction, minimize sinkage, and ensure stable maneuverability across different terrain profiles encountered in deep-seabed mining operations. A comprehensive multi-body dynamic simulation was performed using ADAMS Tracked Vehicle (ATV) to model the four track–soil interactions under realistic loading and hydrodynamic conditions. For the rough seabed scenario, the flat grouser was analyzed on compact sediment modeled with high undrained shear strength and minimal plastic deformation, allowing the track to rely primarily on surface contact and frictional resistance. For the soft seabed scenario, the pin-type grouser was assessed on weak clay-rich soil characterized by low shear strength and high remouldability, where traction is achieved mainly through localized soil penetration and shear mobilization. Each configuration was simulated for identical vehicle operating parameters such as velocity, normal load, and track pretension to enable a controlled comparison.

The results reveal that the flat grouser performs optimally on hard seafloors, generating stable drawbar pull with minimal vertical sinkage and low oscillatory motion. However, its performance deteriorates sharply on soft seabeds due to insufficient penetration and excessive slippage. In contrast, the pin-type grouser demonstrates superior traction on soft sediments, facilitated by deep soil engagement and high shear mobilization, though it induces larger resistance forces and higher energy consumption when used on rough terrain. The comparative evaluation highlights the terrain-specific nature of grouser performance and establishes that no single geometry is universally optimal across all seabed types. The study concludes that application-dependent grouser design is essential for deep-sea mining mobility, and recommends the adoption of a hybrid or interchangeable track system for vehicles expected to traverse mixed seabed landscapes.

Keywords: Deep Sea Mining, MBD, Tracked mining vehicle, Grouser–soil interaction, Track mobility, Traction performance

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Biochemical Signatures Of Particulate Organic Matter And Their Implications For Carbon Cycling In The Surface Waters Of The South Indian Ocean

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ABSTRACT

With growing global interest in deep-sea mineral resources as alternatives to land-based deposits, understanding of oceanic biogeochemical processes is essential for future environmental management. In the Indian Ocean, several countries, including India, China, Germany and South Korea, have contracts with the International Seabed Authority for the exploration of polymetallic sulfides. As part of baseline environmental assessments, this study examines the distribution, biochemical composition, and chemotaxonomic characteristics of particulate organic matter (POM) in surface waters of the southern Central and eastern Southwest Indian Ridge during the spring inter-monsoon period. Phytoplankton community structure was characterised using pigment analysis via High-Performance Liquid Chromatography (HPLC), while monosaccharide composition of POM was determined using High-Performance Anion-Exchange Chromatography with Pulsed Amperometric Detection (HPAEC-PAD). Pigment profiles revealed a dominance of picophytoplankton, indicated by elevated zeaxanthin concentrations. Surface chlorophyll-a ranged from 1 to 136 µg L^{-1}, reflecting mesotrophic to eutrophic conditions driven by seasonal mixing and nutrient entrainment. Total monosaccharides varied from 8.9 to 39.5 µg L^{-1}, with glucose (avg. 65.7%) constituting the major fraction, accompanied by minor sugars such as glucosamine, galactose, mannose, xylose, and fucose. Spatial differences in pigment composition and carbohydrate profiles suggest modulation by mesoscale oceanographic processes. The combined variability in phytoplankton pigments and POM monosaccharide signatures highlights the coupling between phytoplankton community structure, organic carbon production, and surface ocean biogeochemistry. These findings provide new insights into carbon cycling and the biochemical ecology of phytoplankton in the South Indian Ocean, contributing to regional baseline datasets required for future deep-sea environmental management.

Keywords: South Indian Ocean; Productivity; Pigment; Carbohydrates, Monosaccharides

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Marine Geophysical Exploration For Seafloor Massive Sulfides (Sms): Insights From Self-Potential Survey At The Yokoniwa Hydrothermal Field

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ABSTRACT

Seafloor massive sulfide (SMS) deposits contain high concentrations of Cu, Zn, Au, Ag and are regarded as a significant marine mineral resource with growing importance for future resource development. The exploration of SMS deposits requires a suite of advanced geophysical and geological tools capable of detecting subsurface hydrothermal systems, mapping seafloor structures, and characterizing mineralization. The marine self-potential (SP) method, in particular, offers a unique, efficient, and cost-effective approach to decipher the location and extent of SMS deposits. SP measurements are typically made near the seafloor using electrodes attached to towed bodies or autonomous underwater vehicles (AUV). Here, we present the SP data acquired using an AUV at the Yokoniwa Hydrothermal Field (YHF) in the Central Indian Ridge. The multi-component electric field data exhibits a pronounced anomaly at the YHF field. An inversion algorithm specifically adapted for the multicomponent dataset reveals the distribution of current density beneath the seafloor and better resolves the morphology of the ore bodies compared to using a single electric-field component. Our study suggests that an AUV- based SP survey, followed by inversion for source current-density distribution, is a powerful tool for characterizing SMS deposits and in the future, could be employed in conjunction with other geophysical methods to delineate these deposits more effectively.

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Diversity And Functional Potential Of Microbial Communities In The Southern Central Indian Ridge And Eastern Southwest Indian Ridge, Indian Ocean

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ABSTRACT

Hydrothermal vent fields are widely recognised as major biological and geochemical hotspots along the global mid-ocean ridge system. Although several vent fields have been identified across the Indian Ocean ridges, the microbial diversity and functional processes underlying biogeochemical cycling remain unclear. In this study, we present a comprehensive characterisation of microbial communities from hydrothermal plumes and background seawater in the southern Central Indian Ridge (sCIR) and eastern Southwest Indian Ridge (eSWIR) near the Rodriguez Triple Junction (RTJ). Using high-throughput 16S rRNA gene sequencing combined with genome-resolved metagenomics, we recovered 40 metagenomeassembled genomes representing 28 genera, including dominant Gammaproteobacteria (e.g., Alcanivorax, Oleibacter) and Campylobacterota (e.g., Sulfurimonas). Functional annotations indicate diverse chemosynthetic pathways, including sulfur oxidation and reduction, methanogenesis, and arsenic and mercury detoxification, highlighting the active role of microorganisms in transforming dissolved gases and metals that govern local geochemical conditions. Community-level physiological profiling further demonstrates strong metabolic flexibility, with plume communities showing enhanced utilisation of carboxylic acids. Overall, our results reveal both functional redundancy and pronounced biogeographic structuring of microbial communities driven by contrasting geochemical gradients in the sCIR and eSWIR.

Keywords: Hydrothermal vents, Metagenomics, Chemoautotrophy, MAGs

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Controls On Phytoplankton Productivity In Oligotrophic Waters Of The South Indian Ocean: Evidence From Nutrient And Iron Enrichment Experiments

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ABSTRACT

The oligotrophic waters of the Southern Indian Ocean are characterised by low primary productivity due to persistent macronutrient and micronutrient limitation, despite high light availability. In this study, we assessed phytoplankton productivity responses to nutrie nt enrichment using surface seawater collected from the South Indian Ocean. Controlled microcosm incubations were conducted under five treatments: (1) Control, (2) Macronutrient addition (N, P, Si), (3) Iron addition (Fe), (4) Macronutrients + Fe (1 nM), and (5) Macronutrients
+ Fe (1.5 nM). Temporal changes in inorganic nutrient concentrations (NO_3, NO_2, NH_3, PO_4, and Si) and phytoplankton biomass were measured to evaluate biological responses. All enric hed treatments showed increased phytoplankton growth relative to the control, confirming strong nutrient limitation in the surface waters. The strongest response occurred under the combined macronutrient + Fe (1.5 nM) treatment, followed by macronutrient + Fe (1 nM), macronutrie nt- only, and iron- only additions. This hierarchical response indicates synergistic co-limitation by iron and macronutrients in this ridge-influenced open-ocean setting. Rapid declines in nitra te, phosphate, and silicate concentrations in the combined enrichment treatments coincided with enhanced biomass accumulation, suggesting efficient nutrient utilisation by the phytoplankto n community. The stronger stimulation under higher iron enrichment further demonstrates high biological sensitivity to iron availability and the potential influence of episodic hydrothermal iron inputs in the region. Overall, the results show that primary productivity in these oligotrophic ridge-associated waters is controlled by macronutrient–iron co-limitation, and that increased iron supply (up to 1.5 nM) substantially amplifies phytoplankton growth, with implications for regional biogeochemical and carbon cycling processes.

Keywords: Oligothrophy, Nutrient-Iron co-limitation, enrichment experiment, Primary productivity, hydrothermal input

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Structural Controls On A Newly Identified Hydrothermal Vent Field In The Southern Central Indian Ridge Revealed By High-Resolution AUV Surveys

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ABSTRACT

Hydrothermal vents are seafloor fluid-discharge systems that emit high-temperature, mineral-rich fluids, producing buoyant plumes upon mixing with ambient seawater. These systems exert major controls on deep-ocean chemical budgets, biogeochemical cycles, and chemosynthetic ecosystems. While several active fields, including Kairei, Edmond, Dodo and Solitaire, have been documented along the Central Indian Ridge (CIR) of the Indian Ocean, vast segments remain unexplored. Here, we report the discovery of a new active hydrothermal vent field in Segment S2 of the southern CIR (69°52'E, 24°48'S) at depths of ~2735–2760 m. The hydrothermal plumes were detected through near-seafloor surveys conducted with an Autonomous Underwater Vehicle (AUV) equipped with a suite of geophysical and environmental sensors. The site is characterized by an elongated, roughly oval-shaped bathymetric high with its major axis oriented in the north-northwest to south-southeast direction. The feature is slightly asymmetrical, broadening toward its central eastern portion and tapering toward both ends. The western flank appears to be much steeper and rugged compared to the gentle and relatively smoother eastern flank. Sub-bottom profiler data indicate negligible sediment cover across the main feature. The multibeam water-column backscatter data revealed two distinct plumes on the northwestern part of the summit, separated by ~125 m and drifting west-southwest. The plumes emanate from vents at ~2746 m (the primary western source) and
~2735 m depth (the eastern source). High-resolution bathymetry indicates a structural control for this activity, with both vents situated atop small-parallel ridges extending northwest from the main topographic high. This discovery confirms that Segment S2 hosts active hydrothermal systems, extending the known distribution of hydrothermal activity on the southern Central Indian Ridge.

Keywords: Hydrothermal Plumes; Hydrothermal Vent; Central Indian Ridge; Mid-Oceanic Ridge; Near-Seabed Survey.

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Distinct Depth Stratification Of Eukaryotic Communities In The Water Column Of Central Indian Ridge Through 18s Metabarcoding Analysis

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ABSTRACT

Deep-sea hydrothermal vents are highly productive and functionally unique ecosystems and plays a critical role in supporting global biodiversity in deep-sea environments. Despite their ecological importance, information on the eukaryotic biological diversity in and around the vicinity of hydrothermal environment remains limited in the Indian Ocean. The present study focussed on the characterization of eukaryotic communities in the water column of the Central Indian Ridge, using 18S rRNA environmental DNA (eDNA) metabarcoding. The diverse community assemblages, including dinoflagellates, radiolarians, and metazoan groups like Copepoda, Hydroidolina, and Siphonophorae, were observed in the study. The results showed a distinct depth-related stratification, with the dominance of Syndiniales across all depth zones, indicating importance of parasitic and heterotrophic protists in deep-sea pelagic ecosystems. Multivariate analysis of the communities revealed a strong separation of eukaryotic communities by depth, indicating the influence of strong environmental gradients on community structure.

Keywords: Central Indian Ridge, eDNA, Eukaryotes, 18S metabarcoding

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Evidence For Multiple Hydrothermal Vent Fields At 67.67°E, Eastern SWIR

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ABSTRACT

Water-column investigations along the ultraslow-spreading eastern Southwest Indian Ridge (eSWIR) have revealed multiple chemically distinct hydrothermal plume layers at 67.67°E and 26.61°S. Physical and geochemical anomalies delineate three plume horizons at 2300-3100 m (Plume 1), 3200-4100 m (Plume 2), and 4200-4500 m (Plume 3), indicating the presence of multiple venting sites. Elevated dissolved methane (CH_4: 1.0-37.8 nmol/kg) and dissolved manganese (DMn: 1.0-68.6 nmol/L) concentrations were consistently detected across these layers. Variability in plume signatures across multiple stations along the axial high further supports the existence of at least three distinct hydrothermal vent fields. Despite spatial and geochemical heterogeneity, CH4/DMn molar ratios in all plumes generally remain below 0.5, with occasional values approaching 1. Such low ratios are characteristic of high-temperature fluid-rock reactions within mafic lithologies, consistent with basalt-hosted hydrothermal systems typical of mid-ocean ridges. Collectively, these findings point to the presence of multiple hydrothermal systems and suggest the potential for extensive sulphide mineralization across magmatically influenced segments of the tectonically dominated ultraslow-spreading ridges.

Keywords: Hydrothermal plumes, ultra-slow spreading ridge, dissolved CH4, dissolved Mn

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Status Of Biodiversity Documentation In The High Seas: A Case Study Of Selected Benthic Phyla With A Focus On The Indian Ocean

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ABSTRACT

There is a growing interest in documentation and conservation of biodiversity in the high seas, especially considering threats from human activities like shipping, pollution, and deep-sea mining. This study provides an overview of benthic biodiversity in the high seas or 'areas beyond national jurisdiction' (ABNJs) by comparing records of five major marine phyla – Porifera, Cnidaria, Annelida, Mollusca, and Echinodermata using the Ocean Biodiversity Information System (OBIS), a global open-access marine biodiversity database. Based on 3,96,236 benthic records, representing 10,459 species from the aforementioned phyla, the total number of occurrence records, number of species recorded, and the proportion of records with species-level identification across different taxonomic groups and oceanic regions were examined. The results indicate benthic biodiversity research in ABNJ regions is uneven, both taxonomically and geographically. On a global scale, phylum Echinodermata (sea stars and allies) were most widely recorded (1,97,972 records) with a moderate number of species (2,134 species), while phylum Annelida with fewer occurrences (47,451 records), recorded a higher number of species (4,414 species). Among the regions, highest number of records and species were reported from the North Atlantic ABNJ (1,60,270 records and 2,700 species) and Southern Ocean ABNJ (1,17,314 records and 4,442 species). The Indian Ocean ABNJ harbours significantly fewer occurrence records (6,254 records), of which only about 44% are identified at the species level, representing only 648 species. Meanwhile, environmental baseline and biodiversity surveys in the Southwest Indian Ocean ABNJ have led to documentation of over a dozen new benthic species, demonstrating that dedicated surveys and focused taxonomic efforts can bridge the knowledge gap in marine biodiversity and biogeography. Such information is crucial for understanding deep-sea biodiversity and informing global conservation and management strategies for marine ecosystems beyond national jurisdiction.

Keywords: Areas beyond national jurisdiction, baseline environmental surveys, Echinodermata, Porifera, Cnidaria, Mollusca, Annelida, marine biodiversity

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Magmato-Tectonic Controls On A Newly Discovered Hydrothermal Field In The Central Indian Ridge

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ABSTRACT

At mid-ocean ridges, temporal and spatial variations of magmatic, tectonic and alteration processes give rise to a variety of hydrothermal systems. The inactive Yokoniwa hydrothermal system is present on a non-transform offset (NTO) massif, located between the two southern segments (S1 and S2) of the slow to intermediate spreading Central Indian Ridge (CIR). A new active hydrothermal vent site was recently discovered about 4 km N-NW of the Yokoniwa hydrothermal field, and about 9 km east of the neo-volcanic zone of CIR-S1. Here we present the geotectonic setting of this region using high-resolution multibeam bathymetry, backscatter, sub-bottom profiler data, and AUV seabed imagery collected in 2024. Tectonic features such as fault scarps and fissures were identified from the data. The fault scarps are highly deformed and rotated, most likely due to the influence of the horizontal shear along the NTO. Using tectonic strain estimates, fault distribution, and seabed images, we investigate the hydrothermal circulation pattern of this newly discovered hydrothermal vent site, its controlling factors, and its possible link with the Yokoniwa field.

Keywords: Mid-Ocean Ridge, Hydrothermal system, Non-transform offset, AUV Bathymetry.

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Challenges In Powering Subsea Systems With Electro- Optic Umbilical Cable For Deep Sea Mining

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ABSTRACT

Deep-sea minerals are emerging as an alternative resource to compensate for the depletion of land-based reserves required to meet the growing demands of application of renewable energy. Deep-sea mining involves a challenging subsea environment characterized by low ambient temperatures, high pressures, and severe sea surface conditions. The deep-sea mining process involves controlled locomotion and collection, crushing, and pumping of the potato-shaped polymetallic nodules from the seabed, typically at depths of about 5500 m. The remotely operated deep-sea miner is powered through a 6500 - 7000 m long electro-optic umbilical cable wound on a high torque winch mounted onboard the mother ship. This umbilical cable is designed to withstand the ambient pressures and support the total weight of the mining machine. Power and communication signals required for mining operations are transmitted through integrated power conductors and fiber-optic elements. One of the major challenges in powering the high power demands of the mining machine includes handling high voltage levels, ensuring reliable power transmission during operations of deployment and retrieval in heavy seas with the winch rotating and large power surges on seabed operations. The pressure-compensated Field-Installable Termination Assembly (FITA) is a critical component for powering & clear communications. Transmitting large power over long step-out distances necessitates the use of special Medium Voltage Variable Frequency Drives (MVVFDs). A limiting factor is the heating of the cables, especially the middle layers of the multi-layered winch-wound umbilical cable, which leads to de-rating of the ampacity of the cable. The paper brings out the challenges associated with transmitting high voltage and power to the deep-sea miner, and how these issues are effectively being addressed.

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Numerical Investigations On The Performance Of Air Lift Pumping Systems For Deep Sea Mining Applications

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ABSTRACT

Deep sea mining involves the extraction of polymetallic nodules from depths of about 6000 m, requiring reliable lifting systems to transport collected nodules to the surface. Various pumping methodologies are employed to transport nodules, including multistage centrifugal pumps, positive displacement pumps and air lift systems. In recent developments, industry partners have successfully demonstrated air-lift pumps for nodule transport.

Air lift pumping systems use compressed air injected at depth to reduce the density of the fluid column, creating buoyancy that lifts water or slurry through a riser. They are simple design and ability to operate without rotating equipment. In this study, a detailed Computational Fluid Dynamics (CFD) analysis was conducted to assess the influence of submergence ratio and air mass flow rate on performance of air lift pump. The simulations were performed in STAR-CCM+ using the Volume of Fluid (VOF) multiphase model to capture the unsteady interface between air and water, combined with the k–ε turbulence model to represent turbulent mixing within the riser.

The CFD model was validated against experimental data from literature, confirming its ability to predict water mass flow rate at the outlet. A parametric investigation was carried out for a wide range of submergence ratios and air injection rates. Results show that water discharge increases with submergence ratio due to higher hydrostatic head available at the injector. Water flow initially increases with air mass flow rate, reaches an optimum for the given air mass flowrates. Flow visualizations from VOF simulations revealed transitions between different flow regimes, providing detailed insights into volume fraction distribution, pressure and velocity variations along the riser. Future work will focus on extending the model to include polymetallic nodules and three phase slurry transport.

Keywords: Air lift pump, CFD simulation, Nodule transport, Submergence ratio, Air injection

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Identification Of Active Hydrothermal Venting In The Southern Central Indian Ridge

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ABSTRACT

Hydrothermal vents constitute important deep-sea systems that host substantial mineral accumulations and support distinct, evolutionarily adapted biological communities. The intermediate-spreading Central Indian Ridge in the Indian Ocean hosts a diverse range of hydrothermal systems—both active and inactive—associated with magmatic as well as tectonic settings. Here, we report the discovery of an active hydrothermal field at the southern part of Central Indian Ridge, NE of the MESO sulphide mineralization zone. The hydrothermal activity was identified in 2024 using a suite of sensors mounted on a Hugin Superior Autonomous Underwater Vehicle (AUV) surveying at an altitude of 55 m above the seabed. The vent field consists of 13 individual vent plumes at water depths of 2700-3000m. Hydrothermal plumes were detected in the water column as high-intensity backscatter in the multibeam echosounder data and was further supported by water-column temperature anomalies. The newly discovered vent field occur on the flanks of an axial volcanic ridge. Geomorphological analysis of the AUV high resolution (1m) multi-beam bathymetry and associated backscatter data show prominent axial volcanic ridges, extensive fracturing, volcanic mounds, and potential lava flow features, indicating an active magma-driven mid-oceanic ridge setting. These observations suggest a magmatic hydrothermal system and highlight the importance of AUV-based exploration in locating active hydrothermal vent fields along mid-oceanic ridges.

Keywords: Hydrothermal Vents, AUV Bathymetry, Central Indian Ridge, Mid-ocean Ridge

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High-Resolution Simulation of West-Coast Convective Extremes Driven by Arabian Sea Warming: The IOLA Coupled Framework

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ABSTRACT

Recent climate-driven changes across the Indian Ocean, most notably the rapid and persistent warming of the Arabian Sea relative to the Bay of Bengal have intensified the demand for modeling systems that can capture evolving air–sea interactions with far greater precision. This anomalous Arabian Sea warming has boosted ocean heat content and near-surface moisture, supporting not only more frequent and rapidly intensifying cyclones but also an increase in convective activity along the west coast of India. The west-coastal belt, particularly during the pre-monsoon and monsoon transition periods, has experienced more vigorous and localized thunderstorms, heavy rainfall episodes, and offshore trough enhancements, all of which are strongly modulated by fine-scale thermodynamic and dynamical features often missed by coarse- resolution models.

Given these emerging complexities, high-resolution (1–2 km) modeling has become essential for resolving the structure of deep convection, mesoscale vortices, and moisture convergence zones that govern extreme precipitation along the western coastline and the adjoining oceanic region. Such resolutions allow for more accurate depiction of storm-scale processes, boundary-layer evolution, and surface flux feedbacks as critical ingredients for predicting high-impact events influenced by Arabian Sea warming.

To meet these challenges, the Indian Ocean–Land–Atmosphere (IOLA) Coupled Mesoscale Prediction System has been developed as a unified, seamless framework capable of tracking severe weather across both oceanic and continental domains. By integrating a nonhydrostatic dynamical core, storm-following high-resolution nests, ocean coupling, and flexible physics configurations, IOLA provides a consistent platform to simulate the full spectrum of extreme weather from rapidly intensifying cyclones over the Arabian Sea to convective outbursts along the west coast and inland. This unified approach positions IOLA as a next-generation system for improving early warnings and enhancing resilience to India's evolving spectrum of severe weather.

Keywords: Meso-scale models, Land-ocean-atmosphere, Extreme events

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Lagrangian Tracking of Atmospheric Moisture: Quantifying the Arabian Sea's Contribution to the 2025 Indian Monsoon Extremes

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ABSTRACT

The 2025 Indian Summer Monsoon served as a stark case study in hydroclimatic intensification, characterized by an early onset, a rapid advance, and devastating regional extremes, including fatal floods in Northwest India coinciding with a significant deficit in the Northeast. This study suggests that these events are not isolated anomalies but are fundamentally driven by the accelerated warming of the Western Indian Ocean, which has emerged as a primary regulator of of this intensified variability. We employ a multi-framework diagnostic approach, integrating a Mean Residual Life (MRL) extremal index with spatial coherence filtering to identify synoptic- scale precipitation events, complemented by a 3-dimensional Lagrangian particle tracking model to quantitatively attribute their moisture sources. This Lagrangian approach advects virtual air parcels backward/forward in time along four-dimensional wind fields to reconstruct complete moisture pathways from sink to source. The resulting trajectory analysis unequivocally links the most impactful rainfall events to anomalously high sea surface temperatures (SSTs) in the Arabian Sea. These SSTs amplified latent heat flux, steepening the lower-tropospheric moisture gradient and consequently intensifying the Somali Low-Level Jet. Our findings demonstrate that the warming Arabian Sea is now the dominant moisture source for extreme precipitation events over central and western India, contributing over 60% of precipitable water during high-intensity events. This increased atmospheric moisture content was then unleashed by synoptic-scale systems, leading to the season's abundant rainfall and flood incidents. The 2025 monsoon's extremes stem from a reconfigured ocean-atmosphere coupling, with the Arabian Sea now an active driver. Integrating high-resolution ocean data into forecasting is therefore critical for mitigating the escalating climate risks across South Asia.

Keywords: Arabian Sea Warming, Indian Monsoon, Extreme Rainfall, Moisture Tracking, Climate Extremes, 2025 Monsoon, Hydrological Hazards.

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Dust Transport over Arabian Sea during Monsoon and Impact on cloud microphysics

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ABSTRACT

Northern Arabian Sea exhibits significant dust aerosol transport from the Arabian Peninsula by the westerly wind flow during the south-west monsoon. These transported dust aerosols form an elevated layer of aerosol and play an important role in cloud microphysical processes over the region. Observations of clouds and precipitation microphysics within the shallow and deep cumulus over the north-eastern Arabian Sea region during the Indian monsoon 2015 are illustrated in this study with a focus on cloud droplet spectral parameters. The observational period showed a significant incursion of dust aerosol and the presence of giant cloud condensation nuclei (GCCN), modifying the cloud and precipitation spectral properties. Warm rain microphysics was active in these clouds and supported the mixed-phase development and exhibited hydrometeors of snow, graupel and large aggregates as part of ice processes. A rapid broadening of droplet size distribution (DSD) near to the cloud base was noted in in these clouds over the Arabian Sea.

Key Words: Arabian Sea, Dust, Cloud, Microphysics, Rain

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Arabian Sea warming and Indian summer monsoon variability: A 40-Year Perspective

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ABSTRACT

This study examines four decades (1982–2022) of Arabian Sea (AS) warming and its dynamic influence on Indian Summer Monsoon Rainfall (ISMR). A significant SST rise of ~0.8°C is detected across the basin, with the strongest warming (~0.9°C, 99% confidence) in the northern and eastern AS, marking a shift from episodic pre-2000 warming to persistent post-2014 events. EOF analysis identifies three dominant mode with a basin-wide warming in first mode (60.8%) linked to long-term climate change, a west–east dipole EOF2 mode (31.5%) associated with the Indian Ocean Dipole, and an intraseasonal EOF3 mode (1.6%) connected to variations in ocean heat content and vertically integrated moisture transport. Surface fluxes show enhanced latent, sensible, and longwave heat losses over the eastern AS, consistent with reduced shortwave radiation and declining net heat fluxes after the late 1990s. Subsurface changes reveal increasing OHC, mixed-layer deepening (~12 m), and a deepening thermocline (140–160 m), indicating enhanced oceanic heat storage and vertical mixing, especially during summer monsoon and El Niño conditions.

Atmospheric responses show strong climate-mode modulation where El Niño suppresses VIMT by 15–20% and reduces rainfall over southern/central India, whereas positive IOD events enhance VIMT by ~25% and strengthen rainfall across southern and northern India. Pre-monsoon AS warming exhibits a season-dependent influence on ISMR and enhancing June rainfall but suppressing August–September rainfall over central and eastern India. Spatial correlations further reveal a dipole structure, with positive SST–rainfall links ($r = 0.5–0.6$) over central/northern India and negative correlations along the east coast. These findings highlight a strong, evolving thermal–dynamic coupling between the AS and ISMR, demonstrating the critical role of subsurface heat storage, ocean–atmosphere fluxes, and climate modes in driving monsoon variability. The results provide new insights for improving monsoon prediction and understanding Indo-Pacific climate connectivity under continued ocean warming.

Keywords: Arabian Sea warming, Ocean–atmosphere coupling, Empirical Orthogonal function, sub surface heat storage, Indian summer monsoon rainfall

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Recent two decades have witnessed an uptick in monsoon depressions over the northern Arabian Sea

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ABSTRACT

Recent research has found that the rising pressure over the Tibetan Plateau plays a pivotal role in increasing ISM rainfall over northwestern India (NWI). One of the notable components in understanding ISM dynamics is the movement of the intertropical convergence zone (ITCZ) and the formation of synoptic-scale disturbances known as monsoon depressions (MDs). These systems, responsible for a significant portion of monsoon rains, exhibit features of cyclonic circulation spanning thousands of km horizontally, with heights reaching 6 to 9 km. Thereby, providing plentiful rainfall, especially over the south-western section of the system. However, recent studies have indicated a decline in MDs frequency over the Bay of Bengal (BoB), while others have observed an increase in short-lived low-pressure systems and number of dry days, aligning with negative rainfall trends in northern parts of central India/IGP. The weakening of barotropic instability over the head BoB region may be contributing to the declining trend in MDs along with reduced mid-tropospheric relative humidity in recent decades. In contrast, there has been an increase in cyclonic activity over the Arabian Sea, attributed to rising sea surface temperatures driven by global warming. This shift is altering the traditional pattern, with the Arabian Sea now experiencing more cyclones compared to the BoB off India's eastern coast during pre-monsoon and post-monsoon seasons.The analysis reveals that the occurrence of summer Monsoon Depressions (MDs) over the North Arabian Sea is doubling during 2001-2022 compared to the 1981-2000 period. This increase stems from changes in the region's dynamic and thermodynamic conditions. The heightened genesis potential parameter with sea surface temperature and moisture flux transport and its convergence over the North Arabian Sea inducing MDs formation, contrasting to the Bay of Bengal. The dynamic processes involved in its formation, are a combination of barotropic and dynamical instability are leading to increased rainfall over north-western India. Strong East Asian jet variability over East Asia, with an anomalous anticyclone in the north and weak cyclonic anomalies in the south, induces prevailing easterly wind anomalies along the monsoon trough. This leads to poleward shift in the low-level jet, significantly altering dynamic and thermodynamic parameters in the northern Arabian Sea region, leading to a notable increase in MDs.

Keywords: Monsoon depressions, North west India rainfall, ISMR variability

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Impacts of Rapid Indian Ocean Warming on Indian Ocean and Western Pacific Tropical Cyclone Genesis

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ABSTRACT

Global ocean temperatures have risen over the past century, primarily due to anthropocentric climate warming. Studies indicate that the Indian Ocean is warming more rapidly than other tropical basins, with potential implications for regional and global climate. However, the effects of this rapid warming on the genesis and intensification of tropical cyclones remain uncertain. This study uses the Community Earth System Model (CESM2) to investigate how Indian Ocean warming influences tropical cyclone formation across the Indian Ocean and the western Pacific. The experimental setup includes a control simulation and a perturbation simulation that applies observed sea surface temperature (SST) anomaly trends from 1950 to 2024 within the Indian Ocean region. Analysis using the Genesis Potential Index (GPI) shows that Indian Ocean warming enhances cyclogenesis in the basin, particularly at lower latitudes. In the North Indian Ocean, the increase is larger over the Arabian Sea, especially during October–December (OND). In the South Indian Ocean, GPI increases more in the eastern region, with decreases in the western region during OND and December to April (DJFMA). In the western Pacific, GPI decreases overall, except during June–September, where an increase is simulated. Decomposition of GPI into contributing factors indicates that vertical wind shear is the primary driver of these changes, with secondary contributions from relative humidity, maximum potential intensity, and absolute vorticity.

Keywords: Rapid Indian Ocean Warming, Tropical Cyclones, Large-scale circulation changes

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Analysing the dynamic model outputs to understand the mesoscale air-sea interaction processes over western Arabian Sea during the south-west monsoon Season

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ABSTRACT

The Indian summer monsoon rainfall has a bi-weekly intra-seasonal cycle whose variability is primarily governed by the Somalian Jet (SJ) over the western Arabian Sea along the Somali coast. A coastal current called the Somalian Current is driven by this cross- equatorial jet. This coastal current is also associated with several mesoscale eddies including the anti-cyclonic mesoscale eddy called the Great Whirl (GW). Owing to the strong upwelling associated with the mesoscale eddies, there exists a distinct pattern in sea surface temperature where relatively cold and warm waters exists within mesoscale distances. This creates a baroclinic boundary layer in this region. Also in this region, there exists a difference of around 10 W/m² in sensible heat flux, within spatial scales of just 200 km. This is evident in individual year-month summaries and monthly climatology constructed from the marine-met observations obtained from the ships of VOS collected in the ICOADS. Similar mesoscale patterns are evident in climatology of other marine- atmosphere boundary layer variables. Additionally, the same surface observations served to estimate a proxy of baroclinic PV tendency within this region. To understand the effect of this mesoscale air-sea interaction in the MABL and the overlying cross-equatorial jet, model outputs of the coupled model of HWRF-HYCOMM and WRF model with SST forcing are analysed.

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Role of Arabian Sea Warming in Modulating Trough Dynamics and Enhancing the 2024 Dubai Flood Event

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ABSTRACT

Understanding climate extremes is crucial for improving forecasting capabilities and reducing risks to lives and property. On 16 April 2024, Dubai, an arid desert city in the United Arab Emirates, experienced an unprecedented 24-hour rainfall event of nearly 250 mm, it is the heaviest on record. This study investigates the atmospheric and oceanic mechanisms that led to this extreme event, emphasizing both large-scale and synoptic-scale drivers, along with the role of regional ocean warming. Analyses reveal that strong low-level convergence and anomalous moisture transport from the Arabian Sea, Red Sea, and Persian Gulf were central to the convective intensification. The Arabian Sea exhibited anomalously warm sea surface temperatures (exceeding +1.2°C), enhancing lower- to mid-tropospheric moisture and latent heat availability. A pronounced cyclonic circulation anomaly in the lower troposphere, coupled with a deep mid- to upper-level trough, sustained strong vertical wind shear and dynamical instability. The juxtaposition of upper-level anticyclonic and cyclonic patterns in the 200 hPa geopotential height field facilitated large-scale ascent, while an intensified subtropical jet stream enhanced upper-level divergence. The vertical alignment of these dynamical and thermodynamical features promoted deep convection and heavy precipitation over Dubai. Overall, the event underscores the critical role of Arabian Sea warming and associated ocean-atmosphere feedbacks in amplifying rainfall extremes over the Arabian Peninsula. These findings highlight the need for integrated monitoring of regional SST anomalies and atmospheric circulation to improve early warning systems for future high-impact rainfall events in the region.

Key words: Dubai Flood, Extreme rainfall, Arabian Sea warming, Ocean-Atmosphere interactions

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Influence Of Arabian Sea Warming On The Somali Jet–Somali Stream System And Its Impact On Monsoon Rainfall Over India

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ABSTRACT

Rapid warming of the Arabian Sea has begun to alter key land–ocean–atmosphere interactions that support the Indian summer monsoon. Among these, the Somali Jet and the associated Somali Current/Stream strongly influence cross-equatorial moisture transport from the western Indian Ocean into India. This study investigates how sustained Arabian Sea warming is modifying the strength, onset, and vertical structure of the Somali Jet and the downstream impacts on monsoon rainfall. Using satellite fluxes, reanalysis products, and long-term rainfall datasets, we find that enhanced pre-monsoon warming increases the thermal contrast between the Horn of Africa and the warm pool, favouring an earlier onset and intensified low-level jet. Concurrent adjustments in the Somali Stream alter upper-ocean heat content and modulate cross-equatorial energy transport, leading to stronger moisture convergence over the Western Ghats and central India. Years with pronounced warming are associated with strengthened westerlies and elevated extreme rainfall probability, but excessive warming reduces vertical shear and weakens monsoon coherence, leading to regional rainfall deficits. The results highlight the emerging nonlinear influence of Arabian Sea warming on the coupled Somali Jet–Somali Stream system and emphasise its importance for improving seasonal prediction frameworks in a warming climate.

Keywords: Somali Jet, Somali Stream, Arabian Sea warming, Indian monsoon, moisture transport

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Impact Of Assimilation Of Oceansat-3 Winds: A Case Study Of Cyclone Biparjoy Over The Arabian Sea

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ABSTRACT

This study examines the impact of assimilating Oceansat-3-derived ocean surface winds into the Weather Research and Forecasting model for forecasting the unique, unusually long, and extremely severe cyclonic storm Biparjoy, which occurred over the Arabian Sea. The wind observation operator sd_scheme is used to assimilate wind speed and direction, in order to determine the influence of incorporating calculated observation error of scatterometer winds along with a domain-specific background error within the 3D-VAR assimilation framework. The assimilation results in an improvement in the prediction of cyclogenesis and the representation of dynamic features associated with the cyclone, compared to that without assimilation. This study emphasizes the importance of utilizing available non-conventional datasets in data-sparse oceanic regions to enhance cyclone prediction under a scenario of rapid ocean warming.

Keywords: Biparjoy, cyclone, Oceansat-3, assimilation, WRF model.

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Cloudburst Over The West Coast Of India

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ABSTRACT

In the context of global warming, the frequency and intensity of extreme rainfall events have increased significantly. Such events often trigger floods and landslides, causing severe damage to human life, infrastructure, and socio-economic assets. According to the Indian Meteorological Department (IMD) definition, a cloudburst is characterized by high-intensity rainfall, where the rainfall intensity exceeds 100 mm/hr over a station or a 20-30 sq km area. The occurrence of cloudbursts has become more frequent and intense in recent decades, primarily due to climate change and rising sea surface temperatures, which enhance atmospheric moisture content. In India, cloudbursts occur during the monsoon season due to strong convection associated with orographic forcing over the Himalaya, Western Ghats, and northeastern hills. This study analyzes cloudburst events over the West Coast of India using the latest Indian Ocean Land Atmosphere (IOLA) coupled model. The results indicate that the IOLA model effectively captures the cloudburst rainfall with minimal spatial and temporal errors, whereas the GPM observation fails to accurately capture the rainfall intensity. Along with the large-scale and thermodynamic features that drive the cloud burst event in this region, the impact of ocean coupling on the model output is also studied in this work. Overall, this study provides valuable insights for the modeling community, enhancing the understanding of cloudburst dynamics through the use of an advanced coupled Ocean–Land–Atmosphere modeling framework.

Keywords: Cloudburst, IOLA model, numerical weather prediction, West coast of India

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Examination of Ocean Salinity and Temperature Variations Linked to the Indian Ocean Monsoon Advancement Timing

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ABSTRACT

The current study examines three-dimensional salinity and potential temperature anomalies in the Indian Ocean during contrasting scenarios of monsoon progression. Five zones (Arabian Sea, Bay of Bengal, Western Indian Ocean, Eastern Indian Ocean, Southern Indian Ocean) and five depth levels (5–125 m) are included in the analysis, which compares the development of extremely too fast, fast, and late advancement of monsoons from March to July. Favorable ocean- atmosphere coupling for early start is facilitated by pre-monsoon negative salinity anomalies, warm upper ocean thermal anomalies (0–75 m), and prominent vertical stratification in the western Indian Ocean in years of too fast advance. The years with fast progression exhibit intermediate traits, such as steady temporal evolution and moderate anomaly magnitude. Wide positive salinity anomalies (+0.9 to +1.5 psu) that reach into the upper 200 meters are characteristic of late growth years, particularly in the Bay of Bengal and the eastern Indian Ocean. The monsoon is delayed by unfavorable thermodynamic circumstances with profound cold temperature anomalies (-1.2 to -1.5 °C) at 75–250 m in the Arabian Sea. According to regional study, the Arabian Sea displays intricate vertical structures, whereas the Bay of Bengal experiences significant freshwater-driven changes. The southern Indian Ocean continues to exhibit anomalies that point to subtropical teleconnections, whereas the equatorial portions exhibit east-west asymmetries associated with wave dynamics. The results indicate that important prognostic information can be found in underlying ocean conditions that were developed during the pre-monsoon season. The significance of three-dimensional ocean measurements for enhancing seasonal monsoon forecasting and comprehending the ocean- atmosphere connection process is highlighted by the vertical coherence of pre-monsoon subsurface anomalies.

Keywords: Indian Ocean salinity, Monsoon advancement, Ocean-atmosphere coupling,
Seasonal predictability

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Interannual Variability of Chlorophyll Concentrations in the Arabian Sea.

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ABSTRACT

Chlorophyll concentrations in the ocean exhibit marked spatial and temporal variability driven by physical, chemical, and biological processes. Seasonal changes arise from variations in light, temperature, and nutrient supply, whereas interannual fluctuations are often associated with large-scale climate phenomenon such as the El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). These variations play a crucial role in regulating oceanic primary productivity, marine ecosystem health, and global biogeochemical cycles. The Arabian Sea—one of the most biologically productive regions of the global ocean—owes its high productivity to Southwest Monsoon–driven upwelling and winter convective mixing, which deliver nutrient-rich waters to the surface and stimulate phytoplankton growth.In this study, we analysed monthly and seasonal climatologies of chlorophyll-a in the Arabian Sea and examined anomalies over a 24-year period (1998–2021). Our results reveal pronounced interannual variability, with anomalies exceeding +0.2 mg m^{-3} in 2005 and falling to –0.2 mg m^{-3} in 2016. A noticeable shift toward negative anomalies after 2009 indicates a decline in regional productivity during the past decade. Standard deviation analysis of log-transformed chlorophyll anomalies identified five hotspots of variability across the basin, each exhibiting distinct temporal patterns and upwelling signatures.A notable contrast was observed when examining the same season (SON) during two extreme IOD years. In 2016, an intense negative IOD (nIOD) event enhanced coastal productivity, leading to a clear chlorophyll bloom along the west coast of India. Enhanced convection and weakened easterlies during nIOD conditions likely promoted nutrient enrichment and favourable light conditions. In contrast, during the strong positive IOD (pIOD) event of 2019, the same region experienced a sharp decline in chlorophyll concentration, despite occurring in the same season. The suppressed convection and altered wind patterns associated with pIOD conditions appear to have reduced nutrient supply, weakened upwelling and led to diminished productivity.This opposite behaviour between 2016 and 2019 underscores the strong, asymmetric influence of IOD phases on Arabian Sea biogeochemistry and highlights the critical sensitivity of coastal ecosystems to climate variability.

Focusing on the western coast of India, we examined two contrasting subregions: the Southeastern Arabian Sea (SEAS) (72°E–78°E, 15°N–5°N), representing the coastal waters off Kerala and southern Karnataka, and the Northeastern Arabian Sea (NEAS) (70°E–74°E, 21°N–15°N), spanning the Goa, Maharashtra, and southern Gujarat coastline. The SEAS displayed strong year-to-year fluctuations, including a marked positive peak in 2017, reflecting episodic shifts in upwelling intensity. In this region, chlorophyll anomalies closely tracked zonal wind anomalies, highlighting the dominance of wind-driven upwelling in controlling bio[illegible] productivity. Conversely, the NEAS exhibited fewer and weaker anomalies, suggesting

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stable conditions. Here, chlorophyll variations were not directly synchronized with wind anomalies, indicating that additional oceanographic processes—such as mesoscale eddies, stratification changes, or remote forcing—may modulate nutrient availability. These contrasting behaviours underscore the importance of regional-scale analyses when evaluating productivity changes in the Arabian Sea. The clear divergence between SEAS and NEAS dynamics illustrates how even neighbouring coastal systems can respond differently to atmospheric forcing.These findings highlight the complex interplay between atmospheric forcing, oceanic dynamics, and climate variability in regulating Arabian Sea productivity. The observed post- 2009 decline in chlorophyll, coupled with increasing regional

contrasts, aligns with emerging evidence of climate-driven changes in monsoon winds and ocean stratification and IOD frequency. Understanding these evolving patterns is essential for improving predictions of primary productivity, supporting fisheries management, and assessing the broader ecological impacts of climate change on the Indian Ocean.

Keywords: Chlorophyll-a variability, Arabian Sea productivity, Indian Ocean Dipole (IOD), Upwelling dynamics, Climate-driven Ocean changes

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Unraveling the Role of Land Use Changes in Shaping Extreme Rainfall in South India

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ABSTRACT

This study examined how heterogeneous land-use and land-cover (LULC) changes associated with urbanization influence extreme rainfall event (ERE) characteristics across metropolitan and non-metropolitan cities in South India. Our observational analysis indicated a notable increase in the ERE frequency and intensity during 2000-2022 compared to the long-term record (1950–2022), particularly during the summer monsoon season. Concurrently, rapid urbanization across South India has driven substantial LULC transformations, necessitating an investigation into their impact on rainfall patterns. To assess the LULC impact on the ERE simulations, we employed the Weather Research and Forecasting (WRF) model at 1km resolution using different datasets: contemporary Indian Space Research Organization (ISRO) LULC data (2019) versus United States Geological Survey (USGS) data (1993). For each ERE, we conducted ensemble simulations with both datasets and evaluated outputs against observations using standard statistical metrics. Results show that changes in LULC associated with urbanization significantly influence the spatial distribution and intensity of EREs, and simulations using ISRO LULC data consistently outperform those using USGS data across all study regions. The ISRO-based simulations exhibit lower rainfall bias and remarkable performance improvements relative to USGS-based simulations: Hyderabad (75%), Palakkad (71%), and Bengaluru (60%), followed by Chennai (50%) and Tirupati (25%). Additionally, ISRO data simulations enhanced the forecast skill for surface temperature, latent heat flux, sensible heat flux, and soil moisture. The improved ERE representation in ISRO-based simulations stems from more realistic LULC changes that increase surface temperature, convective available potential energy, and elevated planetary boundary layer height while reducing convective inhibition, collectively enhancing convective processes. These findings highlight the critical importance of incorporating current, high-resolution LULC data in weather prediction models for improving the extreme rainfall forecasts over rapidly urbanizing regions, where accurate rainfall prediction is essential for disaster preparedness, land-use policy making, and urban planning.

Keywords: Extreme rainfall events, Land-use Land-cover changes, Urbanization, WRF model, South India.

Theme- Ocean and Climate

Session Title: Blue intelligence: AI for climate and ocean health

Session Convener: Dr. M. Venkatesan

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Exploring a Modified KSSA Approach for Optimal Imputation of In Situ Sea Surface Temperature Data

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ABSTRACT

Sea Surface Temperature (SST) plays a pivotal role in climate and weather phenomena, such as monsoons and El Niño events. SSTs are measured through both in-situ methods and satellite-based remote sensing. However, in-situ measurements often contain missing data due to various challenges, complicating the analysis and modeling of SST. Numerous methods have been proposed to impute missing values in time series data. This study aims to evaluate different imputation methods to address missing SST data, employing a modified Known Sub- Sequence Algorithm (KSSA) strategy for validation. This strategy allows for the selection of the optimal imputation techniques for in-situ SST data, facilitating the recovery of missing values while enhancing the utility of the data for reliable satellite calibration and verification. By utilizing a robust evaluation and validation approach, the modified KSSA strategy differs from typical evaluations of imputation methods, which generally require a complete time series and can be applied to time series that already contain missing data. In this study, ten imputation methods from the 'imputeTS' R package were applied to SST data from five Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) moorings in the Bay of Bengal, spanning from 2007 to 2020. The results demonstrate that the Seasonal Decomposition with Kalman Filters (SEADEC) method consistently yielded the lowest Root Mean Squared Error (RMSE) and Mean Absolute Scaled Error (MASE) scores across various mooring locations.

Keywords: Sea Surface Temperature, Imputation, KSSA, RAMA mooring, Bey of Bengal

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Chl-Conv: Deep Learning-Based Chlorophyll Predictions For The Karaikal Region.

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ABSTRACT

Accurate forecasting of chlorophyll-a concentration is essential for assessing biogeochemical variability and ecosystem function in coastal waters. The Karaikal sector of the Bay of Bengal, strongly influenced by monsoonal forcing, freshwater discharge, and coastal circulation, exhibits nonlinear dynamics that challenge traditional empirical approaches. This study develops and evaluates advanced deep learning (DL) and physics-informed neural network (PINN) architectures for chlorophyll prediction using multi-parameter satellite ocean-colour observations and derived environmental covariates. Eight architectures were implemented: Convolutional Neural Network (CNN), Long Short-Term Memory (LSTM), CNN-LSTM, Eidetic 3D-LSTM (E3D-LSTM), Self-Attention ConvLSTM (SA-ConvLSTM), Physics-CNN, Physics-LSTM, and Physics-ConvLSTM. Data-driven models showed progressive improvements in capturing spatial gradients and temporal evolution, with CNN-LSTM and E3D- LSTM outperforming single-stream architectures. The attention mechanism in SA-ConvLSTM further improved long-range dependency learning and stability during rapid chlorophyll fluctuations. Physics-informed variants introduced advection–diffusion constraints and physical continuity terms into the loss function, reducing error propagation and ensuring dynamical consistency under monsoonal transitions. Physics-ConvLSTM delivered the highest predictive skill (RMSE = 0.126, R^2 = 0.94), surpassing all baseline DL models. The findings demonstrate that integrating physics-based priors with deep spatio-temporal architectures significantly enhances chlorophyll-a predictability in complex coastal systems, providing a robust framework for operational biogeochemical monitoring and early-warning applications.

Keywords: Chlorophyll-a, Deep Learning, Biogeochemical, Forecasting, Neural Network.

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AI Powered Ocean Sensing: Algal Blooms And Water Quality Mapping

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ABSTRACT

Water resource management and aquatic environments face significant challenges due to the increasing frequency of Harmful Algal Blooms (HABs) and the decline of water quality Conventional prediction models often lack the transparency and real-time capability needed to account for complex environmental interrelationships. This paper acquaint an innovational framework for AI-Powered Ocean Sensing that leverages Explainable Artificial Intelligence XAI to enable real-time environmental assessments and reliable forecasting of algal blooms and water lineament degradation. The approach incorporate advanced machine learning ML and deep get word techniques with model interpretation method including Harlow Shapley Additive Explanations (SHAP) and Local Interpretable Model-agnostic Explanations (LIME). The proposed successfully overcomes the critical trade-off between performance and interpretability in environmental science by transforming raw sensor data and satellite imagery into transparent trustworthy and actionable intelligence . This methodology not only delivers high presage truth but also provides valuable insights into the processes driving bloom formation and water quality changes which are essential for water quality mapping. Experimental results across diverse aquatic ecosystems demonstrate a anticipation truth exceeding 95 Interpretability metric function consistently high spot key environmental driver such as temperature dissolved oxygen DO levelsand nutrient concentrations. This work establishes a transparent and trusty AI-driven solution for proactive environmental monitoring and sustainable ecosystem management

Keywords: Ocean Sensing ,Water resource management, Harmful Algal Blooms, Explainable Artificial Intelligence, sustainable ecosystem management.

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PG-Fan: Physics-Guided Fourier Analysis Neural Network For Algal Bloom Forecasting For Karaikal Region.

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ABSTRACT

Harmful Algal Blooms (HABs) have become increasingly frequent and intense along the southeast coast of India, threatening marine ecosystems, fisheries, and the livelihoods of coastal communities. The Karaikal region, influenced by complex monsoonal dynamics and riverine inputs, presents significant challenges for conventional satellite-based detection methods, which often struggle with variability and limited physical realism. To overcome these limitations, this study introduces PG-FAN (Physics-Guided Fourier Analysis Neural Network)—an advanced deep learning framework designed for accurate and physically consistent algal bloom forecasting. Using ocean-color datasets from MODIS and Sentinel-3 (2015–2025), projected over the Karaikal coastal zone, PG-FAN integrates Fourier Analysis Neural Operators with physics-based constraints derived from advection–diffusion equations, mass conservation, and coastline masking. The model was trained on a decade of satellite observations and validated against independent HAB events in November 2024 (post-monsoon) and April 2025 (pre- monsoon). Results show that PG-FAN outperforms traditional deep learning models, achieving F1 = 0.79, AUPRC = 0.86, and AUROC = 0.93, while reducing false detections by over 30%. The model demonstrated strong spatial correlation (r = 0.85) with observed bloom distributions and maintained forecast accuracy up to 16 days in advance. By embedding physical oceanographic principles into a deep spectral learning architecture, PG-FAN provides a robust, interpretable, and operationally reliable framework for real-time HAB forecasting in coastal waters, supporting sustainable marine resource management and early warning systems for environmental protection in the Karaikal region.

Keywords: Deep Learning, Remote Sensing, Coastal Forecasting, Harmful Algal Blooms, Physics Guided Neural Netw

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Advancing Sustainable Marine Ecosystem Monitoring through Knowledge-Guided Deep Learning: An Integrated Neural Framework for Ocean Color Analysis and Chlorophyll Estimation Using Satellite and In-Situ Observations.

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ABSTRACT

Global ocean degradation poses a serious threat to marine ecosystems, with over 3 billion people depending on oceans for food security and livelihoods, and an estimated USD 100 billion lost annually due to declining marine productivity. Monitoring and predicting ocean color variations, which reflect changes in chlorophyll concentration, are therefore vital for assessing ocean health and understanding climate-driven biogeochemical processes. However, conventional empirical and statistical models struggle to capture the nonlinear optical interactions and environmental variability influencing ocean color dynamics. Although deep learning models have improved prediction accuracy, they often neglect the physical laws of light absorption and scattering, leading to non-physical or unstable outcomes.To address these limitations, this study presents an advanced Physics-Informed Neural Network (PINN) framework that fuses physical ocean optics with data-driven learning. The model incorporates radiative transfer and bio-optical equations within a physics-guided loss function, ensuring predictions remain physically consistent while adapting to diverse oceanic conditions. It utilizes multi-spectral satellite data and in-situ chlorophyll observations to train a dual-loss architecture balancing data accuracy and physical consistency. Experimental evaluations demonstrate that the proposed framework achieves up to 15% improvement in predictive accuracy and enhanced interpretability compared with conventional neural approaches. This physics-guided AI model provides a robust and scalable pathway for real-time monitoring of ocean color dynamics, contributing to global efforts in sustainable ocean ecosystem management.

Keywords: Ocean Color Analysis, Chlorophyll Estimation, Sustainable Marine Eco Monitoring, Neural Network, Remote Sensing and In-Situ Data

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PhysTempFusionNet (PTF-Net): A Physics-Guided CNN-Transformer Fusion Network for estimating underwater temperature.

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ABSTRACT

Accurate underwater temperature predictions are critical for marine ecosystem monitoring, climate analysis, and operational oceanography. Classical statistical approaches and traditional deep learning models, such as LSTM, GRU, and RNN, have problems for modelling the nonlinear, depth-dependent, and temporally complicated behaviour of subsurface thermal dynamics. These models frequently lack physical interpretability, resulting in predictions that may contradict accepted oceanographic principles. This research presents PhysTempFusionNet (PTF-Net), a physics-guided hybrid deep learning architecture designed to meet these difficulties. PTF-Net combines a 1D CNN encoder to extract fine-scale temporal patterns with a Transformer encoder to capture long-range relationships. A cross-fusion gating module combines the two representation streams, and a physics-based regularisation constraint enforces the predicted negative correlation between depth and temperature, resulting in physically compatible predictions. PTF-Net is tested on a large-scale underwater observational dataset that includes over 400,000 samples from various stations and depths. Experimental results outperform old and current deep learning baselines. The model achieves 98.30% accuracy, 98.43% precision, 99.05% recall, 98.74% F1-score, and a ROC-AUC of 0.9981 for hotspot identification. PTF-Net's continuous temperature forecasting has an RMSE of 0.2528°C, MAE of 0.1270°C, and R^2 of 0.9881. The findings demonstrate that PTF-Net provides a reliable, accurate, and physically based framework for predicting underwater temperatures.

Keywords: Underwater Temperature Prediction, Physics-guided deep learning, Spatiotemporal Modelling, Oceanographic Forecasting, CNN/Transformer Fusion

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A Hybrid AI/ML Framework for Predicting Heavy Rainfall Events over the Indian Subcontinent

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ABSTRACT

Synoptic-scale low-pressure systems over the Bay of Bengal significantly contribute to the Indian Summer Monsoon (ISM) rainfall, which travels through eastern Indian states, such as Odisha, on its way to the Indian mainland. For conventional physics-based, state-of-the-art high-resolution weather models, predicting heavy rainfall events (HREs) at the district scale with sufficient lead time (up to 96 hours) is extremely challenging. For the first time, these studies has used artificial intelligence (AI), machine learning (ML) and deep learning (DL) methods to improve the rainfall forecast in retrospective and real time using start of art Weather Research and Forecast (WRF) high resolution (3km) with lead time forecasts (up to 96hour/day4) outputs at the district scale over Odisha. The Odisha district-level rainfall forecast was much improved by our proposed model (KU-Net (+A)). The DL models reduced the Mean Absolute Error (MAE) values to less than 8 mm up to Day 4 for Case 1 and less than 15 mm for Case 2. However, WRF shows MAE values of more than 25 mm and 36 mm for both cases, respectively. The rainfall distribution, as shown in Figure 1, indicates that although the WRF underestimates the rainfall by less than 10 mm, the proposed DL model better captures the spatial rainfall distribution. In the second case, the proposed DL model correctly predicts the magnitude, intensity, and dispersion of the HREs, but WRF underestimates them. The DL model's TPR (True Positive Rate) for the LR (Light Rain) and MR (Moderate Rain) classes is higher (>80%) than WRF's (52.5%), and the confusion matrix shows that there were no HREs in Case 1. In the second real- time scenario, the proposed DL model achieves TPRs of 85.7%, 87%, and 100% for the HR (Heavy Rain), VHR (Very Heavy Rain), and HER (Extremely Heavy Rain) categories, respectively.

Keywords: Extreme rainfall events, Deep Learning, Kernelized-based U-Net

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Evaluating the Prithvi Weather-Climate Foundation Model for Zero-Shot Forecasting in the Indian Ocean Region

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ABSTRACT

This study assesses the zero-shot climate forecasting capabilities of the Prithvi Weather-Climate (WxC) foundational model, developed by IBM Research, NASA, and their collaborating research institutes. Prithvi-WxC is a large geospatial foundation model pretrained on long-term MERRA-2 atmospheric reanalysis data covering a wide range of global climate variables. Our objective is to evaluate how efficiently this model can generate short-to-medium-range forecasts for key climate variables—such as sea-surface temperature, winds, and precipitation—over the Indian Ocean region without any task-specific fine-tuning. To do this, we design a systematic workflow that includes preparing MERRA-2 inputs, generating autoregressive rollouts using the pretrained Prithvi-WxC model, and evaluating the predictions with ground truth. This work aims to assess the suitability of foundational geospatial models for regional climate applications and to outline a reproducible framework for testing zero-shot forecasting skill in the Indian Ocean domain.

Keywords: Zero-shot climate forecasting, Prithvi-WxC, MERRA-2, Indian Ocean, Autoregressive rollouts

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Bioinformatics-Driven Ai System For Monitoring Emerging Pathogens In Coastal Waters

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ABSTRACT

Coastal ecosystems are increasingly vulnerable to emerging pathogenic threats driven by pollution, climate variability, and expanding human activities. Traditional laboratory-based detection methods often fall short due to their longer turnaround time, limited scalability, and inability to capture the full complexity of microbial communities in dynamic marine environments. This study presents an integrated Bioinformatics-Driven AI System designed to enable rapid, high-resolution monitoring of emerging pathogens in coastal waters. The framework combines high-throughput metagenomic sequencing with advanced machine-learning and deep-learning models capable of detecting pathogenic signatures, identifying virulence factors, and predicting potential outbreak risks. Environmental metadata—including salinity, nutrient concentration, temperature, and pollutant load—are incorporated to enhance ecological interpretation and improve system accuracy. Real-world water samples from multiple coastal sites demonstrated the system's ability to identify bacterial, viral, and fungal pathogens with significantly higher sensitivity compared to conventional methods. The AI-augmented pipeline offers real-time analytics, automated reporting, and early-warning capabilities, supporting timely interventions and informed decision-making. This multidisciplinary approach provides a scalable, data-driven solution to strengthen marine surveillance programs, protect public health, and enhance preparedness against emerging coastal pathogens.

Keywords: Pathogen surveillance, coastal ecosystems, bioinformatics, artificial intelligence, metagenomics

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Federated Learning for Privacy-Preserving Global Marine Genomic Monitoring

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ABSTRACT

Global marine genomic monitoring is critical for the detection of changes in biodiversity, mapping species distributions, and the early signals of ecosystem stress. Large-scale collaboration, however, is often limited by data privacy, sovereignty, and biosecurity concerns linked to the sharing of raw genomic sequences. Federated learning offers a secure and privacy-preserving framework that enables international cooperation in research without transferring sensitive data across borders. In this decentralized model, artificial intelligence algorithms are dispatched to local institutions where the training on environmental DNA, metagenomic profiles, and population-level genomic datasets occurs locally. Only the model updates, either encrypted or anonymized, are shared, and never the original genomic data. As contributions are aggregated from a wide range of marine environments, a global model becomes robust, accurate, and ecologically representative. Supported by enabling technologies such as differential privacy and secure multi-party computation, federated learning provides an ethical and scalable approach for continuous collaborative marine genomic surveillance.

Keywords: Federated Learning, Marine Genomics, Privacy-Preserving Analytics, eDNA, Global Ecosystem Surveillance.

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AI-Enhanced Detection Of Antibiotic-Resistant Genes In Marine Microbiomes From Polluted Areas

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ABSTRACT

Antibiotic resistance is an escalating global threat, and polluted coastal waters have emerged as significant hotspots for the accumulation and dissemination of antibiotic-resistant genes (ARGs). Industrial discharge, urban wastewater, agricultural runoff, and aquaculture residues introduce selective pressures that enable resistant microbes to thrive and spread within marine ecosystems. Conventional laboratory methods often fall short in capturing the complexity, diversity, and rapid evolution of ARGs at an ecosystem-wide scale. This study introduces an AI-enhanced bioinformatics framework designed to rapidly detect, classify, and monitor ARGs in marine microbiomes collected from polluted coastal environments. The system integrates high- throughput metagenomic sequencing with advanced machine-learning and deep-learning algorithms to improve the accuracy and sensitivity of ARG identification. Sequencing reads undergo quality control, assembly, annotation, and resistance-gene prediction using models trained on curated global databases. The framework also incorporates environmental metadata— such as pollutant concentration, salinity, nutrient load, and temperature—to contextualize ARG patterns and identify conditions that promote resistance proliferation. Findings reveal elevated levels of β-lactam, tetracycline, and multidrug efflux pump–related genes in highly contaminated regions, demonstrating the strong influence of pollution on ARG enrichment. This AI-driven system offers a scalable, automated solution for early detection and continuous surveillance of emerging resistance threats in coastal waters.

Keywords: Artificial Intelligence, Metagenomics, ARG Surveillance, Bioinformatics, Coastal Ecosystems

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Modelling The Effects Of Extreme Weather Events In A Lagoon Region Using Data-Driven Interpretable Decomposition

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ABSTRACT

Understanding the spatiotemporal evolution of upper-ocean processes in the North Indian Ocean is essential for improving predictions of mixed layer dynamics, air–sea gas exchange, and biogeochemical variability. This study applies a Dynamic Mode Decomposition (DMD)–based interpretable analytical framework to examine the mixed layer response of some major tropical cyclones with a focus on their impact on the Chilika mouth region along the Odisha coast, which is the primary exchange pathway between the lagoon and the Bay of Bengal and it plays a key role in maintaining a fragile, highly diverse coastal ecosystem, making it especially vulnerable to cyclone-driven disturbances.

DMD, a data-driven decomposition technique, is used to extract spatiotemporal modes of variability using multi-dimensional oceanographic datasets, including temperature, salinity, ocean circulation, and mixed layer depth from Copernicus Marine Service. The initial results revealed clear physical signatures of cyclone-driven upper-ocean modification, including notable post-cyclone surface temperature cooling, substantial deepening of the mixed layer, and pronounced shifts in salinity.

The findings demonstrated that DMD could efficiently capture the dominant physical modes and underlying variability patterns governing the upper-ocean evolution during tropical cyclones.

The method provided a reduced-order yet physically interpretable reconstruction of spatiotemporal changes without relying on explicit governing equations. Overall, the findings indicate and support the data-driven decomposition approach to be reliable for future ocean modelling and climate research workflows.

Keywords: Dynamic Mode Decomposition, tropical cyclone, Chilika Lagoon, mixed layer depth.

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AI-Driven Algal Bloom Detection in Inland Water Bodies Using Sentinel-2 Remote Sensing.

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ABSTRACT

Algal blooms in inland water bodies have turned into a growing environmental concern owing to their impacts on drinking water quality, aquatic ecosystem health, and local livelihoods. Traditional field-based monitoring methods are often restricted by high cost, low temporal resolution, and restricted spatial coverage. This paper, therefore, proposes an AI-driven satellite remote sensing framework for the detection and mapping of harmful algal blooms in inland lakes and reservoirs. High-resolution multispectral imagery from Sentinel-2 was employed with a dedicated red-edge band highly sensitive to chlorophyll-a concentration and phytoplankton biomass. Atmospheric correction, cloud masking, Normalized Difference Water Index (NDWI) based water extraction, and bloom-indicator indices were derived, including Normalized Difference Chlorophyll Index (NDCI) and Floating Algae Index (FAI). A deep learning classifier is trained on annotated bloom and non-bloom samples to generate pixel-level bloom probability maps. This approach demonstrated good performance in capturing the spatial variability of blooms, discriminated high-density bloom regions more effectively, and proved to be more accurate than traditional threshold methods. The integrated AI–remote sensing approach provides an efficient and scalable solution for near real-time monitoring of algal bloom events in inland waters. Results demonstrate how machine learning can potentially be used in early warning systems and assist water resources managers in making environmentally relevant decisions.

Keywords: Algae Blooms, Inland Waters, Artificial Intelligence, Normalized Difference Water Index, Sentinel-2.

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AI-Driven Algal Bloom And Water Quality Detection

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ABSTRACT

Artificial Intelligence (AI) and deep learning have revolutionized monitoring and management of ocean ecosystems, particularly in the detection of harmful algal blooms (HABs) and assessment of water quality. Harmful algal blooms pose significant threats to aquatic life, human health, and coastal economies, making prompt and accurate detection essential. Traditional monitoring approaches relying on manual sampling and laboratory analysis are limited by their spatial coverage and labor-intensive nature. AI-driven methodologies leverage large-scale remote sensing data, autonomous sensors, and environmental datasets to overcome these constraints. Deep learning models, especially convolutional neural networks (CNNs), have been effectively applied to multispectral and hyperspectral satellite imagery for precise detection and classification of algal blooms. These models extract complex spectral features and spatial patterns, enabling differentiation among algae species and quantifying bloom intensity. Novel algorithms integrate optical data with synthetic aperture radar (SAR) imagery to enhance detection accuracy and compensate for variable environmental conditions such as cloud cover and water turbidity. In parallel, AI frameworks estimate water quality parameters including chlorophyll-a concentration, dissolved oxygen, turbidity, and nutrient levels by analyzing diverse data sources including remote sensing, in situ measurements, and meteorological observations. Machine learning augments traditional models by filling data gaps and improving real-time mapping of water quality, facilitating early warning and intervention in aquatic pollution and eutrophication events. Multi- source data fusion combining satellite optical data, digital elevation models, climate data, and oceanographic measurements with ensemble machine learning models and neural networks enhances the robustness of detection and prediction systems. Explainable AI methods are increasingly incorporated to interpret model decisions, identify key environmental drivers of blooms, and improve trustworthiness of predictions. Overall, AI and deep learning provide scalable, efficient, and accurate tools for aquatic ecosystem monitoring, advancing early detection of HABs and comprehensive water quality assessment. These technologies are pivotal to safeguarding marine biodiversity, public health, and sustainable coastal resource management in the context of growing environmental challenges.

Keywords: Artificial Intelligence, Deep Learning, Algal Bloom Detection, Water Quality Monitoring, Remote Sensing

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Image-Based Algal Bloom Analysis And Machine Learning Classification For Water Quality Assessment

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ABSTRACT

Water quality monitoring is essential for assessing the functionality of aquatic ecosystems and identifying the early stages of algae blooms in ecosystems affected by nutrients. In order to evaluate decreasing trends and forecast turbidity related water-quality conditions, this work combines supervised machine-learning classification with quantitative image-based algal characterisation. To measure the spatial distribution of algal biomass and the formation of biofilms, two field imagery images have been processed via pixel-level spectral decay, luminance modelling, and variation in texture analysis. With the amount of green algae rising to 0.2234 from 0.1115 in the first image and algae-coverage estimated increasing by nearly a factor of magnitude (3.69% vs. 0.36%), the second location showed much greater biological loading. Decreased blue-channel intensities and a lower mean luminance further suggested increased turbidity and the buildup of dissolved or suspended organic matter.High roughness and texture values in both pictures indicated the existence of biomass, but magnified visual signals in Image 2 suggested more advanced acidic conditions and a higher risk of oxygen-depleting microbial activity. Ten machine-learning models were trained to categorise water quality using turbidity-derived criteria in addition to the image analysis. In all measures (Accuracy, Precision, Recall, F1-score, and ROC-AUC = 1.0000), ensemble approaches such as Random Forest, Gradient Boosting, AdaBoost, Voting (LogReg + RF) and Stacking (LogReg + RF → LR) obtained optimal prediction performance. While SVM and KNN had relatively lower recall, logistic regression and bagging similarly shown near-optimal performance (F1 > 0.99). These results show that a reliable, scalable, and non-invasive framework for real-time water-quality monitoring in ecologically sensitive situations may be achieved by combining image-derived algal markers with high-performance machine learning classifiers.

Keywords: Water Quality, Algea Bloom, Machine Learning, Turbidity, Ensemble Learning.

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EBb And Flow Of Insight: A New Paradigm For Ocean Intelligence.

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ABSTRACT

The world's oceans are undergoing rapid change driven by climate forces and human activity. Monitoring and forecasting these shifts are essential, yet traditional methods struggle with the ocean's vast scale, nonlinear dynamics, and sparse observations. Although AI offers major potential, models trained on limited, centralized datasets often miss key marine processes and may produce results that violate physical laws. This framework integrates Physics-Guided AI, Federated Learning, and Multi-Sensor AI to address these challenges. The approach fuses measurements from satellites, Argo floats, gliders, and coastal radars to create a multidimensional picture of ocean conditions. Federated Learning enables global model training without sharing raw data, preserving privacy, supporting data sovereignty, and reducing transfer requirements while allowing broad collaboration. Physics-Guided AI incorporates principles such as conservation laws and ocean dynamics directly into model architectures or loss functions, ensuring physically credible behavior and improving performance in data-poor regions. This strengthens forecasts of marine heatwaves, harmful algal blooms, and pollutant transport. Together, these technologies form a scalable and collaborative system for real-time ocean intelligence, supporting early-warning capabilities, scientific insight, and informed decision- making for communities and policymakers.

Keywords: Physics-Guided AI, Federated Learning, Mult-Sensor Data Fusion, Ocean Monitoring, Climate Resilence.

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BlueEco: Linking SST Anomalies to Biological Impact Using a Two-Stage AI Pipeline

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ABSTRACT

Ocean warming is rising faster than expected, and marine ecosystems are already showing the strain—coral reefs bleaching more frequently, phytoplankton productivity dropping, and entire food webs becoming unstable. Scientists have known for years that higher Sea Surface Temperatures (SST) generally lead to lower Chlorophyll levels, yet most machine learning work still focuses only on predicting SST itself. Very few studies attempt to connect future warming directly to biological indicators, which makes it difficult for conservation groups to plan ahead using reliable, low-cost data tools. The BlueEco project was developed to close that gap and contribute directly to SDG 14: Life Below Water by building a pipeline that links climate forecasts with ecological impact predictions in a way that is practical for long- term planning. The system works in two stages: first, an MR-EDLSTM network generates detailed projections of SST anomalies up to 2035, capturing how warming patterns shift across regions and seasons. These predictions are then passed into an XGBoost model trained on historical ocean data, allowing it to learn how changes in temperature have historically influenced Chlorophyll-a levels—a widely used indicator of overall marine productivity. The final output from this combined approach is the Ocean–Ecosystem Stress Index (OESI), a metric that transforms the model's results into clear risk scores for different marine zones. OESI highlights which areas are likely to face the most ecological pressure in the coming decade and is checked against past observations using R^2 correlation analysis to ensure it reflects real ecological behaviour. By offering a forward-looking view of how warming may impact ocean life, BlueEco gives conservationists, researchers, and policymakers a practical early-warning tool to guide protection efforts and support long-term ocean sustainability under SDG 14.

Keywords: Ocean Warming, Machine Learning, Sea Surface Temperature (SST), Chlorophyll-a, Ocean-Ecosystem Stress Index (OESI)

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Artificial Intelligence–Driven Strategies for Managing Marine Algal Blooms and Nitrous Oxide Emissions

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ABSTRACT

Algal blooms, commonly referred to as hazardous algal blooms (HABs), are sudden increases in the number of algae in marine habitats that have the potential to upset ecosystems, lower oxygen levels, and release toxins that are dangerous to both people and aquatic life. The main causes of ocean algal blooms are examined inresearch studies, with a focus on both natural and man-made influences. Elevated sea surface temperatures, altered ocean circulation, and higher sunlight penetration are important environmental factors that encourage the growth of algae. Eutrophication is greatly accelerated by anthropogenic factors such nutrient contamination from industrial effluents, wastewater discharge, and agricultural runoff, which creates the perfect environment for bloom production.With a potential for around 300 times more global warming than carbon dioxide, nitrous oxide (N_2O) is a powerful greenhouse gas. The world's oceans are a major source of N_2O emissions, mostly due to microbial nitrification and denitrification processes. Innovative approaches to reducing marine N_2O generation and release are examined in researchstudies. Important strategies include increasing nitrogen management in coastal areas to lower nutrient runoff, encouraging microbial communities that support full denitrification to innocuous nitrogen gas (N_2), and promoting oxygenation in hypoxic zones to decrease anaerobic N_2Ogeneration.Strong tools for optimizing tactics targeted at lowering nitrous oxide (N_2O) emissions from maritime settings are provided by artificial intelligence (AI). Microbial nitrogen cycling activities, which are impacted by intricate oceanographic and biochemical factors, are the main source of N_2O. Large datasets from satellites, autonomous underwater vehicles, and ocean sensors can be analyzed by AI-driven optimization algorithms to find emission hotspots and forecast changes in N_2O production.

KEY WORDS: Artificial intelligence, Algal blooms, Eutrophication, Deep learning

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Impact of warming on bethic foraminifera and their contribution to carbon burial

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ABSTRACT

Among the different ecological factors, temperature of the seawater has profound influence on the life processes of the benthic marine organisms. With the increasing global temperature, it becomes pivotal in understanding the response of benthic foraminifera, one of the dominant benthic community, to these changing conditions in the marine ecosystem. The response of these marine organisms can be best studied under controlled laboratory conditions. Here, for the first time, we assessed the behaviour of coastal water benthic community to a diurnally varying ranges of temperature (24-28°C, 25-29°C, 26-30°C, 27-31°C, and 28-32°C). The salinity of the seawater was maintained constant along with the uniform supply of the freeze dried feed to all the experimental sets. Interestingly, the abundance of the living and dead benthic foraminfera increased with the warming temperature. The lowest abundance was recorded at the temperature ranging between 25-29°C, suggesting a large increase in the benthic foraminiferal population with the warming. The number of calcareous foraminifera increased with the increasing temperature reflecting their ability to adapt and withstand the warmer conditions, whereas the abundance of agglutinated benthic foraminifera decreased indicating their shells being least resistant to the thermal stress. The increased abundance of calcareous benthic foraminifera resulted in the higher accumulation of inorganic carbon, highlighting a potential increase in benthic foraminiferal calcification ultimately leading to the carbon burial. The study showed the importance of temperature in regulating the growth, survival and ecological functions of the benthic foraminifera and thus the carbon burial in marine environments.

Keywords: Benthic foraminifera, laboratory culture, tempertaure, carbon burial

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Late Quaternary Turbidites in the Eastern Bay of Bengal

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ABSTRACT

Turbidite sedimentation transports vast amounts of clastic material from land to the deep sea, forming submarine fans and burying terrestrial organic carbon—thereby influencing atmospheric CO_2 over geological timescales. Turbidity currents also pose geohazards by damaging seabed cables. At present, only about 4% of submarine channels remain active and connected to the coast. The Bay of Bengal (BoB) hosts the world's largest submarine fan, the Bengal Fan, formed by massive sediment input from the Himalayas, Indo-Burman Ranges, and Peninsular India through turbidite flows in deep-sea channels.

A high-resolution grain-size analysis of a sediment core collected from the eastern BoB near submarine Channel E7 reveals 14 turbidite depositional layers formed between 27 and 12.5 kyr BP, with turbidite deposition terminating around 12.5 kyr BP. Sr–Nd isotopic data indicate that sediments deposited up to ~12 kyr BP were dominated by material from the Indo-Burman–Arakan Ranges (IBR), while those deposited after 12 kyr BP were primarily sourced from the Irrawaddy River. This shift suggests that Channel E7 was likely connected to the Arakan coast during lower sea levels, confirming the IBR as the principal source of turbidites.

Active turbidite deposition during the Last Glacial Maximum (LGM), unlike in other major submarine fans (e.g., Nile Deep-Sea Fan, Mississippi Fan, and South China Sea), implies intensified river floods in the IBR region. Deep-marine turbidites serve as valuable archives of terrestrial vegetation signals, as they are rapidly deposited and efficiently preserve organic carbon. $\delta^{13}C$ values of organic carbon from Last Glacial Maximum (LGM) intervals indicate C_3 plant dominance, reflecting flood-driven river inputs under wetter conditions. In contrast to C_4 plant expansion under arid LGM conditions in the central and northwestern Bay of Bengal, the C_3-dominated turbidites in this study suggest that the Indian Summer Monsoon remained active during the LGM in the IBR region.

Keywords: Turbidite, Bay of Bengal, Indo-Burman Ranges, Sr–Nd isotopes, $\delta^{13}C$

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Carbon burial dynamics in the southwestern Bay of Bengal driven by hydrographic and biogenic controls

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ABSTRACT

Understanding carbon burial is crucial because it regulates long-term atmospheric carbon dioxide (CO_2) levels and influences the ocean's capacity to buffer climate change. The southwestern Bay of Bengal (swBoB) represents an important yet understudied region for evaluating marine carbon burial processes. Based on 67 surface sediment samples, this study quantifies the patterns and drivers of both inorganic (calcium carbonate $CaCO_3$) and organic (C_{org}) carbon burial in relation to hydrographic and depositional settings. The calcium carbonate burial dominates the total carbon pool across the swBoB, with the $CaCO_3$ content (14.19%) substantially exceeding the values reported from the northwestern and west-central Bay of Bengal. The highest planktic foraminifera abundance (6320 shells/cm^3) and $CaCO_3$ content (774 mg/cm^3) along the southernmost transect reflects the intrusion of high-salinity, carbonate-rich waters from the southeastern Arabian Sea and Gulf of Mannar, which enhances planktic foraminiferal production and shell preservation. The strong positive correlation between total carbon and $CaCO_3$ indicates that calcareous biogenic particles overwhelmingly control carbon sequestration. The organic carbon burial was comparatively low on the shelf due to coarse sediment texture, oxygenated bottom waters, and terrigenous dilution, but increased along the slope where finer sediments promote better preservation. Overall, carbon burial in the swBoB is modulated by monsoon- driven hydrography, sediment texture, and the preservation of biogenic calcareous shells. The exceptionally high $CaCO_3$ and planktic foraminiferal flux underscores the swBoB as a major hotspot for inorganic carbon sequestration. These findings provide a quantitative baseline for assessing future changes in marine carbon sequestration under ongoing climatic and hydrographic shifts.

Keywords: Planktic foraminifera, C_{org}, $CaCO_3$, Monsoon, water mass exchange, Bay of Bengal

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East-west asymmetry in climate-driven shifts of mangrove habitat suitability along the Indian coast.

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ABSTRACT

Mangrove ecosystems are facing increasing stress from both climate change and human activities. We assessed how mangrove habitat suitability and projected species richness differ between the east and west coasts of India under baseline conditions and future climate scenarios. We used an ensemble species distribution modelling framework, integrating outputs from eight algorithms to map the potential distributions of 20 mangrove species. Models were run for one baseline climate and two future scenarios (SSP1–2.6 and SSP5–8.5) based on the HadGEM climate model, with projections generated for 2040, 2060, 2080, and 2100. The modelling results reveal pronounced spatial contrasts in mangrove suitability along the Indian coastline, largely shaped by temperature-related variables and soil properties. Under baseline conditions, the west coast supports higher localised species richness, with distinct hotspots in the Malabar, Canara, and Konkan regions. On the east coast, highly suitable habitats are mainly concentrated in the Bhāgirathi-Hooghly delta and selected stretches of the Godavari coast. Future projections indicate a strongly deteriorating outlook. By mid-century (2040–2060), highly suitable areas along the west coast are projected to decline by ~66% under SSP1–2.6 and by 85–100% under SSP5–8.5, relative to the baseline. On the east coast, highly suitable zones are expected to virtually disappear by mid-century. Toward the end of the century (2080–2100), the west coast is projected to lose all highly suitable areas under SSP5–8.5, while the east coast loses them under both scenarios. Only fragmented low- to moderately suitable patches are predicted to persist, primarily around the Sundarbans and parts of the lower Mahanadi delta. By 2100, most coastal stretches on both coasts are likely to downgrade to low suitability. These findings highlight the urgent need for proactive, climate-informed, and region-specific conservation and restoration strategies for India's mangroves. Without timely adaptation and protection measures, the ecosystem services they provide and the coastal communities that depend on them, may face substantial and potentially irreversible losses.

Keywords: Mangroves, Habitat suitability, Climate change, Ensemble modelling, Conservation prioritization

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Temperature induced monsoon intensity strongly affected the carbonate preservation over the last two millennia in the Gulf of Mannar

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ABSTRACT

A significant fraction of oceanic carbon is stored as calcium carbonate ($CaCO_3$), whose production and burial in the northern Indian Ocean is strongly modulated by monsoon. Because the monsoon system responds differently under varying warming conditions, understanding these linkages is essential to assess the future changes in carbonate preservation. Using a high-resolution sediment core spanning the past ~2000 years from the Gulf of Mannar, we investigate the factors controlling $CaCO_3$ variability. The study uses multiple proxies, including $CaCO_3$ content, coarse fraction (CF), total planktic number (TPN), summer and winter monsoon assemblages (SMA, WMA), and upwelling indicator *Globigerina bulloides*. During the early Roman Warm Period (RWP) and Medieval Warm Period (MWP), a synchronous increase in TPN, CF, and $CaCO_3$ indicate that foraminiferal calcite primarily contributed to the sedimentary $CaCO_3$. This interval was also marked by elevated SMA, suggesting intensified summer monsoon winds that facilitated enhanced upper-ocean mixing, reduced stratification, and lower abundance of mixed-layer species. In contrast, during the later part of the Little Ice Age (LIA), decreasing SMA corresponds to reduced $CaCO_3$ and higher mixed-layer species, suggesting stronger stratification and diminished $CaCO_3$ preservation. The contrasting response, where intense monsoon enhanced mixing during the warm periods but promoted stratification during the LIA, indicates a strong influence of temperature on the monsoon intensity and thus carbonate burial in the northern Indian Ocean.

Keywords: planktic foraminifera, carbon burial, monsoon, upwelling, Gulf of Mannar

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Modern carbon inventory of the rivers in Goa, India

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ABSTRACT

Carbon burial in coastal rivers is crucial to quantify nature's most effective defence against climate change and providing the evidence needed to prioritise the protection of these vital coastal environments. The carbon storage capability of coastal ecosystems is currently seen as a crucial factor in the management of local and global climate. In this study, we have estimated the carbon inventory [Total carbon, inorganic carbon (calcium carbonate $CaCO_3$) and organic carbon (C_{org}%)] in the surface sediments of the seven major rivers (Terekhol, Chapora, Mandovi, Zuari, Cumbharjua canal, Sal, Talpona and Galgibaga) of Goa state in India. The carbon burial was compared with the ambient parameters and sediment characteristics. The pH and salinity showed a decreasing trend upstream in all of the rivers. The main channels of the rivers had sandy sediment, while the banks contained silt and clay associated with vegetation. The organic carbon increased upstream in all the rivers. The highest C_{org} was observed in the Mandovi river (13.26%) at the most upstream station, followed by the Zuari and Galgibaga rivers. The widespread mangrove patches with high density and frequency were observed in these rivers, which make a significant contribution to the C_{org}. The fine sediments on the banks of the rivers contained higher C_{org}. A comparatively higher $CaCO_3$ was observed at stations closer to the mouths in all of the rivers. The calcium carbonate content decreased upstream as the pH and salinity dropped. Galgibaga marked the highest $CaCO_3$ (2.06%), followed by Mandovi (1.88%). We also found the highest abundance of benthic foraminifera (6322/g of sediment) in the Galgibaga river. The organic carbon/nitrogen ratio in most of the rivers was >12, clearly suggesting terrestrial organic matter input. The organic carbon dominated the total carbon content in the rivers. The vegetation, terrestrial input, biogenic shells along with anthropogenic organic pollutants contribute to the modern sediment carbon pool in Goa's rivers.

Keywords: Organic carbon, Inorganic carbon, Estuary, Carbon burial, Nitrogen

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Contrasting controls on total organic carbon and diatom frustule distribution in the surface sediments of the central and eastern Arabian Sea

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ABSTRACT

The Arabian Sea, a productive basin in the western Indian Ocean, is influenced by monsoon-driven circulation, nutrient supply, and an intense Oxygen Minimum Zone (OMZ). These factors collectively influence the cycling and export of organic matter to the deep sea. To understand how environmental gradients affect carbon export in the Arabian Sea, core-top sediments from two regions: central (~4000m water depth) and eastern (~200m water depth) Arabian Sea were studied. A strong correlation between diatom frustules and total organic carbon (TOC) indicated diatoms as important contributors to sedimentary organic matter. Notably, shelf sediments revealed 2-fold higher TOC (1.88%) than open-ocean (0.87%), despite similar diatom abundance (~5×10^4 valves/g). This decoupling was attributed to variations in physical forcing, seasonal productivity, water-column oxygenation, and sedimentary conditions influencing the transport and preservation of organic carbon and siliceous microfossils. In the central Arabian Sea, TOC and diatom frustule abundance were high at stations (north of 15° along 64° E), where open ocean upwelling, winter mixing, and a thick OMZ occurred. Large diatoms that could escape grazing dominated, and their export was favoured by low oxygen and less zooplankton activity within the OMZ. Conversely, oligotrophic, oxygenated southern stations exhibited lower TOC and diatoms. Along the shelf, upwelling-dominated southern stations (11-13° N) showed lesser TOC despite higher diatom fluxes, due to rapid organic matter degradation in oxic waters. Contrastingly, the northern shelf, near the OMZ boundary, showed higher TOC and more diverse diatoms. *Thalassiosira, Coscinodiscus and Nitzschia* were the major diatoms in the shelf. Overall, the spatial patterns of TOC and diatoms across the Arabian Sea sediments are governed by the interplay of monsoonal physical forcing, species-specific traits (size, silicification), oxygenated waters, grazing and sedimentary conditions.

Keywords: Phytoplankton, Organic Matter, Western Indian Continental Shelf, Sediments, Carbon export.

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Productivity and oxygen minimum zone intensity strongly influenced carbon burial in the eastern Arabian sea during the Holocene

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ABSTRACT

The northeastern Arabian Sea is a climatically sensitive region characterized by monsoon driven primary productivity and a persistent oxygen minimum zone (OMZ) that strongly influence sedimentary carbon burial. The monsoon driven winds influence upwelling, convective mixing and nutrient dynamics that sustains marine productivity and thus carbon sequestration in this region. The fate of OMZ and associated carbon burial under imminent global warming is highly debated. Here, we present marine sediment record of carbon burial, OMZ variability and productivity changes during the Holocene, from the northeastern Arabian Sea. The total carbon content of the sediment continuously increased throughout the Holocene. The increase in total carbon was mainly driven by the concurrent increase in organic carbon (C_{org}). The concomitant increase in total carbon and C_{org}, alongside decrease in $CaCO_3$ content, highlights a Northgrippian to Meghalayan transition towards C_{org} dominated carbon burial. A synchronous decrease in C_{org}/N ratio concurrent with an increase in nitrogen content, from the Greenlandian to Meghalayan Age suggests a reduction in terrestrial organic carbon input coupled with enhanced marine productivity. An increase of infaunal benthic foraminifera abundance clearly suggests strengthening of OMZ during the Meghalayan time. The increased carbon burial in the northeastern Arabian Sea during the Meghalayan Age is, thus attributed to the strengthened OMZ. The results indicate that during the Meghalayan Age, the strengthening of OMZ significantly improved the efficiency of carbon burial in the northeastern Arabian Sea.

Keywords: Carbon burial, Productivity, OMZ, Holocene, Northeastern Arabian Sea

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Blue Carbon and Climate Resilience Potential of Seaweed Patches Along the Coromandel Coast: A Satellite-Based Sustainability Assessment

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ABSTRACT

Seaweed patches are critical coastal blue carbon ecosystems, sequestering carbon. Along the Coromandel Coast (7°–21°N, 77°–85°E), natural seaweed beds dominated by Sargassum, Gracilaria, and Ulva, plus expanding Kappaphycus alvarezii cultivation, offer significant climate mitigation opportunities. Despite limited spatial assessments, this study uses multi-sensor satellite remote sensing to quantify carbon sequestration and assess climate resilience.
Methodology integrates four data categories: (A) seaweed biomass from CMFRI, NCSCM, SAC-ISRO; (B) satellite data from MODIS Aqua and Sentinel-2 with reflectance ratios, chlorophyll-a, sea surface temperature, bathymetry, and wave/current data; (C) carbon content of 20–34% dry biomass and productivity of 2–6 kg C m^{-2} yr^{-1}; and (D) climate data from IPCC AR6 and CMIP6 models.
A novel Seaweed Climate Resilience Index (SCRI) incorporating six variables—thermal stability, light availability, nutrients, wave energy, current speed, and sea-level rise—was developed. Species distribution modeling projected habitat suitability for 2050–2100.
Results reveal seaweed ecosystems contribute substantially to regional carbon sequestration, with peak productivity during post-monsoon periods (22–28°C). Gulf of Mannar and Palk Bay show highest potential for cultivation. Thermal stability emerges as the primary limiting factor. This research addresses critical knowledge gaps in macroalgal blue carbon science, demonstrating seaweed ecosystems can contribute significantly to India's blue economy with sequestration rates of 57.64 metric tons CO_2 per hectare annually. The framework provides actionable guidance for coastal communities transitioning to sustainable mariculture while enhancing adaptation to sea-level rise, ocean acidification, and extreme weather events.

Keywords: Blue carbon1, seaweed patches2, Coromandel Coast3, satellite remote sensing4, climate resilience5

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Subterranean Mudflow And Carbon Burial Dynamics In Shallow Coastal Zone: Case Studies From Kerala Coast

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ABSTRACT

The Kerala coast, a dynamically evolving segment of the southwest Indian margin, has experienced a rising frequency of short-term seaward shoreline shifts in recent decades. Historical reports from Kappad, Eravipuram–Kulathumpadu, Kothi, Papanasham and recent event at Purakkad confirm that these occurrences are related to variations in rainfall intensity, fluvial sediment discharge, wind forcing, tidal oscillations and astronomical influences linked to solar and lunar eclipses collectively modulate shoreline recession along the Kerala coast. Kerala's shallow coastal systems—including estuaries, backwaters, mudflats, mangrove fringes and nearshore sandy environments—are important sinks in the regional carbon cycle, functioning as active zones of organic carbon burial. These environments trap terrigenous and marine-derived organic matter, facilitating long-term carbon storage through rapid sediment accretion and anoxic burial. Short-lived seaward shoreline shifts have the potential to disrupt these carbon burial dynamics by re-suspending previously buried organic matter, altering sedimentation pathways and modifying the balance between carbon sequestration and remineralisation. Such disturbances may have cascading effects on coastal carbon budgets and biogeochemical stability. The 2022 doublet events demonstrate how precipitation-driven berm erosion, riverine sediment pulses and tidal amplification during eclipses produced transient seaward shoreline movement followed by rapid natural recovery. Recognizing the combined influence of shoreline dynamics, subterranean mudflow and carbon burial processes is essential for robust coastal hazard assessment, climate-related evaluations and sustainable management of Kerala's coastal ecosystems. We underscore the need for an integrated, state-wide monitoring framework to assess the physical, sedimentological and biogeochemical implications of short-term marine recession events.

Keywords: Mudbanks, Subterranean mudflow, Carbon burial, Shallow coast, Kerala

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Carbon burial pattern in the oxygen deficient waters of the northeastern Arabian Sea

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ABSTRACT

The sharp increase in the atmospheric carbon dioxide (CO_2) in the post-industrialization era due to the anthropogenic activities is a major concern. Oceans have great potential to remove a large amount of atmospheric CO_2 through organic (C_{org}) and inorganic carbon ($CaCO_3$) sequestration, by burying it deep in ocean sediments for a longer time. The northeastern Arabian Sea is a unique basin, and its hydrography is strongly influenced by the seasonal variation in the monsoonal winds, riverine influx and coastal currents. It hosts a prominent perennial oxygen deficient zone (ODZ) at the intermediate depths as well as a shallow water low oxygen zone on the shelf. To understand the modern carbon burial dynamics in this region, we used the coarse fraction (%), total carbon (TC), organic carbon (C_{org}), inorganic carbon ($CaCO_3$), organic carbon to nitrogen ratio (C_{org}/N), bottom water oxygen, total foraminiferal abundance (TFN), and benthic foraminiferal abundance (TBN) in 54 surface sediments. The C_{org} was relatively high in this region and varied between 0.2% to 6.4%. The C_{org} burial was comparatively low on the shelf due to the well oxygenated bottom waters, but increased on the continental slope, where sedimentation rate was high and bottom water oxygen was low. In the deeper parts (>1500 m), the preservation was low due to low sedimentation rate and well oxygenated bottom waters. The $CaCO_3$ concentration varied from 5.4% to 90.7%, gradually increasing from the shelf to slope. The C_{org}/N ranged from 7.5 to 12.6 % suggesting marine derived organic matter. Total carbon and $CaCO_3$ showed a strong positive correlation suggesting that the carbon sequestration was dominantly controlled by calcareous biogenic particles. We report that the oxygen availability plays an important role in regulating and distributing the carbon burial dynamics in this region.

Keywords: Arabian Sea, carbon burial, organic carbon, inorganic carbon, dissolved oxygen

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Biomass and carbon stocks in mangrove forest of Ratnagiri, southwest coast of India

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ABSTRACT

Mangroves and the wide range of ecosystem services they provide are a major global concern, making their conservation utmost global priority. They are widely acknowledged as an important tropical carbon sink, and their contribution in mitigating climate change. However, data from Indian region specifically from a western coast is very limited. In this study, the vegetation structure, composition and biomass carbon stock of mangrove forest was studied as tall and dwarf mangroves at Ratnagiri mangrove forest, south west coast of India. In present study the mangrove forest has been stratified as dwarf (height < 2m) and tall (height > 2m) because of significant differences observed with respect to growth, biomass and species composition. The highest Importance Value Index was observed for the species *Avicennia marina* from dwarf mangroves and *Sonnertia alba* in tall mangroves. The dwarf mangroves are a physiological adaptation to environmental stressors, with *Avicennia marina* and *Rhizophora mucronata* being the predominant species in the study area. In contrast, the tall mangrove forest demonstrates high biodiversity, with Simpson's index of 0.79, along with low dominance and moderate to high evenness, reflecting a stable and ecologically healthy ecosystem. The mean biomass stored in the dwarf mangrove forests of Ratnagiri is 17.23 ± 8.62 t/ha, while that of the tall mangrove forests is 175.80 ± 105 t/ha. The mean ecosystem carbon stock is estimated at 8.76 ± 3.20 t/ha for dwarf mangroves and 81.60 ± 12.97 t/ha for tall mangroves. The findings of this study indicate that the Ratnagiri mangroves hold substantial carbon stocks, highlighting the importance of conserving and sustainably managing these forests to maintain and enhance their carbon storage potential. This underscores the need to expand mangrove cover and rehabilitate degraded areas. Despite being protected by the Mangrove Cell of the Maharashtra Forest Department, these mangrove ecosystems continue to face pressures from illegal sand mining, encroachment, aquaculture activities, and coastal erosion.

Keywords: Mangroves, Community dynamics, Biodiversity, Biomass stock, Blue carbon stock

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Carbon Burial Dynamics In The Mandovi-Zuari Estuarine System: A Proxy-Based Review.

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ABSTRACT

Carbon burial in tropical estuaries plays a critical role in long-term climate regulation by storing both marine and terrestrial organic matter. The Mandovi-Zuari estuarine system in Goa represents a highly dynamic interface where monsoon-driven freshwater discharge, mangrove inputs, and tidal mixing influence the composition and fate of sedimentary organic carbon. Previous geochemical studies have shown that variations in total organic carbon, C/N ratios, and stable isotope signatures ($\delta^{13}C$, $\delta^{15}N$) reflect contributions from mangroves, soils, and in-situ aquatic production (Seleyi et al., 2024). Sedimentological work from the region highlights the role of grain size, mineral associations, and redox conditions in determining long-term carbon preservation (Noronha-D'Mello et al., 2016). Microbial processes such as sulphate reduction further regulate the degradation of labile carbon fractions while enhancing the burial of more recalcitrant material (Naik et al., 2019). Mangrove-fringed zones, in particular, function as effective carbon sinks due to continuous organic matter input and high sedimentation rates (Sasmito et al., 2019).
Understanding these processes through integrated proxy approaches is essential for predicting how climate-driven changes in monsoon intensity, sea-level rise, and human pressures may alter carbon burial efficiency. This review synthesizes current knowledge and highlights the need for long-term, multidisciplinary monitoring to refine blue-carbon assessments in tropical estuaries.

Keywords: Carbon burial, Estuarine biogeochemistry, Stable isotope proxies, Organic matter sources, Mandovi–Zuari estuary

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Early-warning of anthropogenic trace metal pollution using foraminiferal test deformities in Chilika Lagoon, East coast of India

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ABSTRACT

Test deformities in benthic foraminifera provide a sensitive early-warning tool for assessing trace-metal contamination and pollution-driven ecological stress in coastal systems. Chilika Lagoon, the largest brackish-water lagoon in Asia, acts as a major sink for anthropogenic inputs from untreated domestic and industrial effluents and aquaculture. We analysed 63 surface sediment samples for trace metals using ICP-MS and quantified test abnormalities in benthic foraminiferal assemblages from the same stations. Deformed tests were recorded at 22 locations across the lagoon (S46, S44, S43, S42, S40, S39, S38, S37, S36, S34, S31, S29, S27, S25, S22, S20, S14, S12, S11, S9, S8, S1). Observed deformities include reduced or poorly developed chambers, abnormal coiling, twisted or uneven tests, additional chambers and complex, irregular morphologies, collectively indicating persistent sub-lethal stress. The opportunistic species *Ammonia tepida*, a well-known trace-metal tolerant species, shows high relative abundances at metal-enriched sites, strengthening its role as an indicator species. Principal Component Analysis reveals a strong positive correlation between the distribution of deformed foraminifera, silt content and multiple trace metals, whereas *Charophyte* occurrence, *A. tepida* (%) and silt together point to freshwater-borne pollution from the Mahanadi River tributaries as a key driver. Our results demonstrate that foraminiferal test abnormalities, coupled with trace-metal geochemistry, offer a robust biomonitoring framework and highlight the high vulnerability of Chilika Lagoon to ongoing anthropogenic pollution.

Keywords: Chilika Lagoon; Benthic foraminifera; Test abnormalities; Trace metals; Anthropogenic pollution

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Distribution of carbon composition in Indian Ocean Sediments

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ABSTRACT

Spatial and temporal variability of carbon composition (total, inorganic and organic carbon) was measured in the Indian Ocean sediments to understand the changes in carbon productivity and storage. The study region encompassed a wide range of biogeochemical regimes including Bay of Bengal, South of Andaman Sea, Ninety East Ridge, Southeast Indian Ridge, Central Indian Ridge, Central Indian Ocean Basin and the Laccadive ridge. The sediment core samples were collected by using a box corer onboard RV Sindhu Sadhana, subsampled every 1 cm interval and stored at -20°C until further analysis. The total and inorganic carbon were measured by using CN analyser and coulometer, respectively. The total carbon (%) in the study region varied from <1 % to ~ 12% while the inorganic carbon (%) varied from < 1 % to ~ 11 %. The organic carbon was very low (negligible to < 4 %) in the entire study region with higher values at stations close to the continental land mass. The major changes in total carbon concentration were likely to be attributed to the variations in inorganic carbon productivity. Temporal variability in carbon concentration was less pronounced at a few stations while clear zones of varying carbon production/storage was found at a few stations in the study region. The spatial changes observed in carbon concentration could be regulated by productivity, water currents, upwelling/ downwelling, subsurface water topography and remineralization. The organic carbon and nitrogen isotopic composition of the surface sediments varied from -19 to -22.3 ‰ and 5-10.3 ‰, respectively. The reasons for such variations will be discussed.

Keywords: Indian Ocean, organic carbon, inorganic carbon, sediments, ridges

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Morphological and Anatomical Shifts in Benthic Macroalgae: Implications for Ecological Interactions, Ecosystem Connectivity, and Carbon Sequestration

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ABSTRACT

Benthic macroalgae are key components of coastal ecosystems, strongly influencing productivity, habitat complexity, trophic interactions, and carbon cycling. Growing evidence indicates that macroalgae can contribute significantly to global blue-carbon pathways through detrital export and sedimentary carbon burial (Krause-Jensen & Duarte, 2016; Filbee-Dexter et al., 2018). Environmental disturbances—such as nutrient enrichment, warming, and hydrodynamic stress—can drive shifts in macroalgal morphology and tissue anatomy, with consequences for herbivory, epiphytic colonization, and the retention and movement of organic matter (Pessarrodona et al., 2019; Pessarrodona et al., 2023). Understanding how these structural traits influence ecological interactions and near-bottom carbon retention is essential for predicting coastal ecosystem resilience under accelerating climate and anthropogenic pressures.This proposed study focuses on developing a trait-based framework linking macroalgal structure, ecological functioning, and early-stage carbon retention in tropical coastal systems. Specifically, this study aims to: Examine morphological and anatomical variation in dominant benthic macroalgal species across contrasting environmental Assess how these traits mediate ecological settings; interactions.Evaluate whether trait-driven interaction patterns correspond to differences in local sediment organic-matter content, used as a practical indicator of short-term carbon retention.Provide a trait-based framework connecting macroalgal physiology to ecosystem connectivity and blue-carbon processes. To meet these objectives, a streamlined approach would be adopted. Macroalgal individuals would be collected from two or three environmentally contrasting sites and analyzed for core structural traits such as thallus thickness, branching form, and tissue density. Herbivory would be estimated using visible grazing marks or short tethering trials, while epiphyte load would be assessed through cover or biomass measurements. Shallow sediments beneath algal stands would be sampled to determine organic-matter content. Basic environmental parameters (light, turbidity, exposure) would also be recorded to contextualize trait variation. Overall, this study would clarify how specific macroalgal traits shape key ecological interactions and, in turn, influence the early stages of carbon retention in tropical coastal systems. By directly linking morphology and anatomy to measurable biotic and sedimentary processes, the work would establish a clear foundation for evaluating trait-based drivers of ecosystem connectivity and blue-carbon potential. These outcomes would support the development of more targeted approaches for coastal monitoring, restoration planning, and future assessments of carbon sequestration capacity.

Keywords: Macroalgae, Morphology, Anatomy, Ecological interactions, Carbon retention

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Carbon Burial Dynamics In The Riverine Influx Induced Northern Bay Of Bengal

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ABSTRACT

The rising atmospheric carbon dioxide (CO_2) affects both the terrestrial and marine ecosystems. The oceans sequester a large amount of CO_2 and bury it deep within the ocean sediments. The changing climatic conditions and localised effects are likely to affect the carbon burial all over the world ocean. The Bay of Bengal is a dynamic basin in the north-eastern Indian ocean that experiences huge discharge of riverine freshwater and sediment load and change in monsoonal wind patterns. These processes affect the productivity, oceanic conditions and air-sea interactions which in turn strongly influence the carbon burial. In order to understand the modern carbon burial dynamics in this region and to develop a proxy to track its temporal variablity, we have examined the coarse fraction, inorganic carbon ($CaCO_3$), organic carbon (C_{org}), total carbon, organic carbon/total nitrogen (C_{org}/N), planktic foraminiferal abundance (TPN), and the relative abundance of *Globigerina bulloides* in 47 surface sediments with depths ranging from 29 m to 2315 m, collected from the northern Bay of Bengal. Interestingly, at depths shallower than 250 m, C_{org} and total carbon content was low despite of the higher productivity as evident from higher Chlorophyll a content, suggesting decoupling of carbon burial from productivity. At depths between 250 m and 1000 m, we report high carbon burial, contributed by both organic and inorganic carbon. At depths beyond 1000 m, the carbon burial was again very low, indicated by a decrease in inorganic carbon, planktic foraminiferal abundance and organic carbon. The low carbon content at deeper depths is a combined effect of lesser productivity and higher dissolution, indicated by low Chlorophyll a, low *G. bulloides* and high fragmentation index. Surprisingly, despite of the location being close to the riverine influx, the C_{org}/N ranged from 5 to 11, suggesting mainly marine derived organic matter. We conclude that oceanic productivity and dissolution play a vital role in controlling the carbon burial in the northern Bay of Bengal.

Keywords: Bay of Bengal, Carbon burial, Productivity, Dissolution, Organic and Inorganic Carbon, Planktic foraminifera

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Bioturbation-Mediated Ecosystem Engineering and Organic Carbon Preservation in a Stressed Late Permian Marine System, Spiti Basin, Tethys Himalaya

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ABSTRACT

The end-Permian mass extinction—Earth's most severe biotic crisis—resulted in the loss of nearly 81–96% of marine species and triggered a prolonged, multi-million-year delay in benthic ecosystem recovery. In such stressed marine settings, the biological reworking of sediments by infaunal organisms (bioturbation) plays a critical role in regulating mixed-layer dynamics at the sediment–water interface and, consequently, the preservation of organic carbon. In the sedimentary record, bioturbation signatures are preserved as trace fossils within the mixed layer (ML) and the underlying transition layer (TL). However, the evolution of these layers under the dysoxic–anoxic conditions characteristic of the Late Permian remains poorly constrained, particularly in the context of the severe ecological perturbations surrounding the end-Permian extinction. This study investigates the modes, intensity, and distribution of bioturbation in the organic-rich black shales of the Upper Permian Gungri Formation across four key sections—Gungri, Guling, Lingti, and Mud—within the Spiti Basin of the Tethys Himalaya. The integrated ichnological and sedimentological data reveal a progressive decline in bioturbation approaching the Permian–Triassic boundary. We propose that reduced biogenic reworking facilitated enhanced organic carbon burial under increasingly oxygen-depleted conditions. Trace-fossil assemblages from the Gungri Formation indicate a transition from a relatively dysoxic, bioturbation-rich lower interval to an anoxic, weakly bioturbated upper interval, highlighting strong coupling between benthic ecosystem collapse and carbon cycling during the terminal Permian.

Keywords: Bioturbation, Organic Carbon Burial, Gungri Formation, Spiti Basin

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A new perspective on the use of Organic Ligand pathways to enhance carbon sequestration in Mg-Ca silicate rocks for long-term carbon burial: A review

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ABSTRACT

Organic and microbially derived ligands are increasingly recognised as one of the key modifiers of CO_2 mineralisation pathways in basaltic matrices, particularly under anoxic conditions and in CO_2-charged aqueous solutions of different compositions. Polyanionic biopolymers such as alginate, xanthan and other EPS-analogous materials provide functional groups capable of binding Ca^{2+} and affecting carbonate nucleation (Mitchell & Ferris, 2006; Robles-Fernández et al., 2022). Laboratory studies further show that biosurfactants, including rhamnolipids, self-assemble into micelles and alter interfacial behaviour, and can influence $CaCO_3$ precipitation in polymeric matrices (Czaplicka et al., 2022; Baccile et al., 2021). Amino-acid ligands such as aspartate are known to interact with Ca-bearing species and modulate early nucleation chemistry (Finney et al., 2020). EPS structures also modify hydration and interfacial behaviour of mineralising solutions in natural systems, consistent with microbially mediated carbonate formation observed across sediments (Zhu & Dittrich, 2016). These components participate in carbonation-relevant processes, such as ligand-assisted solubilisation of divalent cations as reported in basalt dissolution experiments performed in ligand-bearing fluids (Wolff-Boenisch et al., 2011), localised ion concentration within polymer-rich microenvironments, stabilisation of prenucleation clusters (Gebauer et al., 2008), and organic templating that reduces nucleation energy barriers (De Yoreo et al., 2015). In line with this new perspective of organic ligand and its impact on carbonate nucleation, an experimental framework is set up using basalts recovered from the Indian Ocean and Deccan Trap region to evaluate the effects of ligand using accessible indicators such as dissolution rate, alkalinity evolution, and observable carbonate precipitation. This experimental approach will test whether the ligand-assisted basalt carbonation is a biologically grounded and environmentally compatible pathway for improving the kinetics, stability and long-term effectiveness of geological carbon burial.

Key Words: Basalt, Organic Ligand, Mineral Carbonation, Carbon Sequestration

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Preliminary insights on the factors influencing temporal variation in calcium carbonate preservation in the north-eastern Bay of Bengal

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ABSTRACT

A short sediment core (SSK184 MC38), collected from the north-eastern Bay of Bengal, outside the Preparis South Channel, was analyzed to elucidate the temporal variability in calcium carbonate ($CaCO_3$) content and its controlling factors. The core exhibits consistently high $CaCO_3$ content (>48 %), with a similar trend in the >63 µm coarse fraction. Notably, intervals with elevated $CaCO_3$ concentrations also match with the increased foraminiferal abundance, indicating that foraminifera are the primary contributors to the observed $CaCO_3$ enrichment in the core. Among other factors, the preservation of these calcareous tests is closely linked to oxygenation, as inferred from the change in the relative abundance of benthic foraminiferal morpho-groups. The benthic foraminifera were divided into nine morpho-groups based on test shape and inferred habitat preferences. The foraminiferal assemblage was dominated by tapered cylindrical, flattened tapered, planoconvex, and flattened ovoid forms, while minor groups included rounded planispiral, biconvex, milioline, and spherical morpho-group. The dominance of tapered cylindrical forms, typically deep-infaunal and low-oxygen indicators, suggests episodes of reduced bottom-water oxygenation. A noticeable increase in their abundance between ~21-25 cm coincides with a minimal decline in epifaunal, oxygen-loving planoconvex forms, implying transient low-oxygen conditions. However, the overall limited variability in both $CaCO_3$ content and benthic morpho-group composition suggests a generally stable depositional environment with minimal abrupt environmental fluctuations in the north-eastern Bay of Bengal during the period represented by the core.

Keywords: Calcium carbonate, Foraminifera, Morpho-group, Andaman Sea

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Palynofacies-Based Assessment of Organic Matter Burial and Distribution in the Surface Sediments of the Central Eastern Arabian Sea (Off Goa)

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ABSTRACT

The distribution and preservation of organic matter (OM) in marine sediments are critical for understanding the global carbon cycle and reconstructing past oceanographic conditions. The Central Eastern Arabian Sea, a region characterized by high primary productivity influenced by the seasonal South Asian Monsoon and an extensive Oxygen Minimum Zone (OMZ), acts as a natural laboratory for studying OM burial and preservation. This study investigates the spatial distribution, source, and quality of OM within twenty-five surface sediment samples collected along various transects off the Goa coast.

Palynofacies analysis, complemented by measurements of Total Organic Carbon (TOC), was employed to differentiate OM sources and preservation states. The analysis revealed three distinct palynofacies associations by high concentrations of structured & oxidized terrestrial OM (Phytoclasts) and Amorphous Organic Matter (AOM) and few samples are dominated marine palynomorphs such as dinoflagellate cysts, prasinophytes and scolecodonts etc (Prasad et al. 2007).

This distribution pattern demonstrates a significant shift from fluvially-derived, oxidized OM nearshore to highly preserved, marine-sourced OM offshore, primarily accumulating beneath the productive surface waters. The strong correlation between AOM percentage and high TOC values indicates that enhanced primary production and OMZ conditions are the dominant factors controlling efficient OM burial and preservation on the slope (Bhosle et al. 1988; Babu et al. 1999; Cowie et al. 1999). These findings align with earlier studies that emphasize the collective effect of monsoonal upwelling, biogenic activity, and oxygen deficiency in governing OM distribution in the Arabian Sea (Prasad et al. 2007). The palynofacies approach provides a high-resolution tool for differentiating OM sources and offers critical baseline data for interpreting Quaternary paleoproductivity and paleocirculation proxies in this key marginal marine setting.

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Exploring the Complex Interactions of Carbon Dynamics, Heavy metals, and Ecosystem Health in Estuaries: A Multidisciplinary Approach

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ABSTRACT

Oceans, covering about one-third of Earth's surface, are crucial for life and atmospheric balance, serving as major carbon sinks through physical, chemical, and biological processes. Biological sequestration traps CO_2 in marine biomass, helping mitigate climate change. However, human activities like fossil fuel combustion, deforestation, and pollution have disrupted these cycles, leading to climate change, ocean acidification, and productivity loss. Ocean acidification has lowered ocean pH from 8.2 to 8.1, threatening marine ecosystems and their carbon sequestration capacity. Additionally, microplastics and plastic pollution hinder phytoplankton activity, weakening the ocean's carbon regulation role. Estuarine ecosystems, like the Sundarbans, are particularly vulnerable to these stressors. Exposed to pollutants and heavy metals, including untreated waste, these ecosystems suffer from compromised biodiversity, carbon storage, and resilience. Despite their role in the global carbon cycle, the impacts of pollutants on estuarine carbon dynamics remain poorly understood. Recent field sampling showed high concentrations of total inorganic carbon, total alkalinity, silicate, phosphate, microplastics, and heavy metals in estuarine water, decreasing towards the sea due to dilution and other processes. Partial Pressure of CO_2 (pCO_2) was lower in seawater than atmospheric CO_2, indicating that the sea acts as a larger carbon sink. Chlorophyll concentrations were higher in river and sea waters, but lower in the estuarine zone, with a negative correlation between pCO_2 and chlorophyll. The heavy metal pollution index showed rising pollution levels from river to sea, negatively impacting productivity and carbon dynamics. This study explores the extent of heavy metals and microplastic pollutanion shaping carbon dynamics in estuaries, using a machine learning approch to predict CO_2 fluxes and inform policies to protect marine ecosystems and mitigate climate change.

Keywords: Microplastics, Heavy Metals, pCO_2, Ocean Productivity, Ocean Acidification.

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Comparative Analysis Of Rhizosphere Microbiomes From Natural And Planted Mangroves In Karnataka, India.

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ABSTRACT

Mangrove ecosystems play a vital role in coastal carbon sequestration and ecological stability, yet their microbial dynamics under natural and restored (planted) conditions remain poorly understood. This study provides a comparative metagenomic assessment of rhizosphere bacterial and fungal communities, along with sediment carbon fractions, from natural and planted mangroves of *Rhizophora mucronata*, *Kandelia candel*, and *Sonneratia alba* along the Karnataka coast, India. Sediment texture and organic carbon analyses revealed that planted sites, particularly *Sonneratia alba* (SP), exhibited higher total organic carbon (11.51 mg g^{-1}) and labile carbon pools than natural sites, indicating enhanced carbon turnover and storage potential. Metagenomic sequencing, identified 66 bacterial phyla and four major fungal phyla. *Proteobacteria* dominated the bacterial community (42%), with *Gamma-* and *Deltaproteobacteria* enriched in planted sites, whereas *Actinobacteria* and *Firmicutes* prevailed in natural ones. Fungal diversity was largely dominated by *Ascomycota* (>95%), with *Sordariomycetes* and *Dothideomycetes* abundant in natural sites, while *Lecanoromycetes* dominated planted sites. Functional profiling (FAPROTAX) revealed bacterial pathways linked to carbon metabolism, nitrogen cycling, and organic matter degradation, while fungal functional guilds (FUNGuildR) were categorized as saprotrophic, symbiotrophic, and pathotrophic, reflecting habitat-specific ecological roles. LDA analysis identified distinct microbial biomarkers: natural mangroves were enriched with *Actinobacteria*, *Verrucomicrobia*, and fungi like *Penicillium* and *Nigrospora*, indicating strong decomposer activity, whereas planted sites were dominated by *Proteobacteria*, *Nitrospinae*, and fungi such as *Aspergillus aureoterreus* and *Pichia*, linked to nutrient cycling and adaptation. Overall, plantation practices significantly influence microbial composition and function, aiding ecosystem recovery.

Keywords: Metagenome, ITS, 16S rRNA, Mangroves, Ecosystem restoration

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CFD Investigation of AUV Separation Effects on Parallel Formation in Various Flow Conditions

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ABSTRACT

Autonomous Underwater Vehicles (AUVs) are widely used in marine applications, including environmental monitoring, defense, and underwater exploration. Maintaining a stable parallel formation is crucial for efficient operation, but hydrodynamic forces acting on AUVs vary significantly with flow conditions. Previous studies have primarily examined AUV formations under steady flow conditions, but limited research has explored the effects of varying separation distances under different flow directions, including frontal, lateral, and angled flows. This study investigates the hydrodynamic forces on AUVs in a parallel formation while varying separation distances under different flow conditions. The objective is to determine the total force on the formation and optimize spacing to achieve an even force distribution, ensuring balance and stability in dynamic underwater environments. A Computational Fluid Dynamics (CFD) approach is employed to simulate AUV formations under transient flow conditions. The k-omega SST turbulence model is used for accurate turbulence modeling, and a coupled solver enhances simulation precision. ANSYS Fluent is utilized for the simulations, providing detailed insights into the flow characteristics around the AUVs. The study considers frontal, lateral, and angled flow directions to assess their impact on formation stability. Results indicate that hydrodynamic forces on AUVs vary significantly with separation distance and flow direction. Increased unsteady forces occur under lateral and angled flows, affecting formation stability. Optimal spacing is essential to reduce force imbalances and maintain efficient hydrodynamic performance. The findings emphasize the need for effective formation control strategies to mitigate these effects. This study provides valuable insights into the impact of varying separation distances on AUV formations under different flow conditions. The results contribute to improving formation control strategies, enhancing maneuverability and operational efficiency in AUV swarms. These findings can aid in designing more stable AUV formations for real-world applications in underwater exploration and surveillance.

Keywords: CFD, Autonomous Underwater Vehicles, Formation control, ANSYS Fluent.

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Session Title: Climate connects of microbial processes in ocean's oxygen minimum zones

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ABUNDANCE AND DISTRIBUTION OF *Nosz* GENES IN OCEAN OXYGEN MINIMUM ZONES

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ABSTRACT

Nitrous oxide, a greenhouse gas 300 times more potent than carbon dioxide, is produced and consumed in Oxygen Minimum Zones (OMZ) of the ocean.The only known pathway for consumption of N_2O is through microbial reduction to nitrogen gas. To better constrain and manage nitrous oxide flux to the atmosphere, it important to understand how and where the microbes that reduce N_2O are present and active.

N_2O reductase (N_2OR), an oxygen sensitive enzyme, largely restricted to low oxygen environments, is encoded by the gene *nosZ*. There are three known clades of *nosZ*. Recently discovered Clade III appears to be rare in seawater. While Clade I is generally found in conventional denitrifiers, Clade II occurs in a wide range of organisms. Here we report the distribution of *nosZ* genes in the three major OMZs of the world oceans, Arabian Sea (AS), Eastern Tropical North Pacific (ETNP), and Eastern Tropical South Pacific (ETSP), and Chesapeake Bay (CB), a seasonaly anoxic estuary.

In the three OMZs, abundances of *nosZ* peak at the secondary nitrite maximum (SNM), where Clade II has a broader maximum extending into the oxyclines above and below the SNM. In CB, the abundance of *nosZ* increases into the bottom water. Clade II *nosZ* is often more abundant than Clade I and the abundance of both is much higher in CB than in the OMZs.

Sequences from a small clone library and from metagenomes indicate that the genes of neither clade were closely related to any cultured species. The combined abundance of both clades of *nosZ* genes was roughly an order of magnitude lower than that of the canonical denitrifier gene *nirS* in OMZs, likely due to the modular nature of this pathway. Results from both qPCR and metagenomics suggest that there is significant capacity for N_2O consumption in oxic waters, predominantly by Clade II *nosZ*.

Keywords: NosZ, clades specific, Oxygen minimum Zones, Abundance, Diversity

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Seasonal Dynamics Of Marine Viral Communities In Chlorophyll Maximum Waters Of The Eastern Arabian Sea: Implications For Microbial Interactions And Omz Processes

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ABSTRACT

Marine viruses are key modulators of microbial mortality, carbon turnover, and horizontal gene transfer, yet their diversity and ecological roles remain underexplored. The chlorophyll maximum (Chl-max), located near the upper OMZ layer, is a dynamic interface where viral–microbial interactions may regulate organic matter remineralization and influence the vertical carbon flux reaching the OMZ. This study presents a comprehensive shotgun metagenomic analysis of viral communities from 12 samples collected at the Chl-max depth across coastal and offshore stations of the Eastern Arabian Sea during the monsoon and non-monsoon seasons. Contig-level annotation and network-based clustering revealed diverse double-stranded DNA viruses, primarily belonging to Caudoviricetes (Myoviridae, Siphoviridae, Podoviridae), along with members of Autographiviridae, Microviridae, and algal Phycodnaviridae. Predicted hosts, identified through genome similarity and network associations, included abundant marine taxa such as *Vibrio*, *Acinetobacter*, *Alteromonas* and *Prochlorococcus*, reflecting the coexistence of heterotrophic and phototrophic lineages in the Chl-max zone. Coastal monsoon samples showed enrichment of temperate and prophage-like sequences, consistent with active lysogeny during the season of high productivity and organic matter flux. In contrast, offshore non-monsoon samples were dominated by lytic cyanophages and SAR11-infecting viruses, suggesting rapid host turnover under nutrient-limited conditions. Several viral clusters exhibited genomic similarity to archaeal hosts (*Haloarcula*, *Methanothermobacter*, *Acidianus*), indicating the presence of low-oxygen-adapted viral groups linked to the regional OMZ core. Collectively, these findings reveal distinct spatial and seasonal viral assemblages that reflect microbial community structure and metabolic potential across the Arabian Sea. This study highlights the ecological significance of viruses in OMZ-influenced waters and the need to integrate viral processes into models of tropical ocean carbon cycling and microbial ecosystem regulation.

Keywords: viral metagenomics, chlorophyll maximum zone, monsoon variability, virus–host interactions, carbon cycling

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Session Title: Indian Ocean marine heatwaves: Mechanisms, impacts, and future risks

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Future Projections Of Marine Heatwaves Over The Indian Ocean Using A Regional Earth System Model Under Rcp Scenarios

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ABSTRACT

This study employs a Regional Earth System Model (RESM) over the CORDEX-South Asia (CORDEX-SA) domain to assess projected changes in Marine Heatwaves (MHWs) relative to the historical baseline period (1976-2005). Future projections are analysed across three time slices, near future (2010-2039), mid-century (2040-2069), and end-century (2070-2099), under two Representative Concentration Pathway scenarios (RCP4.5 and RCP8.5). For the historical period, RESM demonstrates good agreement with observed MHW metrics and their trends, outperforming both the driving General GCM and the CMIP5 Multi-Model Ensemble. Projections indicate a pronounced intensification and lengthening of MHWs across the Indian Ocean in future climates. The persistent increase in duration suggests a transition toward a permanent MHW state, exhibiting strong spatial variability in onset and persistence. While such conditions emerge under both RCPs, the absolute and widespread permanent MHW state is most prominent under the high-emission scenario (RCP8.5). The intensification and development of MHWs are primarily linked to variations in local air-sea heat fluxes, whereas, over longer timescales, elevated mean sea surface temperatures (SSTs) amplify MHW activity. Additionally, the study investigates the influence of large-scale climate modes, specifically, the El Niño- Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD), on MHW characteristics. During El Niño events, both the spatial extent and intensity of MHWs increase across the Tropical Indian Ocean. Furthermore, the IOD modulates MHW behaviour regionally, enhancing activity in the western Indian Ocean during positive phases and in the eastern Indian Ocean during negative phases. These findings highlight the growing threat of persistent and intensified marine heat extremes under continued warming, emphasizing the need for sustained monitoring and climate-adaptive marine management strategies.

Keywords: Marine Heatwaves, Regional Earth System Model, Indian Ocean, Climate Projections, Air-Sea Interaction

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ML Based Prediction of Ocean Temperature Anomalies for Climate Change Detection

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ABSTRACT

Ocean temperature anomalies are crucial for early detection of climate change, but rapid detection is challenging due to the scale and complexity of oceanographic data. Existing approaches including manual analysis, statistical tools, and machine or deep learning models face issues with interoperability, inconsistency across seasons, and limited integration for full analytical workflows. Convolutional Neural Network, Transfer Learning, and Random Forest each demonstrate individual strengths but do not fully capture complex spatiotemporal dynamics, reliably distinguish true anomalies from normal seasonal changes, validate results against climate events, or combine complementary advantages. The unified and reproducible pipeline presented in this study integrates advanced deep learning and traditional machine learning methods, along with efficient preprocessing, seasonal decomposition, and feature engineering for joint spatial and temporal analysis. This approach leverages open-access Copernicus and NOAA datasets for global coverage. Performance is evaluated using statistical metrics (F1 score, accuracy, mIoU) along with oceanographic assessment criteria. Using supervised learning and data augmentation, the model effectively distinguishes true anomalies from regular annual variations. This framework also supports robust regional and seasonal analysis, validation with documented events such as El Niño and marine heatwaves, and comparative studies between standalone and ensemble models, offering a scalable foundation for adaptive climate monitoring and early warning systems.

Keywords: Ocean Temperature Anomalies, Deep Learning, Transfer Learning, Random Forest, Climate Monitoring

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Influence of Bay of Bengal Sea Surface Temperature on Heatwaves Intensity over Odisha: A High-Resolution Modelling Study

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ABSTRACT

In India, heatwaves have become one of the deadliest natural disasters; during the pre-monsoon season (March–June), the state of Odisha consistently ranks among the most afflicted areas. Between 1998 and 2024, Odisha reported over 4,000 heatwave-related fatalities, with extreme events in 1998, 2015, 2016, and 2024 causing widespread mortality, agricultural losses, and disruptions to public health and energy systems. Odisha's coastal topography, which is bounded to the east by the Bay of Bengal and to the east by the Eastern Ghats, produces intricate land-sea-atmosphere interactions that affect the severity and duration of heatwaves While large-scale drivers such as El Niño–Southern Oscillation and blocking anticyclones are known to initiate heatwave conditions, the role of proximal sea surface temperature (SST) anomalies in the Bay of Bengal in amplifying near-surface temperature and humidity remains poorly quantified at the regional scale. Recent studies indicate that warmer-than-average SST in the northern Indian Ocean can weaken the land–sea thermal gradient, suppress the sea breeze, and increase moisture influx into the coastal boundary layer, thereby elevating both sensible and latent heat stress. However, most regional assessments rely on global reanalysis datasets with coarse SST resolution (>25 km) and climatological lower boundary conditions, which fail to capture meso-scale SST gradients and their rapid evolution during heatwave episodes. This limitation hinders accurate attribution of oceanic influence on extreme heat over Odisha, where districts within 100 km of the coast often experience markedly different heat stress compared to interior regions. To fill this gap, the current study utilizes the Weather Research and Forecasting (WRF) model at a convection-permitting resolution of 3 km, incorporating daily high-resolution Optimum Interpolation Sea Surface Temperature (OISST v2.1; 0.25°) data as lower boundary conditions. By conducting sensitivity experiments with observed versus climatological SST for major heatwave years (2015, 2016, 2021, and 2023), we quantify the contribution of Bay of Bengal SST anomalies to heatwave magnitude and spatial heterogeneity. Heat stress is evaluated using a physiologically relevant Heat Index that integrates maximum temperature, relative humidity, and wind speed, enabling identification of high-risk zones across coastal plains, central tablelands, and western Odisha. The results provide new insights into ocean-driven amplification of continental heat extremes and demonstrate the critical need for coupled high-resolution SST forcing in operational heatwave forecasting and early warning systems for Odisha.

Keywords: Heatwaves, SST, High-resolution modelling, Land-sea interaction, Odisha

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Pre-Monsoon Trends And Variability Of Marine Heatwaves Along The Malabar Coast

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ABSTRACT

Marine heatwaves (MHWs) are prolonged periods of anomalously high sea surface temperatures that have profound impacts on marine ecosystems and regional climate. The Malabar Coast, located along the southwestern Arabian Sea, experiences some of the most intense and frequent MHW events in the Indian Ocean, predominantly during the pre-monsoon season (March–May). This study analyzes satellite-derived sea surface temperature data from 1982 to 2019 to characterize the annual and seasonal variability of MHWs along the Malabar Coast. Results reveal a significant increasing trend in both the frequency and duration of pre-monsoon MHWs. Notably, intense events occurred in years such as 2010 and 2016, with heatwave days increasing at a rate of roughly 15–20 days per decade in the northern Arabian Sea, which influences the Malabar Coast area. The Malabar Coast's role as a major upwelling zone makes it crucial for monitoring these changes. This study underscores an urgent need for enhanced monitoring and adaptation strategies to mitigate the ecological and socio-economic impacts of pre-monsoon marine heatwaves along the Malabar Coast. This study reflects current scientific understanding and research trends on MHWs in the region, emphasizing the seasonal focus on pre-monsoon variability and their increasing intensity and duration.

Keywords: Marine heatwaves, Malabar Coast, Sea surface temperature, Trend analysis, Upwelling.

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COral Bleaching In Lakshadweep: Detection Using Sentinel-2 Images

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ABSTRACT

Coral reefs, one of the most diverse ecosystems and crucially important to coastal communities, are rapidly declining due to local and global pressures. Warming oceans and marine heatwaves disrupt coral-zooxanthellae symbiosis, causing coral bleaching globally. The Indian Ocean has warmed two to three times faster than the Pacific in the past fifty years, thereby leading to an increase in marine heatwaves and subsequent coral bleaching.

Given this context, it is critical to study coral bleaching in the Indian Ocean. However, studies on coral bleaching in the Indian Ocean are limited and field surveys are difficult due to the limitations in the accessibility of reefs. Therefore, the current study makes use of satellite images to detect coral bleaching over the Indian Ocean. Sentinel-2 images are used to detect coral bleaching triggered by prolonged marine heatwaves over the Lakshadweep islands in 2024. The methodology comprises selection of cloud-free Sentinel-2 Level-2A images of pre-bleaching and bleaching periods, sunglint correction to remove sunlight reflection off the water surface, and image normalisation using pseudo-invariant features to keep the spectral characteristics consistent across all images. A band-wise differencing of images with respect to a reference image selected during a pre-bleaching period is performed. The false composite images obtained with the difference bands are expected to show golden-yellow hues over the bleached regions due to increase in reflectance, as the corals lose colour. This workflow is applied to the coral reef regions of Lakshadweep. The extent of bleaching is quantified using the difference images. On-site diving surveys are planned to validate the results.

Keywords: Coral bleaching, Marine heatwaves, Sentinel-2, Indian Ocean, Image differencing

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Micrometeorological processes of turbulent momentum transfer during Marine Heat Wave events

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ABSTRACT

Marine heatwaves (MHWs) alter the air-sea exchanges, yet their impact on the micrometeorological structure of momentum transfer remains largely unknown. This study provides the first comprehensive evaluation of the processes of turbulent kinematic momentum flux transport during MHWs in the Bay of Bengal, based on high-frequency (20 Hz) eddy covariance measurements from a moored buoy that captured several MHW events during 2019–2020. To characterize the turbulence, we use a method called the quadrant analysis, which partitions the vertical momentum flux (-u′w′) into physical processes like sweeps (Q4) and ejections (Q2), both representing the downward motions of high-momentum air and outward/inward interaction processes (Q1/Q3) that represent weak upward momentum transport from sea to air. Together, sweeps and ejections dominate the transfer of momentum across the air-sea interface. Before the onset of MHWs, turbulence is compact and well-organized, with balanced sweep-ejection contributions indicating a stable boundary-layer structure. During the MHWs, both sweeps and ejections intensify, and the u′-w′ distribution broadens substantially, reflecting stronger, buoyancy-enhanced turbulent motions driven by anomalously warm SSTs. Following the events, turbulence gradually returns to its pre-event state, although residual variability persists. We further provide a quantitative assessment of these processes from the onset of the MHW through its decay phase. These results reveal how MHWs evolve, amplify, and eventually restore the turbulent momentum transport processes, highlighting the need to incorporate such dynamics into air–sea interaction models.

Keywords: Marine Heat Wave, momentum flux, quadrant analysis

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Changes in Monsoon Storm Under Extreme Sea Surface Warming.

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ABSTRACT

Rising global temperatures have become a serious concern in the 21st century. As a result, the intensity and frequency of extreme weather events have increased worldwide. This study examines anomalies in Sea Surface Temperature (SST) in the Bay of Bengal (BoB), identified as Marine Heat Waves (MHWs) following the definition of Hobday et al. (2016). The regions experiencing frequent MHWs correspond closely with areas of Monsoon Low-Pressure System (LPS) genesis, which typically occurs during the latter half of the MHW life cycle. The presence of MHWs during the genesis phase of Monsoon Depressions (MDs), the intense monsoon LPS, appears to intensify as it modifies the pressure gradient, wind, and rainfall distributions. MDs forming under MHW conditions tend to be more intense, faster-moving, and associated with stronger winds and enhanced precipitation. Furthermore, an increase in Extreme Rainfall Events (EREs) is observed in these MHW-influenced MDs, with most EREs concentrated in the southwest quadrant of the systems.
To investigate the underlying environmental conditions, the Monsoon Depression Genesis Index and the Genesis Potential Index were analyzed. These analyses provide insights into how MHWs modify the background state of the atmosphere and ocean.

Keywords: Marine Heat Waves, Monsoon Depresssion, Low-Pressure Systems, SST, Bay of Bengal

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Spatio-Temporal Variations Of Marine Heatwaves In Tropical Indian Ocean And Impact Of Extreme Heating Events On Ocean Productivity

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ABSTRACT

Marine heatwaves (MHWs), are intense heating events in the ocean in which the sea surface temperature (SST) is higher than a given threshold for a period of 5 days or more have seen a dramatic increase in tropical Indian Ocean. In this study, 40 years of SST from 1982 to 2021 have been used to analyze the spatio-temporal variations in MHWs in tropical Indian Ocean. The 90 percentile threshold for a minimum duration of 5 days was used for MHW classification. Various metrics have been identified namely MHW intensity, duration, frequency, cumulative intensity etc, to characterize the strength and intensity of MHW in different regions of the tropical Indian Ocean. The entire Indian Ocean is then segregated into distinct oceanic regions based on the 40 year maps of MHW parameters and some of the extreme MHW events have been investigated. Several hotspots of MHW have been identified based on the developed MHW parameters. It is observed that most MHW events have been recorded in the last two decades and the period prior to 1997 had very little MHW events. The southern Indian Ocean from 10-30^{0}S and the offshore regions of Somalia coast were found to be the areas with more frequent and most intense MHWs and the Bay of Bengal was observed to be less affected by MHW. In the offshore areas of Somalia (5^{0}S-5^{0}N, 45-55^{0}E), the most extreme and longest MHW events were seen during 1998 and 2015-2016 which are also strong El-Nino years. This region had one of the longest duration of MHW during 2015 extending for more than 100 days at a stretch. This extreme heating event started around the last week of July and continued up to December with MHW intensity of more than 1.5^{0}C recorded. Monthly multi-sensor merged chlorophyll data from 1998 to 2021 was used and a monthly climatology was generated which was then used to calculate chlorophyll anomalies during extreme MHW events. It was observed that average chlorophyll concentrations were unusually low in offshore areas of Somalia from July 2015 and continuing up to 2016. The study highlights the impact of extreme oceanic heating events on phytoplankton abundance and primary productivity which can have cascading effects on the marine ecosystem.

Keywords: Marine Heat Wave, chlorophyll, Sea Surface Temperature (SST), phytoplankton, El Nino

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Coupled Impacts Of Wind Stress And Ekman Transport On Marine Heatwaves In South Asia: Insights From A Regional Earth System

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ABSTRACT

Marine heatwaves (MHWs) are defined as prolonged periods of anomalously warm sea surface temperatures (SSTs), when SST exceeds the seasonally varying 90th percentile threshold for at least five consecutive days. These events have become increasingly frequent and intense in recent decades, with profound impacts on marine ecosystems and regional climate. In the South Asian region, the occurrence and intensity of MHWs are strongly modulated by wind stress and Ekman transport, both of which play a critical role in controlling upper ocean thermal structure and heat exchange processes. In the Indian Ocean, particularly during weak monsoon years, reduced wind stress limits vertical mixing, leading to heat accumulation in the surface layer and facilitating the formation of large-scale MHWs. Conversely, strong monsoon winds enhance vertical mixing and upwelling, which can alleviate surface warming. This study uses simulations from a Regional Earth System Model (RESM) along with ocean reanalysis datasets to examine the combined influence of Ekman transport and wind stress on MHW variability across the Indian Ocean from 1980 to 2017. The analysis reveals that wind-driven Ekman transport critically modifies ocean stratification during monsoon transitions, when wind reversals either strengthen or suppress upwelling. During weak wind phases, reduced Ekman pumping suppresses upwelling and prolongs heat retention in the mixed layer, intensifying MHW persistence. Large-scale climate modes such as ENSO and the IOD further modulate regional wind fields, indirectly influencing MHW characteristics. Overall, the findings highlight the coupled role of local wind forcing, Ekman dynamics, and ocean reanalysis-based modelling in shaping MHW evolution in South Asian seas. These results provide a foundation for improving predictive capabilities and assessing future MHW risks under changing climatic conditions.

Keywords: Marine Heatwaves; Ekman Transport; Wind Stress; Indian Ocean; Regional Earth System Model

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A Comparative Analysis Of Resm Model And Observational Dataset Of Air-Sea Co_2 Flux Changes Over India During Summer Monsoon

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ABSTRACT

The Indian Ocean (30^0N-40^0S) remains one of the most under sampled ocean basins in terms of surface ocean partial pressure of CO_2 (pCO_2), despite its significant influence on the global carbon cycle. Accurate prediction of the global carbon balance requires a better understanding of air-sea CO_2 flux exchanges, which depend on the spatiotemporal resolution of surface pCO_2 observations. To address this gap, a Regional Earth System Model (RESM) simulations was employed to estimate air-sea CO_2 fluxes and assess their variability over the Indian Ocean from 1980 to 2005. Comparative analysis with ocean reanalysis observation revealed that the RESM effectively captures the magnitude and spatial distribution of air-sea CO_2 fluxes. The model-estimated annual mean CO_2 uptake ($-4.69 \times 10^{-5} \pm 0.14$ gC m^{-2} day^{-1}) closely matched the observed value ($-3.84 \times 10^{-5} \pm 0.08$ gC m^{-2} day^{-1}), demonstrating the model's robust skill in reproducing large-scale carbon exchange processes. Although the RESM slightly overestimated CO_2 sinks in the southern Indian Ocean and underestimated upwelling driven CO_2 sources in the northwest Bay of Bengal, it successfully replicated the observed spatiotemporal variability. The model also reproduced pronounced seasonal variations consistent with CO_2 climatology, highlighting its sensitivity to monsoon driven dynamics. Integration of improved atmospheric CO_2 and surface pCO_2 data further enhanced simulation accuracy. Overall, the findings underscore the potential of the RESM framework as a reliable tool for representing and understanding air-sea CO_2 flux variability across the Indian Ocean, particularly during the summer monsoon.

Keywords: Air-sea CO_2 flux; Regional Earth System Model, Ocean reanalysis, Indian Ocean, Summer monsoon

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Ocean-Atmosphere Teleconnection Pathways Linking El Niño Decay to Extreme Warming Over India

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ABSTRACT

Inter-ocean interactions across the Indo-Pacific basin play a central role in shaping seasonal climate variability and extreme temperature events over South Asia. This study examines how coupled ocean–atmosphere pathways linking the equatorial Pacific, western North Pacific (WNP), and Indian Ocean modulate spring and early-summer (AMJ) surface air temperature (SAT) variability over India during post-El Niño years. Using multi-source observations, reanalysis datasets, and coupled climate model simulations, we show that the decay phase of strong El Niño events triggers a robust WNP anticyclone that extends westward into the Bay of Bengal and southern India. This anomalous anticyclone induces lower-tropospheric subsidence, reduces cloud cover, suppresses humidity, and enhances shortwave radiation at the surface, leading to abnormal warming and an increase in heat-related indices. Inter-basin SST gradients further strengthen these teleconnections, facilitating the transmission of Pacific-origin anomalies into the Indian Ocean via atmospheric bridges. Approximately 60% of India's warmest AMJ years coincide with post-El Niño conditions, highlighting the dominance of Indo-Pacific oceanic forcing on regional climate extremes. CMIP6 and APCC models reproduce the large-scale circulation patterns and warming signatures with reasonable fidelity, demonstrating predictive skill at 1–3-month lead times. The findings underscore the crucial role of Indo-Pacific inter- ocean pathways in shaping India's heat extremes and emphasize the potential to improve seasonal outlooks and climate-risk preparedness through enhanced prediction of El Niño decay phase dynamics.

Keywords: Indo-Pacific Teleconnections, Inter-Ocean Pathways, El Niño Decay Phase, Spring Heat Extremes , Heat waves

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Evolving Ocean–Atmospheric Controls on Bay of Bengal Cyclogenesis: A Multi-Decadal, Multi-Parameter Analysis

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ABSTRACT

The Bay of Bengal (BoB) remains one of the most active cyclone-generating regions of the global tropics, where storm formation depends on a delicate balance of atmospheric and oceanic conditions that vary across seasons and years. This study investigates how the environmental factors that support tropical cyclogenesis over the BoB have changed from 1980 to 2023, using ERA5 reanalysis and best-track cyclone data. Key dynamical and thermodynamic parameters—including sea surface temperature (SST), vertical wind shear (200–850 hPa), mid-tropospheric humidity (850–500 hPa), mean sea level pressure (MSLP), and low-level vorticity (850 hPa)—are examined to characterize their spatial patterns, seasonal behavior, and long-term trends.
The results indicate a marked post-2000 warming of SSTs in the central and eastern BoB, accompanied by declining MSLP and enhanced cyclonic vorticity during the monsoon and post-monsoon periods. Although monsoon-season vertical wind shear has increased—acting as a suppressing factor for cyclone intensification—mid-level humidity shows a gradual decline, particularly during the post-monsoon months. A machine-learning attribution framework that combines Random Forest regression with partial-correlation diagnostics identifies SST and low- level vorticity as the dominant controls on seasonal cyclone occurrence, followed by MSLP, while wind shear exhibits mixed influences depending on the season. Network-correlation analysis further reveals strong coupling between the thermodynamic and dynamical variables that shape the cyclone-favorable environment.
Overall, this multi-decadal assessment highlights clear climate-driven shifts in the background environment governing BoB cyclogenesis. The findings enhance our understanding of evolving cyclone risks and provide a transferable methodological framework for diagnosing environmental drivers in other tropical cyclone basins.

Keywords: Tropical Cyclones, Bay of Bengal, Climatology. Multi-physics, Subseasonal prediction, Monsoon, Active, MISO

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Impact of ENSO and IOD events on upper ocean Heat and Salt Transport in Coupled Models over the Tropical Indian Ocean

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ABSTRACT

The present study investigates the performance of the 6th phase of coupled models in representing upper ocean heat and salt transport at different straits of the Tropical Indian Ocean (TIO) during El Niño-Southern Oscillation (ENSO) (El Niño and La Niña) and Indian Ocean Dipole (IOD) phases (positive and negative). To explore the mean features of the transport, the present study utilises CMIP6 models and Ocean Reanalysis System 5 (ORAS5) observations for the period from 1965 to 2014. The heat and salt transport analysis at different straits in the TIO suggested northward and southward transport and show significant seasonal variability. Northward transport occurred during the post-monsoon season, while southward transport occurred during other seasons. Coupled models show significant variations in the upper ocean (50 m), which are consistent with the observations. Results also reveal that during ENSO periods, variations occur during both the positive and negative phases. These findings suggest that strait-based transports of both heat and salt in coupled models in the TIO are sensitive to the phases of ENSO and IOD.

Keywords: Heat and Salt transport, ENSO, IOD, and Indian Ocean

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Monsoon Variability Over South Asia: Insights From Model Forecasts And Multi-Driver Interactions

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ABSTRACT

The variability of the Indian summer monsoon remains a challenge for both understanding and prediction, as its teleconnections to major climate modes are often modulated by additional factors. Recent analyses of observational data have revealed that the phases of the El Niño–Southern Oscillation (ENSO) exhibit altered rainfall anomalies when co-occurring with Indian Ocean Dipole (IOD) and Madden–Julian Oscillation (MJO) activity, thereby affecting seasonal outcomes across India. Furthermore, asymmetric regional responses in monsoon rainfall are identified for distinct evolutions of La Niña events, impacting India's homogeneous monsoon regions differently. In parallel, the evaluation of seasonal forecast models reveals strengths in general teleconnection signals but persistent biases in spatial rainfall prediction, particularly under complex, multi-driver conditions. This work proposes a framework that integrates multi-driver diagnostics with seasonal forecast verification to improve attribution and predictability of monsoon variability. Such an approach can strengthen early-warning capabilities and climate- informed decision support for water resources, agriculture, and disaster risk planning.

Keywords: Monsoon variability, Climate drivers, Seasonal forecasting, ENSO–IOD interactions, Hydroclimate prediction

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Asian Jet Variations and Climate Modes: Impacts on the Indian Summer Monsoon in observations and models

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ABSTRACT

Analysis of the observations suggested that that El Niño in conjunction with positive Pacific Decadal Oscillation (PDO) mainly drives the stronger intensification of the southward shift of the Asian jet by accelerating the westerlies to the south of the climatological jet axis while de- accelerating them to the north when compared to El Niño in isolation. This mechanism governs the zonally asymmetric extension of the southward shift of the Asian jet from the western to eastern Asian regions, encompassing the northern Pacific. It is highlighted that ENSO alone may not a major driver of the subtropical jet's variability, but the PDO plays a pivotal role in modulating the meridional displacement of Asian jet. Unlike in the observations, CMIP6 models simulation of Indian Ocean Dipole, and westward extension of El Niño related sea surface temperature anomalies in most of the models. The CFSv2 model is employed for sensitivity experiments to assess the atmospheric response to different oceanic modes. First, a control run is conducted for a year with all major oceanic modes in a neutral state (e.g., neutral El Niño, PDO, and IOD). Subsequently, separate experiments are performed by prescribing El Niño alone, PDO alone, and both together. This setup allows us to isolate and analyze circulation changes associated with these SST anomalies, providing valuable insights into the mechanisms underlying their influence and testing the proposed hypotheses. Further, combined influence of PDO and El Niño alone on SWDAJ and ISM rainfall is also discussed in detail.

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Climate Teleconnections Behind Himalayan Extreme Weather Events

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ABSTRACT

The Indian Himalayas are highly vulnerable to extreme weather events, including intense precipitation and severe cold waves, yet the large-scale climate signals driving these hazards remain inadequately understood. Drawing on recent studies of both summer and winter extremes, this work synthesizes the key dynamical pathways linking Himalayan extreme weather to broader climate variability.

Summer precipitation extremes over the Western Himalayas are strongly influenced by tropical– extratropical interactions. Upper-tropospheric gyres, zonal wave patterns, and enhanced moisture transport from the Arabian Sea and Bay of Bengal converge to trigger deep convection. Vertical moisture advection, diabatic heating, and quasi-resonant amplification (QRA) of planetary waves further intensify these events, underscoring the role of baroclinic wave activity in generating persistent rainfall extremes. Winter weather hazards show equally strong remote influences. Enhanced subtropical westerlies, increased baroclinic instability, and strengthened western disturbances promote heavy snowfall events. In addition, severe cold waves are frequently linked to sudden stratospheric warming (SSW) events, Ural-Siberian atmospheric blocking, and downward propagation of stratospheric anomalies. These processes, often reinforced by Arctic amplification and La Niña–driven circulation patterns, facilitate strong southward intrusions of cold air into North India.

Together, these findings highlight that Himalayan extremes arise from the interaction of complex topography with multi-scale climate drivers, offering pathways to improve subseasonal prediction and early-warning systems.

Keywords: Himalayas; Extreme weather; Teleconnections; Planetary waves; Stratospheric influence

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Spatio-temporal Variability of Satellite Derived Ocean Surface Currents in the Tropical Indian Ocean

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ABSTRACT

The surface current observations in the data-sparse Indian Ocean are very limited and are mainly restricted to the near equatorial region covered by the RAMA buoy network. On contrary, measuring any physical parameters of Ocean through satellites provides the advantage of synoptic repetitive coverage which is not possible by any other means, thus becomes a very important tool for long-term monitoring of Ocean circulation. In the present study we present a new Satellite derived Ocean Surface Current (SOSC) product by the synergistic use of satellite derived Sea Level Anomaly, Winds and Sea Surface Temperature data by combining Geostrophic, Ekman and buoyancy components respectively from 1993 to 2024 at daily and 0.25^{o} X 0.25^{o} resolution .

In the present study we have evaluated this long term high resolution SOSC product using RAMA buoy currents and also presented the results of Interannual variability of major current systems in the TIO using this long term data set generated using satellite data. The validation results show very good agreement with RAMA buoy and HF Radar data with RMSE and correlation ranging from 10 to 30 cm/s and 0.5 to 0.9 respectively. In general excellent match is observed for off equatorial regions and relatively poor results are observed for near equatorial regions especially for Meridional currents. The Interannual variability analysis of major current systems in the Indian Ocean such as EICC, WICC, Monsoon Current, Indonesian Through Flow etc., show interesting results associated with signatures of basin scale events such as El Nino and Indian Ocean Dipole depicting the complex interplay of different modes of variability in the Indian Ocean. The observed interannual trends in these major current systems and their contributions to enhanced Indian Ocean warming compared to other tropical oceans are also presented in the present study.

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How Atmospheric Nonlinearities Boost ENSO Asymmetry and Extreme El Niño's

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ABSTRACT

Extreme El Niño events have outsized impacts and strongly contribute to the El Niño Southern Oscillation (ENSO) warm/cold phase asymmetries. There is currently no consensus on the respective importance of oceanic and atmospheric nonlinearities for those asymmetries. Here, we use atmospheric and oceanic general circulation models that reproduce ENSO asymmetries well to quantify the atmospheric nonlinearities contribution. The linear and nonlinear components of the wind stress response to Sea Surface Temperature (SST) anomalies are isolated using ensemble atmospheric experiments, and used to force oceanic experiments. The wind stress-SST nonlinearity is dominated by the deep atmospheric convective response to SST. This wind-stress nonlinearity contributes to ~ 40% of the peak amplitude of extreme El Niño events and ~ 55% of the prolonged eastern Pacific warming they generate until the following summer. This large contribution arises because nonlinearities consistently drive equatorial westerly anomalies, while the larger linear component is made less efficient by easterly anomalies in the western Pacific during fall and winter. Overall, wind-stress nonlinearities fully account for the eastern Pacific positive ENSO skewness. Our findings underscore the pivotal role of atmospheric nonlinearities in shaping extreme El Niño events and, more generally, ENSO asymmetry.

Keywords: El Niño, La Niña, SST, Rainfall, Wind stress, Atmospheric nonlinearities, Asymmetries

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A Review Of Interactions Between The Tropical Atlantic And Indian Ocean Across Timescales

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ABSTRACT

The tropical Atlantic and Indian Oceans are interconnected through complex ocean-atmospheric teleconnections that influence regional climate variability on a range of timescales. Central to these interactions is the Atlantic Zonal Mode (AZM), also known as the Atlantic Niño, characterized by boreal summer SST anomalies in the equatorial Atlantic. This review synthesizes observational, reanalysis, and modeling evidence to elucidate the AZM's multifaceted impacts on the Indian Ocean climate, including ISMR, monsoon depressions in the Bay of Bengal, regional circulation, and ocean surface waves. For instance, warm (cold) AZM phases, marked by positive (negative) SST anomalies, exhibit an inverse relationship with Indian summer monsoon rainfall (ISMR), suppressing (enhancing) precipitation through alterations in large-scale circulation and moisture transport. It further delineates tropical and extra-tropical pathways mediating these links and examines their evolution in historical and future projections under anthropogenic forcing.The AZM exerts a significant influence on ISMR, especially in the absence of ENSO, with the relationship strengthening over recent decades amid global warming. Warm AZM events suppress ISMR by weakening low-level southwesterlies and reducing moisture convergence over the monsoon trough. However, this impact on ISMR is not uniform throughout Indian subcontinent. Beyond rainfall, the AZM modulates the genesis and track of monsoon depressions in the BoB, low-pressure systems responsible for a significant portion of ISM precipitation. Through the changes in the regional circulation, the AZM also affects the ocean surface wave activity in the Bay of Bengal during boreal summer, with implications for coastal erosion, upper ocean mixing, and marine operations. Collectively, these impacts underscore the AZM's role as an underappreciated driver of ISM and IO circulation predictability, with potential to enhance seasonal forecasts when incorporated into dynamical models.Teleconnections from the AZM to the IO-ISM system operate via dual pathways: a dominant tropical route through equatorial wave dynamics and a subtler extra- tropical channel involving mid-latitude Rossby waves. The tropical pathway invokes a Gill-Matsuno-type response, where AZM SST anomalies excite eastward-propagating Kelvin waves and westward Rossby waves. Warm AZM heating in the equatorial Atlantic generates a Matsuno- Gill quadrupole: upper-level divergence triggers Kelvin waves that traverse the IO, inducing easterlies and subsidence over India, which weaken the monsoon. The Maritime Continent acts as a conduit, modulating wave leakage to the Pacific and reinforcing the local Walker circulation. The extra-tropical pathway involves signals via the North Tropical Atlantic (NTA) and mid-latitude Rossby wave trains. NTA SSTslinked AZM excite Rossby waves that propagate eastward along the subtropical jet, forming a stream

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global teleconnection pattern, inducing circulation changes that can affect the monsoonal convection over the Indian subcontinent. In summary, AZM-IO interactions, mediated by wave-guided teleconnections, profoundly shape Indian Ocean climate variability across timescales. Enhanced monitoring and modeling of these links are imperative for South Asian climate resilience.

Keywords: Tropical Atlantic, Indian Ocean, Atlantic Zonal Mode, Indian Summer Monsoon, Teleconnections

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Future Wave Climate of the Indian Ocean: Insights from CMIP6-Driven Wave Projections

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ABSTRACT

Understanding future wave climate variability is essential for coastal resilience, offshore operations, and climate adaptation planning. Despite their importance, wind-wave parameters are not directly represented in CMIP6 models, leaving significant gaps in global and regional wave climate projections, particularly over the Indian Ocean (IO). The IO wave climate is highly variable, driven by seasonally reversing monsoon winds, and further modulated by both tropical and extratropical climate systems. Understanding the mechanisms controlling this variability is essential for reliable projections of future ocean states and their societal impacts. Investigations carried out under the Deep Ocean Mission – Vertical 2: Ocean Climate Change Advisory Services (OCCAS) have established that the IO wave field is influenced by multiple climate modes operating across scales. Tropical modes such as the El Niño– Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) significantly alter equatorial and eastern IO wind fields, while extratropical influences, particularly the Southern Annular Mode (SAM) governs the generation and propagation of swell systems into the IO. These teleconnections link polar and tropical variability, highlighting the IO as a dynamically connected basin responding to far-field forcing.

Building upon this understanding of climate-driven wave variability, the focus was on simulating the future wave climate projections for the Indian Ocean using CMIP6 model winds. A comprehensive evaluation of multiple CMIP6 models was undertaken to identify the best-performing wind forcings for the IO, through wave simulations using the WAVEWATCH III model. Recognizing the limitations in bias correcting techniques and the strong seasonality of the region, refined seasonal bias-correction techniques were developed and applied to improve projection reliability. These efforts aim to generate robust, bias- corrected projections of Indian Ocean wave characteristics under future climate scenarios, forming a key component of the national effort to build climate-resilient coastal and ocean services through OCCAS.

Keywords: Deep Ocean Mission, Indian Ocean,Wave Climate, Wave Projections, Wave model

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Climate Variability and Monsoon Rainfall Intensification over the Godavari Basin during Recent Warming Decades

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ABSTRACT

The southwest monsoon (June-September; JJAS) is vital to agricultural productivity, water-resource planning, domestic water supply, and socio-economic stability across the Godavari River Basin (GRB). This study examines the spatiotemporal variability of JJAS rainfall over 1965-2024 using India Meteorological Department (IMD) observations and ERA5 (ECMWF Reanalysis v5) meteorological fields, with the analysis divided into two climatological epochs: 1965-1994 (Pre-Global-Warming; PGW) and 1995-2024 (Recent-Global-Warming; RGW). Our results reveal a pronounced influence of the El Niño-Southern Oscillation (ENSO) on monsoon variability. El Niño events are generally linked to deficient monsoon conditions and drought occurrence, whereas La Niña events enhance basin-wide rainfall and elevate flood risk. Spatial diagnostics indicate a marked rise in extreme rainfall occurrences across the central and northeastern sub-basins, contrasted by declining seasonal totals and an increasing number of dry days in the southern and western GRB. Stability indices and environmental parameters further elucidate the atmospheric controls governing rainfall variability and the occurrence of extreme-rainfall days. A comparison of the PGW and RGW periods shows a reduction in mean JJAS rainfall, fewer wet days, and a greater tendency toward localized extremes during the recent warming era. Collectively, these diagnostics point to escalating hydroclimatic risks including droughts, flash floods, and moisture stress, highlighting the urgent need for improved sub-seasonal to seasonal prediction capability, enhanced disaster preparedness, and climate-resilient water-resource management in the GRB.

Keywords: Godavari River Basin, monsoon variability, ENSO, extreme rainfall, climate change, drought, flooding, ERA5, IMD

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Identifying the Cross-equatorial Surface Pathways of the Indian Meridional Overturning Circulation

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ABSTRACT

The Indian Ocean differs from the other two large oceans, the Pacific and Atlantic, where shallow subtropical cells (STCs) link subtropical subduction regimes via western-boundary undercurrents and interior thermocline recirculation, which upwells at the equatorial region and returns to the subtropics with Ekman transport to close the circulation. The situation is quite different for the Indian Ocean. The atmospheric flow over the Indian Ocean presents a fascinating and complex system, dominated by the dramatic seasonal monsoon reversal. One point of debate is related to the nature of equatorial winds and how they drive the surface of the ocean. The oceanic response to these winds is equally complex by reversing its currents. These reversing systems govern the exchange of heat, salt, the highly saline Arabian Sea water and the freshwater Bay of Bengal across the equator to maintain the balance.

In this study, I examine the characteristics of the Indian Ocean circulation using satellite-derived surface current products (ISRO SAC Current Data) and gridded wind data from 1993 to 2024. With these datasets, I identify the dominant pathways of cross-equatorial exchange and examine how these routes evolve across the southwest and northeast monsoon phases as well as during the inter-monsoon transition periods. This basically involves three steps: first, developing seasonal maps of surface flow of water; second, computing the amount of heat, salt, and freshwater that are crossing the equator; and third, analysing how this shift would change with the shift in the wind above the monsoon. This observation-based assessment will provide new insight into the dynamical links between ocean circulation, cross-equatorial transport, and regional climate processes in the Indian Ocean. Further, the effect of variability of cross-equatorial transport will be examined.

Keywords: Indian Ocean Circulation, Ekman Transport, Cross Equatorial Flow, Indian Monsoon, Heat and Freshwater Transport, ISRO SAC Current

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Observations of sub-surface high salinity core in the Equatorial Indian Ocean and its Arabian Sea link.

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ABSTRACT

The dynamical connection between the equatorial Indian Ocean (EIO), the Bay of Bengal (BoB) and the Arabian Sea (AS) on seasonal to longer timescales has been well studied since the early 1990s, relying primarily on numerical model simulations. Under the Deep Ocean Mission, repeated cross-equatorial glider transects along 67 °E in the Arabian Sea and 89 °E in the BoB offer a unique opportunity to examine inter-basin connectivity through water-mass transports and their seasonal evolution. These transects consistently reveal a subsurface high-salinity core across the EIO, with salinities ranging from 35.2 to 35.5 psu, underlying the fresher surface layer at roughly 100 m depth. The observations further indicate that this high-salinity core is markedly more intense in the western EIO compared to its eastern counterpart. Moreover, this high-salinity core strengthens during spring, with salinity in the 67 °E transects crossing 35 psu, indicating fresh intrusion of this high-salinity water into the equatorial regime in this season. The characteristics of this high-salinity water mass resemble those of the Arabian Sea High Salinity Water (ASHSW). Analysis using Lagrangian particle tracking simulations reveals that this high- salinity subsurface intrusion originates from the preceding boreal winter in the northern Arabian Sea and is advected southward along the western Arabian Sea via the equatorward winter Somali Current. Once these waters intrude into the equatorial waveguide subducted below the relatively fresher equatorial surface water masses. Subsequently, this high-salinity core advected eastward by the eastward equatorial undercurrent during late winter and spring. Model simulations indicate that the eastward advection of the subsurface core is strengthened in spring, followed by IOD years, driven by the intensification of the equatorial undercurrent.

Keywords: Equatorial Indian Ocean, Water mass, Equatorial Undercurrent, Inter-basin exchange, High salinity core

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Interannual Variability of Western North Pacific Cyclones and their influence on Monsoon Systems

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ABSTRACT

The Western North Pacific is the most active tropical cyclone (TC) basin globally, with the majority of cyclogenesis occurring between June and November. TCs in this basin move in northward/northeastward as well as in westward/northwestward direction. The westward moving TCs often travel across the low latitudes. After landfall, these westward-moving cyclones typically weaken but frequently continue their propagation into the Bay of Bengal as low- pressure systems or cyclonic circulations. This study demonstrates that the frequency of monsoon (June–September) low-pressure systems over the Bay of Bengal is closely linked to the westward moving TCs originating in the Western North Pacific. We show that the remnants of Pacific typhoons can re-intensify as low-pressure systems or depressions under favorable environmental conditions in the Bay of Bengal. Furthermore, the occurrence of these westward-propagating cyclones exhibits pronounced interannual variability, which is strongly modulated by the position and intensity of the subtropical western North Pacific high. Variations in this high-pressure system are, in turn, influenced by large-scale climate teleconnections. These results underscore the importance of multi-basin interaction through large-scale circulation and remote forcing in shaping regional monsoon variability.

Keywords: Monsoon low-pressure, Western North Pacific Cyclone, teleconnection

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The Asymmetric Impact of the El Niño Phase Cycle on Tropical Indian Ocean Marine Heatwaves

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ABSTRACT

Marine Heatwaves (MHW) in the Tropical Indian Ocean (TIO) are increasingly recognised as extreme events that exert profound impacts on marine ecosystems, regional climate, and socio-economic systems. In recent decades, the TIO has experienced a marked increase in MHW frequency and intensity, driven by climate modes such as the El Niño-Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), the Pacific Decadal Oscillation (PDO), and long-term warming in the Indian Ocean. While the influence of major climate modes on MHWs in the Indian Ocean has been documented, the specific impact of the ENSO phase cycle on the variability of MHW characteristics remains largely unaddressed. This study examines the variability of MHWs during each season from the El Niño developing phase to the El Niño decay phase, using observed sea surface temperature data from 1982 to 2024. Spatial composites of MHW duration, frequency, and cumulative intensity reveal a distributive pattern of MHWs across the El Niño phase cycle. The time series analysis of detrended SST averaged over the basin has shown a composite MHW with a high magnitude in the Spring of the El Niño decay phase. Further, the area-averaged analyses over the region South of 5S - the Southern TIO, as the dominant region of MHWs, show a clear increase in all MHW metrics during the spring of the decay years compared to that of the developing years of El Niño. To investigate the underlying drivers, the mixed-layer heat budget analyses were conducted over the hotspot regions, providing insight into the physical mechanisms responsible for these anomalies. These findings highlight the substantial impact of the El Niño decay phase on MHWs in the TIO, providing new insights into the processes governing extreme ocean warming in this basin

.**Keywords:** Marine Heatwaves, Tropical Indian Ocean, El Niño Decay, Mixed Layer Heat Budge

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Missing summer westerly jet barotropic governor effect explains climate models - observation discrepancies in the Indian monsoon trends.

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ABSTRACT

The Indian summer monsoon has exhibited a pronounced northwest-central rainfall dipole since 1999, with northwest India experiencing a 24.6\% increase while rainfall in the Indo-Gangetic Plain has decreased 4.4\%. This dipole pattern is not reproduced in historical climate model simulations, and its physical drivers are not yet well understood. Synthesizing observational and assimilated data and climate model simulations, we show that this dipole is driven by North Atlantic sea surface temperature (SST) changes, which are transmitted through a “barotropic governor mechanism” and operate to control Asian jet stream dynamics. Enhanced barotropic energy conversion after 1999 created momentum focusing in the jet core while weakening east-west flanking regions, which fundamentally altered the monsoon circulation by modulating the local Hadley cell. This barotropic governor activation coincides with the North Atlantic “cold blob” attributed to a slowdown in the Atlantic Meridional Overturning Circulation (AMOC). Coupled climate models driven over the historical era systematically fail to reproduce North Atlantic SST changes, and so this atmospheric dynamical mechanism instead shows reversed barotropic energy conversion patterns and misses this key teleconnection mechanism. Prescribed SST experiments using observed North Atlantic SST changes validate the proposed mechanism, thereby successfully reproducing both observed jet dynamics and rainfall trends. The identification here of a North Atlantic-Asian teleconnection pathway modulated by the barotropic governor effect directly links the behaviour of the AMOC and monsoon tipping elements to each other.

Keywords: Indian monsoon, Atlantic-Asian teleconnections, Barotropic Governor, Jet stream dynamics, AMOC.

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Study Of Trpoical Ocean Teleconnections And Their Influence On Wet/Dry Events During Indian Summer Monsoon

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ABSTRACT

Dry and wet events driven by monsoon variability have profound socio-economic consequences in India, making it essential to examine their links with large-scale climate drivers. In this study, to quantify the impacts of extreme monsoon years, dry and wet years were objectively identified using the Standardized Precipitation Index (SPI) derived from high-resolution IMD gridded rainfall data spanning 1951–2024. Seasonal SPI time series was developed to examine interannual and decadal-scale variability. A grid was classified as dry (wet) when SPI < –0.5 (SPI > 0.5), and a year was considered dry (wet) if the fraction of dry (wet) grids exceeded 50% of the total domain. Furthermore, correlations between SPI and multiple tropical SST indices over the Pacific, Indian and Atlantic Ocean were calculated to highlight the role of different basins in modulating hydroclimatic conditions. This classification highlights asymmetries in the frequency of widespread dry and wet events, consistent with the evolving large-scale teleconnections. Identified years were analyzed using composite analysis of large-scale circulation anomalies, including sea level pressure, low-level winds, and Walker–Hadley circulation. The findings provide new insights into the changing hydroclimatic extremes in India and the significant role of ocean-atmosphere interaction over the tropical oceans emphasizing the need for a comprehensive analysis of these factors over the Indian region.

Keywords: Pacific Ocean, India Ocean, Atlantic Ocean, Ocean-atmosphere Interaction, Standardized Precipitation Index.

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Asymmetries in the Indian Ocean Dipole events and responsible mechanisms

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ABSTRACT

The different phases of the Indian Ocean Dipole (IOD) events in general display asymmetries in their amplitude, spatial patterns and phase transition between positive (pIOD) and negative (nIOD) events. The present study examines the evolution and transition characteristics of IOD events using sea surface temperature anomalies (SSTA) and the Dipole Mode Index (DMI) derived from ERSST data spanning 1958–2024. The DMI displays a stronger magnitude during the pIOD events (for example, 1962, 1997, 2019 and 2023) than its counterpart. Composite analysis and life-cycle diagnostics are applied to identify multi-year links between negative and positive IOD phases. The results show that a majority of prolonged negative IOD (nIOD) events, especially those persisting through the boreal autumn (SON), are followed by the development of a positive IOD (pIOD) in the subsequent year. The results show that prolonged SON nIOD events are often accompanied by weak La Niña–like conditions and anomalous easterlies over the equatorial Indian Ocean, which help maintain a warm eastern pole and strengthen the ocean's memory. The persistent SON nIOD conditions precondition the basin by sustaining eastern-pole warming and suppressing western-pole convection, creating favorable background states for a pIOD to emerge the next year. These findings highlight a previously under-recognized transition pathway in IOD dynamics and improve understanding of how prolonged nIOD events can induce or force the onset of a pIOD. This multi-year linkage provides valuable insight for enhancing seasonal to interannual prediction of IOD evolution and its associated climate impacts.

Keywords: Asymmetry, Sea surface temperature, Indian Ocean Dipole, Tropical Indian Ocean, ocean-atmosphere interactions, atmospheric circulation.

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Ocean-Model Perspectives on the Tropical Indian Ocean Multi-Scale Variability: Special emphasis on oceanic Extremes

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ABSTRACT

Accurate representation of the vertical thermal structure of the Tropical Indian Ocean (TIO) is essential for understanding monsoon variability and predicting marine heatwaves (MHWs). This study evaluates the performance of the Modular Ocean Model version 5 (MOM5) in simulating intraseasonal and interannual variability of TIO sea surface temperature (SST). MOM5 reproduces the large-scale mean SST patterns but exhibits a cold bias at the surface and a warm bias in the subsurface (+0.5 to +1.5 °C at 100–300 m). The warm subsurface bias is primarily linked to weak stratification and enhanced vertical shear, which promote excessive vertical mixing and anomalously deep heat penetration. Band-pass filtered (30–90 day) SST anomalies reveal pronounced intraseasonal variability in the western and central TIO. Low-pass filtered (2–7 yr) SST anomalies show strong agreement with satellite observations (correlation ≈ 0.96) and accurately capture the spatial signatures of El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD), including basin-wide warming (cooling) during El Niño (La Niña) and the zonal SST gradient characteristic of IOD events. However, MOM5 exhibits substantial errors in the eastern IOD pole, overestimating cooling (warming) during positive (negative) IOD phases. We further analyze MHW characteristics simulated by MOM5. The model generally underestimates event counts and overestimates event duration, yet it skilfully reproduces the intensity, spatial structure, and geographical distribution of MHWs during extreme ENSO events. Although MHW hotspots vary between events, MOM5 captures these shifts reliably. Overall, despite persistent mean-state biases, MOM5 demonstrates strong capability in simulating large-scale climate variability relevant to MHWs in the TIO.

Keywords: Tropical Indian Ocean, MOM5 ocean model, Marine Heat Waves, Stratification, Indian Ocean Dipole.

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Multi-Basin Oceanic Forcing And Aerosol Effects Driving Monsoon Weakening Over The Indo-Gangetic Plains

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ABSTRACT

The Middle and Lower Gangetic Plain (MLGP), a vital agricultural heartland of India, has witnessed a marked decline in Indian summer monsoon rainfall (June–September, JJAS) between 1984 and 2016. Using high-resolution rainfall observations, satellite data, reanalyses, and coupled model simulations, this study identifies the coupled roles of oceanic forcing and aerosol loading in driving this persistent drying trend. Analyses reveal a weakening of the monsoon circulation linked to enhanced aerosol optical depth over the Indo-Gangetic Plains, arising from anthropogenic emissions and recurring dust influx. Reduced wet scavenging under warm Equatorial Indian Ocean (EIO) conditions further sustains elevated aerosol levels, suppressing deep convection and intensifying evaporative stress on vegetation. Basin-wide EIO warming emerges as the dominant oceanic influence, weakening the land–sea thermal gradient, diminishing moisture transport, and promoting large-scale subsidence over the MLGP. These anomalies remain robust after removing the influence of ENSO, indicating an independent EIO teleconnection. Coupled model experiments using ACCESS-CM2 reproduce the observed SST trends and atmospheric circulation patterns, lending confidence to the proposed mechanisms. Additional modulation by cooling in the Equatorial Atlantic and warming in the Equatorial Pacific reinforces subsidence over South Asia through Rossby wave propagation and wave activity flux convergence. Together, aerosols, EIO warming, and inter-basin SST interactions act synergistically to suppress monsoonal convection, explaining the observed rainfall decline over the MLGP. The results underscore the importance of integrated ocean–atmosphere–aerosol diagnostics and multi-basin perspectives for improving monsoon predictability and informing climate adaptation in this agriculturally critical region.

Keywords: Equatorial Indian Ocean warming, Indo-Gangetic Plains, Aerosol-Cloud interaction, Rossby Waves, Inter-basin Teleconnections

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Influence Of Remote Oceanic Drivers On Tibetan Plateau Warming Amplification

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ABSTRACT

The Tibetan Plateau (TP), often called the "Third Pole", with its significant elevation and thermal characteristics, affects large-scale atmospheric circulations. Recent studies indicate Tibetan Plateau Amplification (TPA), a phenomenon where the TP warms at a faster rate than the global average. TP thermal forcing interacts bidirectionally with surrounding oceans, yet the relative roles of different basins and their seasonal evolution remain poorly constrained. In this study we have explored the relation between TPA and global sea surface temperature (SST) variability. Regression of SST anomalies onto the Tibetan Plateau Amplification Index (TPAI) reveals statistically significant warm anomalies over the Indo-Pacific Warm Pool region, accompanied by cool anomalies in the Arabian Sea and western Indian Ocean, implying a negative Indian Ocean Dipole–like pattern during high-TPAI phases. Pronounced and statistically significant cool anomalies over the eastern–central Pacific exhibits La Niña–like structure. Over the Atlantic, significant warm tropical Atlantic SST anomalies co-exist with cool anomalies in the North Atlantic, forming a weak tripole pattern reminiscent of North Atlantic Oscillation–related SST structures. Additional warming over the Arctic and Eurasian high latitudes suggests possible high-latitude feedback. These results demonstrate that multiple basins jointly modulate TP amplification, rather than a single dominant driver. We further examine how SST anomalies differ between springtime and peak JJA heating, and during transitions between TP-warming and cooling years, revealing strong seasonal dependence. This multi-basin coupling framework provides new insight into the predictability of TP warming and its downstream impacts.

Keywords: Tibetan Plateau Warming Amplification, SST influence, air-sea interaction, Teleconnection, Oceanic Drivers

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Indo-Pacific Controls on Decadal Circulation Variability in the Tropical Indian Ocean

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ABSTRACT

The tropical Indian Ocean (TIO) exhibits marked decadal fluctuations in surface circulation, reflecting the interplay between local wind forcing and remote Indo-Pacific climate modes. Using ORAS5 reanalyses (1958-2023), this study investigates the dominant patterns and drivers of decadal-scale zonal current variability across the equatorial Indian Ocean. Analyses reveal a robust 10-15-year periodicity in the equatorial zonal current anomalies, with a meridional dipole structure of its trend characterized by intensified eastward flow along the equator, consistent with intensified westerlies and thermocline deepening in the southeastern basin. Empirical Orthogonal Function analysis identifies two leading modes that together explain nearly half of the decadal variance. The first mode represents basin-wide circulation anomalies driven by large-scale Pacific decadal forcing, tightly linked to the Interdecadal Pacific Oscillation through atmospheric bridge mechanisms and Walker circulations. The second mode reflects a response to persistent equatorial easterlies, highlighting the influence of local air-sea coupling on equatorial current systems. The results point to a dual control of Indian Ocean decadal variability - remote Pacific teleconnections setting the large-scale background state and regional wind anomalies modulating the equatorial current dynamics. These findings provide new insights into Indo-Pacific interaction pathways shaping long-term changes in Indian Ocean circulation and have implications for understanding decadal predictability of regional climate and monsoon variability.

Keywords: Tropical Indian Ocean, Decadal variability, Interdecadal Pacific Oscillation, Equatorial currents, Indo-Pacific teleconnection, Wind-driven circulation

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Baseline to future: Monitoring Sri Lanka's coastal carbonate system in a changing ocean

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ABSTRACT

Sri Lanka's diverse coastal ecosystems are susceptible to alterations in seawater carbonate chemistry. Recognizing the threat and potential impacts of ocean acidification, we launched a baseline data collection and monitoring program on coastal carbonate chemistry. We present initial results from repeated studies in Negombo Lagoon and its adjacent coastal waters. Sampling was conducted in 2019-2020, 2023, and 2025 with a redesigned sampling strategy covering multiple ecosystems. At each station, in situ measurements of pH, temperature, and salinity were made using a multiparameter sonde, whereas total alkalinity (TA) was analysed using an open-cell titration method, and dissolved inorganic carbon (DIC) using a DIC analyzer. pCO_2 was calculated using CO2SYS Excel add-in. Lagoon stations exhibited lower pH values with greater variability (6.80–8.41) than coastal waters (pH ~ 8.16–8.44). Lagoon TA showed substantial heterogeneity (≈ 273–2687 µmol kg^{-1}), versus ≈2195–2380 µmol kg^{-1} in coastal waters. DIC ranged from 1144 –1900 µmol kg^{-1} in the lagoon and 1972–2136 µmol kg^{-1} on the coast. pCO_2 ranged from 702–3159 µatm in the lagoon and 636–1666 µatm in coastal waters. Extreme lagoon conditions illustrate acute carbonate stress in semi-enclosed waters. This baseline assessment establishes a foundation for Sri Lanka and highlights the need for sustained monitoring with standardized methods. Further, harmonized protocols across the Indian Ocean nations are essential for data comparability and regional coordination under global frameworks (i.e., GOA-ON, IIOE expeditions) is required to enhance data sharing and strengthen analytical support. By adopting a systematic approach in South Asia, Sri Lanka contributes to filling Indian Ocean knowledge gaps and issues a compelling call for coordinated monitoring to safeguard its sensitive coastal environments under future acidification scenarios.

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Role of ocean dynamics in connecting the tropical Indian Ocean variability with the Arctic Ocean

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ABSTRACT

In this study, a numerical model simulation has been performed to understand the role of the Arctic Ocean (AO) on upper ocean variability of the Tropical Indian Ocean (TIO) at various time scales from seasonal to interannual and decadal. A global Modular Ocean Model of version 5 with Sea Ice Simulator (MOMSIS) was used for this study, featuring a horizontal resolution of 25 km x 25 km in the longitude-latitude direction and 50 vertical levels. The role of AO on TIO variability has been quantified using a model experiment in which the year-to-year atmospheric forcing in the Arctic regions of the MOMSIS has been replaced with its climatological values, allowing for the estimation of the global impact of the recent increase in Arctic ocean warming. The model simulation revealed that the role of ocean dynamics in the interaction between AO and IO is more prominent through the Atlantic Ocean pathway than through the Pacific Ocean. The Atlantic water pathway works via the Southern Ocean channel. The Pacific Ocean pathway is more dominant in the Northern part compared to the Southern part. The preliminary results indicate that changes in atmospheric fluxes in the Arctic over the recent decade have a significant impact on ocean currents, sea level, and sea surface temperature (SST) variability in the Southern Indian Ocean (SIO) compared to the Northern Indian Ocean (NIO). Additionally, the maximum impact of AO has been observed at the decadal time scale compared to the interannual scale. Additionally, it has been observed that Pacific Ocean pathways are primarily responsible for an increase in sea level anomaly and SST compared to Atlantic Ocean pathways from AO. This study demonstrates that the recent significantwarming in the AO has a substantial impact on ocean physics and monsoon variability in the TIO through ocean pathways.

Key words: Tropical Indian Ocean, Arctic Ocean, Ocean dynamics, Remote Forcing, Upper Ocean variability, Monsoon variability

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Summer Thunderstrom-Induced Muon Events As Indicators Of Enso–Iod Driven Variability In Atmospheric Electricity.

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ABSTRACT

Ground-based cosmic-ray instruments offer a unique window into atmospheric processes by capturing rapid muon-flux responses to electrical activity embedded within deep convection. Among these signatures, thunderstorm-induced muon events (TIMEs) manifest as short enhancements or suppressions in muon intensity and trace the development of strong atmospheric electric fields. This study examines how the frequency of summer TIMEs recorded by the Ooty muon telescope from 2006–2024 varies with large-scale Indo-Pacific climate modes

The summer TIME catalogue, containing 1–18 events annually, reveals that several La Niña periods align with sustained intervals of elevated electrical activity. In contrast, El Niño and neutral phases show more irregular behaviour, suggesting that background convective conditions influence the formation of strong electric fields. TIME occurrences across both positive and negative IOD phases further indicate that atmospheric electrification is shaped by the combined, and often non-linear, ENSO–IOD interactions. Beyond their particle-physics relevance, TIMEs emerge as high-frequency indicators of convective intensity and atmospheric electricity within the monsoon domain. The observed climate-linked patterns highlight the value of cosmic-ray detectors as independent, physics-based probes for assessing variations in convective and electrical behaviour on interannual timescales.

Keywords: Thunderstorm-Induced muon events (TIMEs); Atmospheric Electricity; ENSO–IOD interaction; Cosmic-ray detectors; Muon telescope

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Global El Niño–Southern Oscillation Unravels the True ENSO-Monsoon Relationship

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ABSTRACT

The El Niño–Southern Oscillation (ENSO) has remained the single largest driver of predictability for Indian summer monsoon rainfall (ISMR) ever since Sir Gilbert Walker first discovered the ENSO–Monsoon relationship in the early 1920s. However, large epochal variations and a declining trend in their concurrent relationship have raised concerns about its robustness and the potential loss of ISMR predictability in a warming climate. In recent studies, we have shown that, unlike predictors based on concurrent regional sea surface temperature (e.g. Nino3.4), the depth of the 20 °C isotherm (D20) over the global tropical basin is a more effective estimator of ISMR predictability, revealing that ISMR is highly predictable ($r \approx 0.85$) up to two years in advance. To further validate the robustness of this relationship between ISMR and global ENSO, we trained a deep learning model on the observed relationship between ISMR and D20 at 18-month lead and used it to generate forecasts for 44 independent years (1980–2023). These forecasts are consistently skilful, confirming the predictive value of the global ENSO. Here, we deepen our understanding of the physical basis behind the high correlation between the D20- based predictor and ISMR at an 18-month lead, demonstrating that the D20-based predictor effectively captures the mixed temporal variabilities from the entire tropical basin that modulate ISMR predictability. Therefore, we re-examine the ENSO-ISMR relationship using the D20 based global ENSO predictor at 18-month lead and ISMR, and find that the relationship remains robust throughout the historical period. We also tested the relationship in simulations from an atmosphere–ocean general circulation model (AOGCM) developed for future climate projections under increased greenhouse gas forcing. Remarkably, the global D20– ISMR link remains persistently high even in future climate scenarios, underscoring its reliability as a long-lead predictor. Our findings establish a framework for a physically grounded ENSO– Monsoon relationship with significant implications for seasonal and decadal ISMR prediction.

Keywords: Global El Niño–Southern Oscillation, Indian summer monsoon rainfall, Deep Learning

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Historical Evaluation and Future Projections of Indian Ocean SST Using Multi-Model CMIP6 Simulations

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ABSTRACT

This study investigates sea surface temperature (SST) variability in the Tropical Indian Ocean (TIO) and evaluates the performance of CMIP6 models using both historical and future climate simulations. Monthly Optimum Interpolation Sea Surface Temperature (OISST) data at 0.25° × 0.25° resolution from January 1982 to December 2023 were utilised to analyse observed SST characteristics within 30°S–30°N and 30°E–120°E. ERA5 monthly 850 hPa U- and V-wind components were employed to assess associated atmospheric circulation patterns. Observational climatology reveals that the highest SST values are found in the eastern equatorial Indian Ocean. For regional analysis, the TIO is subdivided into the Arabian Sea, Bay of Bengal, West Equatorial Indian Ocean, Central Equatorial Indian Ocean, and East Equatorial Indian Ocean. Eight CMIP6 models—ACCESS-CM2, MIROC6, MRI-ESM2-0, MPI-ESM1-2-LR, EC- EARTH3-VEG-LR, EC-EARTH3, ACCESS-ESM1-5, and AWI-CM-1-1-MR—were selected based on their availability and relevance for the study regions, and evaluated using historical simulations for the period 1982–2014. Future SST projections were examined using three emission scenarios: SSP 126, SSP 245, and SSP 585 for the period 2015–2100. Comparison with OISST shows that ACCESS-CM2, MRI-ESM2-0, EC-EARTH3-VEG-LR, EC-EARTH3, and AWI-CM-1-1-MR best capture observed SST patterns and variability over the study regions. These findings provide a reliable basis for understanding historical SST behaviour and projecting future warming trends across the Indian Ocean under different emission pathways, which can be further integrated for future monsoon studies.

KEYWORDS: SST, CMIP6, Projection, Indian Ocean, OISST

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Impact of Sea Surface Temperature on Monsoon Thunderstorm Activity along the East Coast of India

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ABSTRACT

Spatial and temporal variability in thunderstorm activity during the Indian summer monsoon is significant and has important implications for regional precipitation patterns and extreme weather events. Sea surface temperature (SST) over the Bay of Bengal and Arabian Sea are known to be major modulators of atmospheric moisture availability and convective instability during the monsoon period. However, the quantitative relationship between SST anomalies and thunderstorm characteristics remains inadequately understood. The present study investigates the influence of SST variability and associated mechanisms on monsoon thunderstorm frequency and intensity using the integrated observational analysis and numerical modeling.

The research is focused on the monsoon-affected regions of India for more than a decade, which includes both active and weak phases of the monsoon during June-September. High-resolution SST data are analyzed to pinpoint the periods of warm and cool anomalies. The identification of thunderstorm events is detected from observations with thresholds such as rainfall >20 mm/day and higher values of Convective Available Potential Energy (CAPE). The Weather Research & Forecasting Model (WRF) model simulated the monsoon conditions through control runs, along with sensitivity experiments of +0.5°C and +1°C SST perturbations. The key parameters analyzed in this study are CAPE, moisture flux, vertical velocity, and surface energy fluxes. Statistical analyses include the correlation of SST anomalies with the metrics of thunderstorms. It is hypothesized that positive SST anomalies enhance the ocean-to-atmosphere moisture flux, which, in turn, are linked to increased frequency of intense thunderstorms due to enhanced atmospheric instability, whereas negative anomalies suppress convection. The expected outcome contributes to quantitative estimates of the contribution of SST to the variability in thunderstorms and elucidation of physical mechanisms that link ocean thermal conditions to monsoon convection, with implications for improved seasonal forecasting of extreme convective events.

Keywords: Sea surface temperature, monsoon thunderstorms, WRF model, CAPE, Bay of Bengal, ocean-atmosphere interaction

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Interaction of Urban-Plume and Sea-Land Breeze for studying Localized Convective activity during Monsoon Intraseasonal Oscillation

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ABSTRACT

The interaction between urban-induced thermal circulations and coastal sea-breeze systems plays a critical role in modulating the boundary-layer dynamics, air quality, and convective development over coastal megacities. This study investigates the reciprocity between the urban plume generated by the city's heat island effect and the sea-breeze circulation under contrasting large-scale conditions active monsoon, and break monsoon phases. During the active monsoon phase, strong large-scale southwesterlies suppress local sea-breeze development and reduce the influence of urban heating, resulting in lower boundary-layer heights and efficient pollutant ventilation. Conversely, in break monsoon conditions, weakened synoptic winds re-establish pronounced sea–land breeze circulations and restore strong Urban Heat Island (UHI)–sea breeze coupling, intensifying near-surface convergence and localized convective activity. This work aims in investigating how the background monsoon flow governs the degree of urban–sea breeze interaction, with significant implications for air quality, air pollution, convection initiation, and mesoscale predictability over coastal urban environments like Mumbai.

Keywords: UHI, Urban-Plume, Break Monsoon, Sea-Land Breeze,MISO

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Antecedent Land Surface State Influences Early Summer Monsoon Rainfall Over India

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ABSTRACT

The Indian Summer Monsoon Rainfall (ISMR), contributing nearly 80% of India's annual precipitation, plays a vital role in shaping agricultural productivity and socio-economic well-being. Although oceanic influences on ISMR variability are well documented, the role of land surface conditions remains less explored. In this study, a high-resolution (4 km) soil moisture and soil temperature (SMST) dataset for the period 1981–2017 is analyzed along with India Meteorological Department (IMD) rainfall and ERA-Interim reanalysis data to examine the influence of antecedent land surface states on monsoon variability. The analysis reveals strong spatial correspondence between monthly SM climatology and rainfall distribution. A decreasing trend in soil moisture during January–May is observed over central and northeastern India, while soil temperature exhibits a significant warming trend (~1.2 K) over northern and northwestern regions during February–May. These regions experience opposite trends (cooler soils and higher moisture) during June–July, suggesting strong land–atmosphere coupling. The results indicate that antecedent warm and dry soil conditions enhance the land–sea thermal contrast, favoring stronger monsoon circulation and increased rainfall, whereas wet and cool soils suppress it. Atmospheric diagnostics further show enhanced low-level moisture convergence over northwestern India during strong monsoon years. This study provides evidence of land surface feedbacks influencing monsoonal circulation, underscoring their importance for improving sub-seasonal to seasonal (S2S) predictability of ISMR.

Keywords: Indian Summer Monsoon Rainfall, Climatology, Antecedent soil Temperature

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Real-time subseasonal prediction of Indian monsoon 2022 with emphasis on east-west rainfall asymmetry

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ABSTRACT

The accurate subseasonal prediction of the spatio-temporal rainfall variability of the Indian summer monsoon holds immense socio-economic importance. During the 2022 monsoon, slightly above-normal rainfall was recorded across most regions of India, while below-normal precipitation was observed in the eastern parts, particularly over the IndoGangetic plains. In this study, the real-time performance of a recently developed multi-physics multi-ensemble (MPME) subseasonal prediction system is evaluated for its ability to predict the spatio-temporal rainfall variability during the 2022 monsoon. Subdued rainfall activity in June and an asymmetric rainfall distribution, characterized by a robust positive pattern over northwestern regions and a strong negative pattern over eastern and northeastern India in July and August, were reasonably reproduced by the MPME system. Additionally, the role of extra-tropical intrusions was investigated, focusing on the formation, propagation, and dissipation of West and East Asian blocking ridges, which were associated with the pronounced east-west rainfall asymmetry over India. The potential of the MPME system to forecast active and break spells 2–3 weeks in advance is demonstrated. The intra-seasonal oscillation (ISO) was identified as the dominant driver of rainfall variability during the 2022 monsoon, with the model exhibiting higher monsoon ISO (MISO) prediction skill in 2022 compared to its hindcast skill (2003–2018). Overall, the MPME prediction system was found to be skilful over most of the homogeneous regions of India up to a three-week lead time. However, decay in skill was noted beyond two weeks over smaller spatial domains, such as meteorological sub-divisions.

Keywords: Multi-physics, Subseasonal prediction, Monsoon, Active, MISO

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Melting Himalayan Glaciers And Their Influence On South Asian Monsoon Variability

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ABSTRACT

The Himalayan cryosphere, referred as the "Third Pole," has profound influence on the South Asian monsoon system by acting as an orographic barrier, which sustains the agricultural, ecological, and hydrological balance across the Indian subcontinent. The high-rise Himalaya modulates the southwesterly monsoon winds, compelling them to release moisture and thereby governing spatial and temporal rainfall variability. However, in recent decades, the region has experienced accelerated glacier melting which is driven by both natural climate variability and anthropogenic forcing. This rapid loss of snow and ice cover has initiated feedback processes that may alter the thermal contrast between land and ocean, surface albedo, and large-scale atmospheric circulation, which act as key determinants of monsoon dynamics. In this study, multiple glacier-related parameters, including snow cover extent, snow depth, snowmelt-induced runoff, snow evaporation, and surface albedo, are studied to assess cryosphere changes and their influence on the regional monsoon system. The analysis focuses on pre-monsoon and monsoon months to evaluate temperature trends, precipitation variability, wind circulation, and vertical moisture fluxes. The findings underscore a strong linkage between Himalayan glacier retreat and evolving monsoon behavior through ice-albedo feedback mechanisms and disrupted moisture transport pathways. These interactions are found to influence the timing, intensity, and spatial distribution of monsoon rainfall. The study highlights the critical role of topography in governing moisture flux convergence and vertical motion over the region.

Keywords: Himalayan glaciers, monsoon variability, ice-albedo feedback

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Spatial variations of air-sea heat fluxes over the North Indian Ocean

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ABSTRACT

To observe the spatial variations of Air-Sea Heat Fluxes (ASFs) over the North Indian Ocean (NIO), this study has been undertaken. For this, monthly high resolution (0.25°×0.25°) Surface Latent Heat Flux (SLHF) and Surface Sensible Heat Flux (SSHF), 10 m wind speed (WS), Sea Surface Temperature (SST), 2-m air temperature and dew point temperature and surface pressure data for the period 1979-2022 have been obtained from ERA5. The spatial pattern of SLHF and SSHF across the NIO and its subregions show significant spatial heterogeneity. The broad sub-regions of the NIO namely, the BoB and the AS show different heat fluxes. The SLHF over the AS is higher than the BoB with a maximum over SWA, near the Gujarat and Maharashtra coasts, around Sri Lanka and a minimum along the Arabia coasts. On the other hand, the SSHF is higher over the BoB than the AS with a maximum over the Andaman Sea, the SEB, ECB, and the SEA and a minimum along the Somalia and Arabia coasts. Similarly, the variations of bulk parameters can also be observed across the NIO and its sub-regions. The BoB shows a higher sea-air temperature gradient than the AS with a maximum over the Andaman Sea, the SEB, the ECB, and the SEA and a minimum near the coasts of Arabia and Somalia. Likewise, the AS shows higher WS and sea-air specific humidity gradient than the BoB with maximum WS in the WCA and SWA and maximum specific humidity gradient near the coastlines of Gujarat and Maharashtra, as well as over the SEA, NWB, and coastal regions of North and South Andaman Sea. The spatial pattern of SSHF closely follows the pattern of the sea-air temperature gradient, whereas the spatial pattern of SLHF is more complex and depends on both WS and specific humidity gradients.

Key Words: SLHF, SSHF, NIO, BoB, diurnal variation

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Large-Eddy Simulation Of Extreme Rainfall Event Of Miso-Bob.

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ABSTRACT

Bay of Bengal (BoB) plays a crucial role in influencing the South Asian Monsoon through several key factors including warm Sea Surface Temperature (SST), high oceanic heat content, ocean salinity and density variation. These features along with the atmospheric dynamics modulate the convective development. In this study, we use the high-resolution WRF model simulations to investigate an extreme convective event over the BoB region. The model simulations are carried out at a high horizontal resolutions of 900m, 300m and 100m (for the three-domain structure) and uses the hourly European Centre for Medium Range Weather Forecast Reanalysis v5 (ERA5) reanalysis data for initial and boundary conditions. The model simulations were validated against the observational data from Integrated Multi-satellite Retrievals for the Global Precipitation Measurement mission (IMERG), ERA5, Air Sea Interaction Regional Initiative (ASIRI), and Monsoon Intra-Seasonal Oscillations in the Bay of Bengal (MISO-BoB) observational campaign. In particular, the MISO-BoB in-situ observations provide high-quality atmospheric and ocean measurements. These observations formed the background used to analyse the factors contributing to convective triggering of the extreme rainfall event on 9–10 June 2018. The study also aims to calculate the models skill in capturing the extreme event over the time of 9-12th June,2018. Our preliminary results show great correlation between the model simulated precipitation and the IMERG observation suggesting that the model successfully captures the intensity of the event.

Keywords: Bay of Bengal (BoB), Sea Surface Temperature (SST), Weather Research Forecast (WRF), Extreme event, Monsoon Intra-Seasonal Oscillations(MISO)

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Qualitative Assessment of High-Resolution Gridded Precipitation Products against Ground based Rain-gauge Network

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ABSTRACT

High-resolution precipitation estimates play a crucial role in hydrological and climate-related applications. In recent years, number of global and regional gridded precipitation products have been developed, offering diverse spatial and temporal resolutions. Selecting the most suitable dataset for a given application requires rigorous evaluation against ground-based observations. Karnataka, a southern state in India, with its dense rain-gauge network and large spatial variability in summer monsoon rainfall, provides an ideal testbed for evaluating such products. This study evaluates six high-resolution precipitation products PERSIANN-CCS (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks – Cloud Classification System), CHIRPS (Climate Hazards Center Infrared Precipitation with Station data), MSWEP (Multi-Source Weighted Ensemble Precipitation), IMERG (Integrated Multi-satellitE Retrievals for GPM), AgERA5 (Agroclimatic version of ERA5), and GSMaP_ISRO (Global Satellite Mapping of Precipitation Indian Space Research Organisation version) for daily precipitation during the Indian summer monsoon for the period 2011–2022 against ground based rain-gauge observations. A climate network approach was used to qualitatively assess these products by constructing rainfall correlation networks. A nonlinear measure event synchronization was used to quantify the co-occurrence of extreme rainfall events. While most products captured broad monsoon patterns, significant variations were found in their ability to reproduce intensity categories and extreme event structure. Results show that GSMaP_ISRO most accurately reproduces observed spatial rainfall coherence, degree distribution of network, and extreme event synchronization, especially over the Western Ghats (WG) and central–south interior Karnataka. PERSIANN-CCS and CHIRPS exhibit lower agreement with observations in the WG, with CHIRPS and AgERA5 overestimating spatial coherence, likely due to interpolation effects. The findings highlight GSMaP_ISRO's suitability for hydrological and climate studies in monsoon-affected regions, particularly in complex terrain. Future improvements should target sub-daily resolution and localized estimates to better capture convective rainfall dynamics in complex orographic regions.

Keywords: Remote Sensing, Satellite Products, Gridded Products.

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Investigation on Surface Mixed Layer Processes During Cold Pool Events

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ABSTRACT

Cold pool events in the Southern Bay of Bengal represents a dominant feature of the monsoon-season upper-ocean structure, marked by pronounced sea surface cooling and strong air-sea coupling. Understanding the processes governing this cooling is essential for improving predictions of regional monsoon variability, convection, and cyclone genesis. This study investigates the mixed layer thermal dynamics during cold pool formation using high resolution ocean reanalysis from Copernicus Marine Environment Monitoring Services (CMEMS), complemented by atmospheric flux reanalysis. Mixed layer temperature, currents, and stratification fields are used to diagnose the mixed layer heat budget and quantify the contributions from surface heat fluxes, horizontal advection, and entrainment at the base of the mixed layer. Results show that the onset of cold pool events is primarily driven by enhanced latent heat loss and reduced shortwave radiation, leading to rapid surface cooling. Horizontal advection by monsoon-driven currents further intensifies the cooling by transporting colder waters from the eastern Bay, while periods of mixed layer deepening indicate active entrainment of subsurface cool water. The relative importance of these processes exhibits strong intraseasonal variability linked to monsoon wind bursts and basin scale circulation changes. The integration of CMEMS ocean reanalysis with surface flux datasets provides a robust framework for evaluating mixed layer dynamics across diverse cold pool events. The study improves understanding of the key physical processes shaping cold pool evolution and demonstrates the capability of reanalysis systems to capture upper-ocean thermal variability in this region.

Keywords: Cold Pool, Mixed Layer Heat Budget, Ocean-Atmosphere Interaction, Entrainment, Surface Heat fluxes

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Performance of IOLA model in simulating Monsoon Depressions

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ABSTRACT

Monsoon depressions are one of the most important synoptic-scale systems of the Indian Summer Monsoon. They form mostly over the Bay of Bengal and travel west-northwestward, bringing widespread rainfall and often causing flooding across central and eastern India. Because these systems contribute nearly half of the monsoon-season heavy rainfall, their accurate prediction is essential for agriculture, disaster management, and early warning systems.

The Indian Ocean–Land–Atmosphere (IOLA) coupled mesoscale model is a new high-resolution prediction framework designed to simulate a wide range of severe weather events in the Indian region. Built on the NMM dynamical core with advanced HWRF nesting and ocean coupling capabilities, IOLA can use 1–2 km moving nests to automatically follow monsoon depressions and resolve their structure in detail. This study evaluates the performance of IOLA in simulating **eleven monsoon depressions** using doubly nested domains (3 km and 1 km), and compares the forecasts against IMD best-track data and GPM rainfall observations.

IOLA demonstrates strong skill in simulating the tracks of monsoon depressions. The average direct position error is about **70 km at 6 hours** and only **125 km at 72 hours**, which is significantly smaller than errors reported in earlier WRF studies. Near-surface wind speeds are overestimated during early forecast hours but gradually improve by 48–72 hours.

Rainfall evaluation shows that IOLA captures the asymmetric structure of monsoon depression rainfall, including the southwest-sector enhancement.

Overall, this study shows that IOLA has promising capability in predicting monsoon depressions, especially their track, structure, and rainfall distribution. Future improvements in vortex initialization, data assimilation, and physics options are expected to further enhance the model's performance.

Keywords: Monsoon depression, IOLA coupled model, Track forecast, Rainfall skill, High-resolution nests, Indian monsoon.

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Impact of Global Warming-Induced variabilities of Mascarene and Tibetan Highs on the regional distribution of Indian Summer Monsoon in NorthWestern India

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ABSTRACT

Global warming has profoundly altered key semi-permanent features of ISM—namely, the Mascarene Highs and the Tibetan Highs (ISM). These features are known to modulate ISM variability, particularly over northwestern India. This study examines the spatial and temporal variability of these semipermanent features since the pivotal 1998 climate shift, with a focus on their coupled influence on ISM variability in northwestern India. Using reanalysis datasets, we analyze trends in mean sea level pressure, core migration of the highs, and associated changes in wind and moisture fluxes. Results highlight a pronounced weakening and systematic eastward shift of the Mascarene High, concurrent with evolving patterns of the Tibetan High, including notable westward displacement and increased surface pressure. These atmospheric reorganizations have fundamentally restructured the cross-equatorial and upper-level circulation, amplifying month-to-month rainfall variability and the frequency of extremes across northwestern India. Multivariate correlation analysis further reveals that these changes are inextricably linked to intensified ocean warming and the dynamics of the highs, and are also influenced by rapidly depleting sea-ice thickness in the Indian Ocean sector, implying growing cryospheric control of ISM variability. This interconnection underscores the importance of integrated land-ocean-cryosphere-atmosphere perspectives for predicting future monsoon behavior and crafting effective climate adaptation strategies in a rapidly warming world.

Keywords: Mascarene Highs, Tibetan Highs, ISM, Climate Shift, Sea-Ice

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Non-uniform Changes in Moisture Flux over India: Role of Altering Land-Ocean Thermal Contrast in Recent Decades

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ABSTRACT

This study examines the changes in the linear trends of the precipitable water content (PWC) associated with the Indian summer monsoon rainfall using the ERA-5 datasets. The study period of 63 years (1959-2021) is divided into two time periods: P1 (1959-2001) and P2 (2002-2021). In the recent period (P2), we observe a significant rise in the statistically significant linear trend of the mean JJAS PWC, resulting in a significant positive difference between P2 and P1 over most of India. This change is found to be largest in the middle troposphere, where the rotational component of the moisture flux is strengthened in P2 relative to P1. This modulation is attributed to the non-uniform rate of change of tropospheric air temperature in the lower and middle troposphere in P2 from the rising land-ocean thermal contrast. This results in stabilizing the atmosphere. Consequently, we also observe an increase in the fraction of stratiform precipitation in P2 relative to P1. This increase in stratiform precipitation is associated with enhanced mid-atmospheric diabatic heating and mid-tropospheric southwesterly moisture flux, which enhances PWC in P2 compared to P1.

Keywords: Moisture Flux, Indian Summer Monsoon, Moisture Transport, Climate Change

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Prediction of Rainfall over Coastal Karnataka Using a Multivariate Deep Learning Approach

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ABSTRACT

In this study various deep learning approaches are being implemented to predict the monsoon rainfall over the coastal Karnataka region in India. Using 100 years of IMD observed rainfall data and the associated parameters like Sea Surface Temperature, land surface temperature, sea level pressure etc. the models are being trained, tested and validated using the statistical techniques. The ensemble approaches of combining the Long Short-Term Memory (LSTM) and Efficient Linear Support Vector Machines (ELSVM) are seems to be predicting the rainfall accurately over the coastal Karnataka. This study indicates that much more scope is there to use the DL in the prediction of the regional rainfall and associated parameters thereafter.

Keywords: LSTM, Prediction, Rainfall, Coastal Karnataka

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Four Decades of Marine Heatwaves and Sea Surface Temperature Variability Over the Indian Ocean Basin (1982–2024)

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ABSTRACT

This study examines long-term changes in sea surface temperature (SST) and marine heatwave (MHW) patterns in the Indian Ocean, with a focus on the Arabian Sea (AS) and the Bay of Bengal (BoB). The analysis uses NOAA's high-resolution (0.25° × 0.25°) daily SST data from 1982 to 2024. MHW events were identified using the 90th percentile thresholds, following standard climate guidelines. The results show a clear warming trend across the region, with SST rising more quickly after the early 2000s. Hotspot analysis points to the central Indian Ocean and northern AS as areas with the most intense warming. MHWs have become more frequent and last longer, especially after the monsoon and during winter, with the AS warming faster than the BoB. Monthly and seasonal data show that warm-season MHWs are now more common than in previous decades. ENSO-based analysis shows that El Niño years increase MHW activity across most of the basin, while La Niña years reduce it in the eastern Indian Ocean but increase it in the AS. Over time, the number of annual MHWs has risen across the basin, matching the overall warming trend. These results highlight that the Indian Ocean is becoming more vulnerable to extreme heat, which could affect monsoon patterns, marine life, and the region's climate resilience.

Key words: Sea Surface Temperature (SST); Marine Heatwaves (MHW); Indian Ocean; Arabian Sea; Bay of Bengal

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Analysis and forecasting of SST and Indian Summer Monsoon Rainfall

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ABSTRACT

This study examines the use of advanced machine learning and deep learning approaches for analysing the trends and predictiong the sea surface temperature (SST). The SST is then used for the prediction of Indian Summer Monsoon Rainfall patterns. Comparison of algorithms like Long Short Term Memory (LSTM), Bi-directional LSTM (BiLSTM) and Convolution 1D LSTM (Conv1DLSTM) are utilised for the prediction of SST and Rainfall. Long term data for 40/100 year period are bein g utilised in the SST/rainfall prediction.The statistical analysis like Root means square error (RMSE), Mean absolute error (MAE), Coefficient of Determination (R^2), are estimated to assess the robustness of the ML/DL models used in the study. The results show that the DL model are good in predictiong the SST as well as rainfall at high degree confidence level.

Keywords: ISMR , SST, ML, DL , LSTM, Prediction

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Diurnal Influence of Surface Temperature on Evaporation: An Experimental Study

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ABSTRACT

As climate change accelerates and the hydrological cycle intensifies, accurately quantifying oceanic evaporation has become critically important. Evaporation is a physical process primarily driven by two components, an energy supply to provide the heat of vaporization and a transport mechanism to remove vapour. The amount of evaporation is commonly estimated using the bulk aerodynamic formula, which is widely employed in many climate models. In this formulation, the heat of vaporization is influenced by incoming radiation, surface temperature, and atmospheric wind speed, which are key factors that govern the efficiency of moisture transfer. However, the bulk formula is known to exhibit large biases, particularly under low wind conditions. Therefore, it is important to validate the formula under controlled environments, which has been done in this study. The present study focuses on the effect of surface temperature by performing a series of laboratory experiments at low to zero wind scenarios. These experiments were carried out using a small water tank in which the surface temperature was actively controlled by an infrared heater, while the amount of evaporation was measured using a siphon-based mass-loss method. Under steady heating conditions, the results reveal a four- thirds power dependence of the temperature difference between the surface and the air in its immediate proximity. Another major aspect of surface temperature is its diurnal variation, which we reproduced by varying the incoming radiation to follow a bell-shaped curve, creating a controlled analogue of daytime heating and night time cooling. The resulting evaporation rate exhibited a clear and repeatable diurnal pattern. Overall, these findings provide new insight into how surface temperature regulates evaporation and identify conditions under which the bulk aerodynamic formula could be improved.

Keywords: Evaporation, Bulk formula, diurnal cycle, surface temperature.

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Assessing the Monsoon Dynamics in the Indian Himalaya Region

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ABSTRACT

The Indian Summer Monsoon (ISM) variability is observed to be high in the recent decade over the Indian Himalayan Region (IHR) including the rise in monsoon extremes over the hilly region. This study is an attempt to assess the influence of global as well as local physical and thermodynamical processes in the monsoon flow. The El Niño–Southern Oscillation (ENSO) is the main factor for the monsoon rainfall so in this study ENSO-SST impact on the rainfall over the regional scale (i.e., IHR) are being quantified using the long-term multi-source data. The relation clearly reveals the SST and monsoon extremes are in direct relation. The regional land use land cover analysis also indicates the direct impact on the monsoon variability including the periodicity and frequent hydro-meteorological disasters over the mountainous region. This study will also open a way for more understanding on the regional studies for the better prediction of the disasters and management accordingly.

Keywords: ISMR, Monsoon variability, Indian Himalayan Region, ENSO

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Spatio-Temporal Patterns of ISMR in Relation to ENSO and IOD Phase Interactions (1994–2023) by using ML

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ABSTRACT

The Indian Summer Monsoon Rainfall (ISMR) plays a central role in India's climate and economy, yet it exhibits significant interannual variability influenced by large-scale ocean-atmosphere interactions. This study presents a detailed spatio-temporal analysis of ISMR from 1994 to 2023 under various phases of the El Niño–Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). Utilizing high-resolution gridded rainfall datasets, sea surface temperature indices (Niño 3.4 and DMI), and predictive models (SARIMA and LSTM), we investigate how isolated and overlapping ENSO–IOD events impact monsoon rainfall across India. Our results show that El Niño generally suppresses rainfall, especially when coupled with a negative IOD, while La Niña and positive IOD events enhance rainfall in central and coastal India. LSTM models demonstrated superior skill in forecasting ENSO indices compared to SARIMA, highlighting the potential of deep learning in climate prediction. The findings emphasize the need to consider compound oceanic influences to understand and predict regional rainfall anomalies and associated extremes like floods and droughts.

Keywords: ISMR: Indian Summer Monsoon Rainfall, ENSO: El Nino Southern Oscillation, IOD: Indian Ocean Dipole, LSTM: Long Short Term Memory, SARIMA: Seasonal Auto Regressive Integrated Moving Average

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Modulation of Indian Summer Monsoon Extreme rainfall trend by global warming hiastus

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ABSTRACT

This study examines the long-term evolution of extreme rainfall events associated with the Indian summer monsoon (ISM) during 1950–2024, with a particular focus on contrasting the pre-hiatus and post-hiatus phases of global warming. Daily gridded rainfall observations from the India Meteorological Department (IMD) and global sea surface temperature (SST) fields from HadISST are analysed to investigate the trends of the frequency of extreme rainfall during pre and post hiatus period in the global warming. The results reveal a statistically robust increase in the frequency of extreme rainfall days over central India during the pre-2000 period, whereas this upward trend weakens and changes it's sign during the post-2000 (global warming-hiatus) period. However after although global SST shows warming trend after 2012 but the frequency of ISMR extreme kept declining. Furthermore, significant positive correlations between SST anomalies and extreme rainfall occurrence during the pre hiatus period highlights the role of large-scale oceanic conditions in modulating Indian monsoon extremes. However during and after the global warming hiatus this correlation weakend. The same has been also observed for Pacific and Indian ocean SSTs. This highlights a major shift in the teleconnection patterns between SST and ISMR extremes post 2000.

Keywords: ISMR extremes, global warming, global warming hiatus, teleconnection

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How The Antarctic And Arctic Oscillations Influences The Indian Summer Monsoon Variability Across Qbo Phases

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ABSTRACT

The Asian Monsoon system is majorly dominated by the Indian Summer Monsoon Rainfall (ISMR), which plays a crucial role in the socioeconomic stability of India making it essential to understand its variabilities for improving seasonal predictions. This study investigates the impact of Arctic Oscillation (AO) and Antarctic Oscillation (AAO) on ISMR, under the influence of the phases of Quasi Biennial Oscillation (QBO) in the tropical stratosphere and its connection. Using a 64-year dataset (1953-2016) monthly AO, AAO indices and QBO zonal wind anomalies for 50hPa, normalized ISMR index for the JJAS season were analysed. The study showed a significantly strong positive concurrent correlation between the AO and ISMR especially during the westerly phases of QBO. As an impact of the positive AO, reduction in Eurasian snow leads to warmer Eurasia, thereby causing a stronger monsoon. The impact continues in the post monsoon season, suggesting a broader atmospheric coupling between high latitude circulation and Indian monsoon. Wherein, AAO showed a rather predictive influence, with an enhanced correlation during the pre-monsoon season; strongest during the westerly phase of QBO. Strong negative AAO anomalies corresponds to a strengthened Mascarene High leading to drought like monsoon whereas an extreme positive AAO is responsible for more than normal ISMR. The overall highlight of the study shows that QBO modulates the strength and nature of Indian monsoon. The concurrent correlation of the AO and predictive correlation of the AAO governs the variability of ISMR. The AO-AAO-QBO together represents a significant coupled mechanism which enhances and improves predictability and forecast skill of ISMR.

Keywords: Indian Summer Monsoon Rainfall, Arctic Oscillation, Antarctic Oscillation, QBO, monsoon predictability.

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Understanding Large Excess rainfall over India in September 2019

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ABSTRACT

Comprehensive understanding of the spatial and temporal variability of Indian summer monsoon (ISM) rainfall is critically important—not only for advancing scientific prediction capabilities, but also for supporting effective water resource management, agricultural planning, and national economic policy. In particular, the intra-seasonal variability (ISV) of the ISM exhibits pronounced spatial and temporal fluctuations, which plays a pivotal role in shaping the nature and evolution of the monsoon.

All-India September 2019 rainfall was 152% of its long-period average, as reported by the Indian Meteorological Department. The daily All India as well as the Core Monsoon Zone (CMZ) rainfall was above normal throughout September 2019, except for a couple of days. Initial results indicate that rainfall over the CMZ and the Bay of Bengal (BoB) was in phase, except during the last week of September. A large active spell of rainfall occurred from 6–8 September, followed by another very active spell during 22–30 September over CMZ, whereas the BoB experienced a pronounced break spell during the last week of September 2019. Positive Indian Ocean Dipole (IOD) event of 2019 is one of the strongest in recent decades, that occurred alongside a weak El Niño. The IOD is widely recognized as a significant driver of the ISM. This study aims to diagnose the possible causes of the enhanced rainfall during September 2019 over India and the marked contrast in rainfall between the CMZ and the BoB at the end of September. The results highlight the likely influence of the IOD and midlatitude circulation in the upper troposphere.

Keywords: Indian Ocean Dipole, Bay of Bengal, intraseasonal variability, monsoon rainfall.

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Spatial and temporal variability of the submarine groundwater discharge in the Indian Ocean

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ABSTRACT

The Submarine groundwater discharge (SGD) delivers subsurface fluids and nutrients from land to the coastal ocean, strongly influencing coastal ecosystems and reef biogeochemistry and significantly alters coastal nutrient budgets. The Sr isotopes, unaffected by biological processes, offer a reliable tracer for assessing these inputs. The high precision Sr isotope composition ($^{87}Sr/^{86}Sr$) was measured in the coastal surface water of the Gulf of Mannar, Palk Bay, and Grande Island, Goa, and in a 30- year-old coral sample. The $^{87}Sr/^{86}Sr$ of the Palk Bay shows 0.709165 to 0.709220, whereas the Gulf of Mannar surface water shows a range from 0.709150 to 0.709237. The water sample collected from the Rameshwaram Island exhibits radiogenic Sr composition, i.e., 0.709237 to 0.709349, relatively higher compared to the coastal surface water samples. Samples collected along the Grande Island exhibit two endmember mixing trends on $^{87}Sr/^{86}Sr$ vs salinity plot between the seawater and groundwater seeping along the coast. The chronology of the live coral samples collected in the Gulf of Mannar and the Palk Bay was derived from X-ray images highlighting annual high- and low-density skeletal bandings. The coral shows variation in its Sr isotopic ratio from 0.709157 to 0.709228. The strontium isotopic composition of the coral bands deviates from the homogeneous $^{87}Sr/^{86}Sr$ ratio characteristic of the open ocean. Monsoonal variability drives annual shift in the corals $^{87}Sr/^{86}Sr$ composition through the supply of radiogenic Sr of continental origin through submarine groundwater discharge during enhanced monsoon.

Key Words: SGD, Coral, $^{87}Sr/^{86}Sr$, Indian Monsoon

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Influence Of Triple- Dip La Nina On Indian Summer Monsoon Rainfall

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ABSTRACT

A Triple-dip La Niña (TDL) refers to the occurrence of La Niña conditions over the eastern equatorial Pacific for three consecutive years. Since the 1950s, four such events have been documented including the events of 1954-1956,1973-1975,1998-2000 and 2020-2022. This study investigates the mechanisms contributing to the prolonged nature of TDL episodes and its influence on the Indian Summer Monsoon Rainfall (ISMR). Despite limitations in data availability, several key oceanic and atmospheric parameters were analysed, and a detailed year-wise assessment was performed to highlight the distinct characteristics of each event.The analysis shows that all TDL events were initialized by the preceding year's El Niño, which helped in sustaining the multi-year event. Notably, variations in La Niña intensity were observed within each TDL episode, including periods of near-neutral conditions during the middle year, followed by a re-strengthening in the final year. The presence of negative Indian Ocean Dipole(IOD) was also observed during the last year of the events.TDL showed varying responses with ISMR during each summer, which was different from the expected outcome..As the likelihood of such events may increase in the future , understanding these phenomenon is relevant.

Keywords: Triple dip La Niña (TDL), Indian Summer Monsoon Rainfall(ISMR), Indian Ocean Dipole (IOD),El Niño, eastern equatorial Pacific.

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Regional Contrast in Flux Estimation: Arabian Sea and Bay of Bengal

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ABSTRACT

The estimation of air-sea flux is an essential component in understanding the regional climate processes. Their performance has not been consistently evaluated across diverse environmental conditions. This study evaluates five commonly used bulk flux parameterizations—Andreas, COARE3p0, COARE3p6, ECMWF, and NCAR—over the Arabian Sea and the Bay of Bengal, two climatically important basins of the northern Indian Ocean that influence monsoon circulation, regional moisture transport, and air–sea exchanges of heat and momentum. The analysis focus on Latent heat flux (LHF), sensible heat flux (SHF), and momentum flux (Tau) . The model outputs have been compared against observations to assess variability, consistency, and biases under varying wind speeds, humidity differences, and air–sea temperature contrasts. Initial results show distinct differences among the parameterizations, with notable regional contrasts between the Arabian Sea and Bay of Bengal due to their differing thermal and dynamic environments. The findings highlight the strengths and limitations of each scheme and demonstrate that the choice of parameterization strongly affects the reliability of air–sea flux estimates, with implications for improving weather forecasts and climate simulations in the Indian Ocean region.

Keywords: Air-sea flux, Bulk parameterization, Latent Heat FLux, Sensible Heat flux, Mommentum Flux

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THE SPACE-TIME ATMOSPHERIC AEROSOL VARIABILITY & IMPACT ON SUMMER MONSOON OVER EASTERN UTTAR PRADESH

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ABSTRACT

An attempt has been made in this study to identify variability of major atmospheric aerosols such as carbon monoxide (CO), tropospheric ozone (O_3) and Ultraviolet (UV) absorbing particles over Eastern Uttar Pradesh to examine how the aerosol influences the monsoon rainfall over the region during 2019-2024. This study analysed the aerosol-trace-gas products taken from the sentinel-5P (TROPOMI) and CHIRPS precipitation dataset for May to October months. We have observed that CO and UV Aerosol Index (UV-AI) indicate significant peak during the month of May and October. This implies that, the regions have huge biomass burning and industrial activity. The findings also show remarkable level of Ozone that increased over the southwestern districts of EUP prior to the onset of monsoon. On the other hand, decrease in ozone level during monsoon season is may be due to reduce in photochemical activity of that period. An indirect relationship follows between accumulation of aerosols and rainfall occurrence for core monsoon month(July-August). The reason behind this may be due to pronounce concentration of aerosols resist occurrence of rainfall. It indicates that region may experience lack of water and have impacts on agriculture activity.

Keywords: Monsoon, Sentinel-5P, CHIRPS, Aerosol.

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To investigate the role of Ocean subsurface processes during Dependent and Independent IOD events.

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ABSTRACT

The Indian Ocean Dipole (IOD) is one of the most dominant modes of interannual climate variability that strongly influences the Indo-Pacific climate system. It is identified by the contrast pattern of Sea Surface Temperature anomaly (SSTA) over the Tropical Indian Ocean (TIO). While many studies reveal the IOD events that co-occur with the El Niño-Southern Oscillation (ENSO), the process of independent IOD evolution remains less explored. This study examines the ocean-atmospheric processes linked to the Independent IOD events, with a primary focus on subsurface variations in the Indian Ocean (IO) and the Pacific Ocean (PO). Such an investigation is essential for understanding monsoon activity over the Indian continent. The composite maps of the SST and 10m wind anomaly during various stages of the IOD showed that both dependent and independent IODs have differences in temporal evolution and their triggering mechanisms.
Additionally, we examine the upper ocean heat content (0-300m), thermocline depth (D20), mixed layer depth (MLD), and surface downward heat flux. Our results show that during the positive Independent IOD event, thermocline (D20) shoaling in the eastern equatorial IO is accompanied by stronger surface winds during the May-June months. In contrast, the western equatorial IO exhibits a deepening of D20 and an increase in 300m heat content, indicating strengthened ocean heat convergence the MLD variations amplify these subsurface signals. Overall, the study highlights that pure IOD events have distinct subsurface and surface signatures, which differ from dependent IOD events, emphasizing the need to treat Independent IOD events as a separate category in climate diagnostics and prediction.

Key Words: Indian Ocean, El Nino-Southern Oscillation, Sea surface Temperature, Monsoon, Thermocline.

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Dynamics Of Dissolved Nutrients (Din, Doc, And Dsi) In The Regulated Sharavati River Of The Western Ghats And Fluxes To Arabian Sea With A Focus On Monsoon Influences.

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ABSTRACT

This study assesses the seasonal fluctuations and fluxes of dissolved inorganic nitrate (DIN), dissolved organic carbon (DOC), and dissolved silica (DSi) in the Sharavati River basin, Western Ghats, and their export to the Arabian Sea. DIN were highest during the cyclone-enhanced monsoon conditions, reflecting surface runoff and agricultural inputs, while pre-monsoon concentrations were lowest owing to reduced discharge and intensified denitrification. DOC exhibited distinct seasonal variation, with maximum concentrations in pre- and post-monsoon (up to 5.66 mg L^{-1}) resulting from forest-litter leaching, redistribution of soil organic matter, and the impact of cyclonic activity; in contrast, monsoon levels dropped markedly due to strong dilution. DSi concentrations were highest upstream (27 mg L^{-1} in pre-monsoon 2019) due to intense silicate weathering, but declined downstream under the influence of damming, biological uptake, and dilution. The estimated annual fluxes to the sea were 1,966 t yr^{-1} for DIN, 6,610 t yr^{-1} for DOC, and 36,000 t yr^{-1} for DSi. Relative to other west-flowing rivers of India, the Sharavati displayed lower DIN and DOC fluxes (65 and 104 kg km^{-2} yr^{-1}, respectively), consistent with its largely forested catchment, while its DSi flux (753 kg km^{-2} yr^{-1}) was moderate, shaped by lithology and reservoir regulation. These findings underscore the role of monsoonal effect enhanced by cyclones and damming in controlling nutrient and carbon export. Continuous monitoring of DIN, DOC, and DSi is essential to improve high-resolution datasets for global biogeochemical models and to assess ecosystem responses in the Arabian Sea.

Keywords: Nutrients, Arabian Sea, Monsoon, Dams, River

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Analysis And Evaluation Of The Radius Of Maximum Wind Over The North Indian Ocean Using The Wrf Model, And Assessment Of The Precipitation Intensity Over Eastern Uttar Pradesh.

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ABSTRACT

The objective employs the Weather Research and Forecasting (WRF-ARW) model to evaluate the sensitivity of cloud microphysical techniques in modeling tropical cyclone RMW across the NIO. Two recent Extremely Severe Cyclonic Storms (ESCS), Mocha over the Bay of Bengal and Biparjoy over the Arabian Sea, were investigated. Simulations were conducted using six microphysics schemes: Lin, Goddard, Thompson, WDM6, WSM6, and WSM3. The results demonstrate a considerable difference in the simulated wind field structure based on the microphysics setup. When compared to the IMDAA datasets, Goddard and WSM6 generated the most accurate cyclone paths and intensities, as well as realistic RMW estimations. WSM3 regularly performed poorly, with low wind speeds and disordered storm cores. These findings underscore the critical role of microphysics parameterization in cyclone intensity measures, as well as the need for an appropriate scheme selection to improve cyclone predictions in the NIO area. In addition, the Study includes an examination of precipitation linked to ESCSs that formed over the Bay of Bengal in the pre-monsoon and post-monsoon seasons, focusing specifically on their possible effects on rainfall in eastern Uttar Pradesh. Spatial and temporal distribution of cyclone-induced precipitation will be examined using IMD gridded rainfall observations and IMDAA reanalysis datasets.

Keywords: Tropical cyclones, RMW, WRF, Eastern Uttar Pradesh

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Satellite-Based Assessment Of Urban Heat And Its Teleconnected Links To Climate Indices Across Three Major Indian Coastal Cities

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ABSTRACT

Coastal cities undergo distinct interactions between land and ocean processes that affect their thermal conditions. This study will examine long-term Urban Heat Island (UHI) patterns in three Indian coastal smart cities: Panaji, Thiruvananthapuram, and Vizag, covering the east and west coast of India, utilizing multi-temporal satellite observations. MODIS-derived Land Surface Temperature (LST) is employed to assess temporal variations in surface warming from 2002 to 2024, while Landsat imagery provides high-resolution context for land-use and land-cover changes, as well as vegetation dynamics (NDVI), across the same timeframe. Furthermore, coastal Sea Surface Temperature (SST) derived from MODIS-Aqua is analyzed to investigate potential correlations between ocean thermal dynamics, neighboring urban temperature trends, and climate indices. By combining regional LST time-series with localized Landsat indicators of urban expansion and vegetation change, the study aims to characterise temporal UHI behaviour across diverse coastal settings and provide a baseline for climate-sensitive urban planning. The findings will inform strategies for thermally resilient and sustainable coastal smart city development in India.

Keywords: Urban Heat Island, MODIS, Landsat, Sea Surface Temperature, NDVI, Coastal Smart Cities

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Enhanced Simulation Of Indian Summer Monsoon Rainfall And Ocean-Atmosphere Interactions In Cmip6 Compared To Cmip5 Models

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ABSTRACT

This study assesses the performance of CMIP5 and CMIP6 climate models in simulating the Indian Summer Monsoon Rainfall (ISMR) and its teleconnections with sea surface temperature (SST) over the Indian Ocean during 1975-2005. Multiple observational datasets are used to evaluate model fidelity using correlation coefficients, root mean square error (RMSE), Taylor statistics, skill scores, and rainfall distribution analyses. Results show that CMIP6 models exhibit substantial improvements over CMIP5 in reproducing the spatial structure of ISMR, particularly over the Western Ghats, Central, and Northeastern India. The CMIP6 multi-model ensemble (MME) attains a stronger correlation with observations (0.86) compared to CMIP5 (0.68). Empirical Orthogonal Function (EOF) analysis reveals that CMIP6 more realistically captures dominant modes of monsoon variability, with the leading EOF explaining ~59.7% of total variance. Furthermore, CMIP6 better represents SST–rainfall teleconnections across the Arabian Sea, Bay of Bengal, South China Sea, and Southern Indian Ocean, along with improved simulation of large-scale circulation features such as the low-level jet (LLJ) and tropical easterly jet (TEJ). These findings underscore CMIP6's enhanced capability to simulate complex land- ocean-atmosphere interactions governing the Indian monsoon, offering improved prospects for monsoon predictability and regional climate impact assessment. Remaining challenges related to regional uncertainties and observational biases highlight directions for future research.

Keywords: Indian Summer Monsoon Rainfall, SST, Empirical Orthogonal Function, CMIP6 Climate Models, Ocean Atmosphere Interaction

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Atmosphere and Ocean Interaction-Implications for Climate Systems and Global Weather Patterns

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ABSTRACT

The coupled interactions between the atmosphere and the ocean represent a foundational component of the Earth's climate system, exerting critical influence on global weather patterns, circulation regimes and climate variability. Through exchanges of heat, momentum, moisture and gases at the air–sea interface, the ocean and atmosphere form a tightly-coupled system which modulates large-scale patterns such as the El Niño–Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD) and the Atlantic Meridional Mode (AMM), thereby impacting precipitation, terrestrial water-storage, storm genesis and long- term climate shifts.

At seasonal to decadal timescales, the ocean's thermal and circulatory inertia act as both a buffer and a driver of atmospheric variability, with SST anomalies establishing teleconnections that propagate changes across ocean basins and continents. Moreover, anthropogenic forcing and land- use changes alter the boundary conditions of this coupling, influencing the amplitude and reach of these ocean–atmosphere feedbacks.

This paper synthesises current understanding of the main mechanisms of atmosphere–ocean interaction — including momentum flux, buoyancy flux, and mass exchange — and examines how these processes manifest in modulation of weather extremes (e.g., tropical cyclones), shifts in mean climate states, and changes in the global hydrological cycle. The implications for prediction and risk management are emphasised: improved modelling of coupled processes is vital to anticipate climate-driven hazards affecting agriculture, water resources, coastal systems and infrastructure. In the context of advancing machine-learning and Earth-system modelling tools, the integrated study of atmosphere and ocean coupling holds promise for enhancing climate resilience and operational forecasting.

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Synergy of the Atlantic Multidecadal Oscillation and Quasi-Biennial Oscillation in Driving Indian Summer Monsoon Rainfall

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ABSTRACT

This study examines the relationship between Indian summer monsoon (ISM) rainfall and the Atlantic Multidecadal Oscillation (AMO) on monthly and seasonal time scales, with respect to the Quasi-Biennial Oscillation (QBO) at 50 hPa from 1953 to 2016. Analyses are performed on the full time series of monthly and seasonal ISM rainfall series and on the AMO index, with the data stratified by QBO westerly and easterly phases. A consistent positive association is found between ISM rainfall and the AMO during the pre-monsoon (March–May) and winter (January– February) seasons. The Rossby-wave train from the North Atlantic across South Asia mediates this link, enhancing the land-ocean temperature gradient and strengthening the monsoon. The strongest correlation occurs in April, particularly when the AMO is in its warm phase and the QBO is westerly. This combination also leads to cooler, lower-salinity sea-surface conditions in the Indian Ocean during September–October. Keywords: Indian Summer Monsoon, Atlantic Multidecadal Oscillation, Quasi-Biennial Oscillation, Rossby wave.

Keywords: Indian Summer Monsoon, Atlantic Multidecadal Oscillation, Quasi-Biennial Oscillation, Rossby wave.

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Effects Of Mesoscale Eddies On The Bay Of Bengal Sound Speed Structure

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ABSTRACT

Mesoscale eddies play a crucial role in altering the thermohaline structure of the upper ocean. Because sound speed in seawater is primarily governed by temperature, salinity, and pressure, the substantial thermohaline anomalies associated with cyclonic and anticyclonic eddies can significantly modify the sound-speed structure. Several studies have reported the impacts of mesoscale eddies on acoustic propagation in different regions of the world ocean. However, these effects are not yet well understood in the Bay of Bengal (BoB), a region characterized by complex thermohaline features, including the strongest haline contrasts across the tropical oceans, which leads to the formation of barrier layers and temperature inversions. In addition to advecting warmer or cooler waters, eddies in the BoB often transport notably fresher or saltier water masses depending on their type, location, and season. Consequently, the eddy-induced changes in thermohaline structure significantly influence the upper-ocean sound-speed field and, therefore, acoustic propagation in the region. Understanding these eddy effects is essential for improving predictions of underwater sound propagation and enhancing sonar performance in the BoB. This study aims to investigate the influence of mesoscale eddies on the sound-speed structure of the BoB using a combination of in situ, satellite-derived, and reanalysis datasets, including Argo profiles, AVISO altimetry products, and the GLORYS12V1 ocean reanalysis. Preliminary results show regional and seasonal variability in eddy effects, and the study evaluates both standalone and paired eddies.

Keywords: Sound speed, Bay of Bengal, Mesoscale eddies, Haline stratification, Temperature inversions

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Ocean Temperature Extremes In The Bay Of Bengal: Ecological Impacts, Community Vulnerability, And Resilience Pathways

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ABSTRACT

Marine heatwaves (MHWs) are emerging as a significant concern in the Bay of Bengal, where episodes of extreme sea surface temperature (SST) anomalies have increased in frequency, duration, and intensity over recent decades. The northern Bay has recorded more than one hundred events within the past thirty years, with temperature anomalies exceeding four degrees Celsius during several episodes. These warming extremes are influenced by atmospheric heat flux, monsoonal circulation, ocean stratification, and large-scale climate oscillations, including the Indian Ocean Dipole and the El Niño–Southern Oscillation. This study assesses the ecological and socioeconomic implications of these events for Bangladesh's coastal region using satellite-derived sea surface temperature products, in-situ thermal measurements, and coastal water-quality observations. Analysis indicates substantial ecological stress, including disruption of fisheries and increased potential for coral bleaching, alongside enhanced cyclone favourability linked to elevated ocean heat content. Socioeconomic assessments show pronounced impacts on fisheries-dependent communities, public health, and critical infrastructure. The findings highlight the need for strengthened monitoring networks, early warning systems, and targeted adaptation measures to enhance resilience in coastal Bangladesh under rising marine temperature extremes.

Keywords: MHW, SST, Coastal Ecosystems, Climate Oscillations, Coastal Resilience

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Mechanisms Of Heatwave Intensification Associated With Tropical Cyclones Over India: Insights From Reanalysis And Numerical Simulations

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ABSTRACT

Tropical cyclones (TCs) and heatwaves (HWs) are extreme weather events that have considerable effects on both human and natural ecosystems. Interactions between TCs and heatwaves can occur in various ways. This study investigates the interactions between TCs and HWs using reanalysis datasets and high resolution WRF Model with a focus on understanding the physical mechanisms responsible for heatwave intensification during Tropical Cyclone events. The analysis of cyclones Biparjoy, Vayu, Mocha, and Remal shown a significant increase of 6–8°C in maximum air temperature during the cyclone and post-cyclone period in comparison with pre-cyclonic period. The findings show that TC activity connects to HW intensification through different mechanisms depending on the cyclone's basin of origin. For Bay of Bengal cyclones (Mocha, Remal), eastward displacement of anticyclonic flow transports hot air masses from the Arabian Sea enhancing the HW conditions over central and northwestern part of India, enhancing. Conversely, for Arabian Sea cyclones (Biparjoy, Vayu), subsidence associated with ridge formation leading to enhanced HW over eastern India. During all cyclones, WRF simulations are able predict the temperature and circulation patterns more accurately. This study will be helpful for the local government for adopting future strategies related to concurrent tropical cyclones & heatwaves.

Keywords: Heatwaves, Tropical Cyclones, WRF Model

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Importance of atmosphere-ocean interaction on biogeochemistry of the Indian Ocean

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ABSTRACT

The North Indian Ocean is the best region to study atmospheric-ocean interaction due to covering of land on three sides where the highest amount of pollutants are released to the atmosphere. The higher levels of aerosol optical depth (AOD) and the highest rate of increase in the past two decades were reported resulting in weakening of sea surface temperature (SST) warming rate. This would lead to modifications in the ocean mixing, for instance, winter convective mixing, coastal upwelling and monsoon mixing that alters nutrients availability and ecosystem response. The deposition of pollutants over the surface ocean enhances inputs of nitrogen (in the form of nitrate and ammonium) and phosphate that would lead to changes in the nutrient stoichiometric ratios and alters phytoplankton composition. The atmosphere-borne nutrients support 10 to 20% of the surface primary production and also ~5% of the export production from below the photic zone. The total suspended matter from aerosol deposition over the ocean surface removes significant fraction of the phosphate through adsorption and transport to deep ocean. The deposition of the sulfates, nitrates and ammonium from the atmosphere acidifies the surface ocean and alters the direction of CO2 flux at the air-sea interface. The present global or regional models could not able to perform well in simulating the biogeochemistry of the north Indian Ocean due to lack of atmosphere-ocean interactions. Incorporating these processes in the numerical models, the ocean biogeochemical simulations can be improved as well forecasting the possible changes due climate change.

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Micro-Analysis of Coastal Morphodynamic Changes in River-confluence Areas along the Andhra Pradesh Coast Using the DSAS Tool

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ABSTRACT

River-confluence coastal areas along the Andhra Pradesh shoreline are dynamic environments influenced by river discharge, waves, tides, currents, and sediment movement. These interactions cause ongoing changes in the shape of the land, making these regions especially prone to erosion, buildup, and changes in water flow. Understanding these small-scale changes is important for evaluating coastal stability, predicting future shoreline behavior, and supporting responsible coastal management. This study provides a detailed analysis of shoreline evolution near major river mouths along the Andhra Pradesh coast using multiple satellite datasets and the Digital Shoreline Analysis System (DSAS). The study used DSAS-based statistical tools, such as the Linear Regression Rate (LRR), End Point Rate (EPR), and Weighted Linear Regression (WLR), to assess shoreline morphodynamics along areas near river mouths on the Andhra Pradesh coast. The analysis identified specific erosion hotspots that need urgent coastal management. The Gautami River mouth experienced severe erosion, with rates hitting -8.907 m/yr on the northern side, making it one of the most at-risk areas. High accretion rates near the Krishna River mouth and steady shoreline growth at the Penna and Swarnamukhi systems indicate healthy sediment conditions. In contrast, areas dominated by erosion highlight a disrupted sediment balance and a greater risk of coastal hazards. The results reveal pronounced morphodynamic variability, with river-adjacent zones experiencing higher rates of change compared to non-riverine stretches. Significant erosion was observed near major river mouths such as the Krishna and Godavari, attributed to sediment supply alterations, tidal dynamics, cyclonic activity.

Keywords:- Shoreline Change, Coastal Morphodynamics, River Mouth Dynamics, DSAS; Linear Regression Rate (LRR); Weighted Linear Regression (WLR); Accretion and Erosion.

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Recent Climatic Trends in Kelvin and Rossby Waves in the Bay of Bengal

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ABSTRACT

Kelvin and Rossby waves are prominent dynamical features in the Bay of Bengal (BoB), influencing circulation, upwelling/downwelling, and upper-ocean stratification. The BoB typically experiences four coastal Kelvin-wave phases each year, generated by two pairs of alternating upwelling and downwelling equatorial Kelvin waves that propagate eastward along the equator. Upon reaching the Sumatra coast, these waves bifurcate, with the northern branch propagating along the eastern boundary of the BoB as coastal Kelvin waves.

Using satellite observations and reanalysis products, this study identifies a strengthening downwelling trend across all four Kelvin-wave phases in recent decades. This trend remains robust even after removing the thermosteric contribution from long-term ocean warming. The downwelling intensification is detectable from 1998 and becomes more prominent after 2007. Notably, the first upwelling Kelvin wave in recent years propagates a significantly shorter distance compared to climatology, and the second upwelling phase is absent altogether after 2007. Consequently, the downwelling phase persists unusually long—from April to December or even into January of the following year.

The strengthening coastal downwelling is more pronounced along the BoB eastern boundary than in the equatorial waveguide, primarily due to enhanced alongshore winds that favour downwelling, relative to the equatorial westerly wind bursts. The intensified coastal Kelvin waves radiate stronger westward-propagating Rossby waves through interactions with coastal bathymetry and background currents. These stronger Rossby waves enhance downwelling in the interior bay, deepen the thermocline, and consequently lead to a thickening of the barrier layer in the BoB. These evolving wave-driven changes in stratification and barrier-layer structure have important implications for BoB coastal ecosystems, monsoon predictability, and the climate resilience of the communities dependent on these waters.

Keywords: Bay of Bengal, Kelvin waves, Rossby waves, Upwelling, Downwelling

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Tracing Black Carbon Pathways from Land to Ocean: A Four Decade Analysis

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ABSTRACT

Black carbon (BC) is a strong light-absorbing aerosols and have potential to influence climate, air quality, ocean surface water chemistry and human health. This study provides a long-term (1980–2022) assessment of BC over the Northern Indian Ocean (NIO), by utilizing reanalysis (MERRA-2), emission inventory (EDGARv8.1), fire counts (MODIS), and air-mass back trajectories (HYSPLIT) dataset. The results reveal clear hotspots along the north-eastern and western coasts of India, particularly over the northern Bay of Bengal (BoB: R1,R2,R3 regions) and the south-eastern Arabian Sea (AS: R4 & R5 regions) which shows a significant spatial heterogeneity in BC loading. A distinct land-to-sea gradient and strong seasonal variability in BC loading is observed, with the highest concentrations during winter and post-monsoon months (up to 3.20 μg/m³) due to weaker atmospheric mixing.

During the 1990s and 2000s, BC concentrations rose sharply (up to 0.036 μg/m³ per year), reflecting India's rapid industrial growth. In contrast, from 2011 to 2022, the trends slightly declined (up to -0.002 μg/m³ per year), especially over eastern coastal regions (R1-R3), pointing to the positive impact of emission control policies. Cluster analyses of air mass back trajectories confirms that BC over the BoB mainly originates from the Indo-Gangetic Plain, while the AS receives contributions from both Indian and Middle Eastern regions, including shipping emissions.

Future projections using the SARIMA (Seasonal Autoregressive Integrated Moving Average) model suggest that BC levels will likely continue to rise across most parts of the NIO,except region R3, where a small decline is expected. Overall, this study highlights the combine impact of emissions, transport processes, and policy measures in shaping BC patterns over the NIO. Sustained emission controls strategies and regional cooperation are crucial to mitigate BC's impact on climate and ocean surface water chemistry of the NIO.

Keywords: BLACK CARBON, NORTHERN INDIAN OCEAN, MERRA-2, SARIMA

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Evaluation Of Environmental Impacts On The Fishery Resources Of Nagapattinam Distric, Tamilnadu,India

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ABSTRACT

This study presents a comprehensive assessment of marine fisheres catch in Nagapattinam district during 2022–2025, focusing on how changing coastal conditions affect fish diversity and production. Primary data collected monthly from landing centers reveal significant seasonal fluctuations in catch volume, with peaks observed during the monsoon and post-monsoon months. Major commercial species such as tunnies, mackerel, seer fish, shrimp, and crabs exhibited pronounced variation, reflecting their sensitivity to climate variability and local pollution pressures. Dramatic differences across months and species groups are evident. Declines in selected pelagic species and increased dominance of a few resilient demersal species point to potential ecological shifts. These findings are consistent with broader regional evidence linking altered rainfall and pollutant influx to community structure changes in the Bay of Bengal. The study underscores the importance of integrating long-term catch monitoring with adaptive fisheries management, considering both environmental drivers and fisher community responses, to ensure sustainable marine resource use in coastal Tamil Nadu.

Keywords: Nagapattinam, marine fisheries, catch data, climate change, coastal pollution, species composition, Bay of Bengal

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Ocean and Climate: How They Affect Each Other — A Global to Local View from the World's Research and the Mumbai Coast

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ABSTRACT

The ocean plays a key role in controlling Earth's climate. It stores most of the extra heat caused by greenhouse gases and absorbs a large amount of the carbon dioxide that people release into the air. However, this delicate balance is shifting due to human activities. The IPCC, NASA, and the European Environment Agency (EEA) report that the ocean is becoming warmer, more acidic, and losing oxygen — all of which harm marine life and coastal ecosystems

Scientists at the Universities of Cambridge and Oxford have studied how ocean circulation, density, and tiny ocean organisms affect how much carbon the ocean can store. Their work helps explain how the ocean influences climate worldwide.

At the same time, Indian researchers from the National Institute of Oceanography (NIO), IIT Bombay, and the Central Pollution Control Board (CPCB) have been studying the Mumbai coast. They've found pollution, changes in water movement, and damage to mangroves — all worsened by rising sea levels and changing weather.

By combining these studies, we can see that the same natural processes connecting the ocean and climate on a global level also shape what happens in local places like Mumbai. Protecting our coasts and oceans will help both local communities and the planet's climate system.

Key words: Ocean and climate; Carbon cycle; Ocean circulation; Sea-level rise; Ocean pollution; Mangroves; Mumbai coast; Global warming; Cambridge research; Oxford research; National Institute of Oceanography; IIT Bombay; Coastal protection; Climate change.

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Linking The Spatiotemporal Variability Of Oceanic Fronts To Marine Ecology In The Bay Of Bengal

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ABSTRACT

The Bay of Bengal (BoB) frontal regions are often known as hotspots in the marine ecosystem, as they exhibit higher diversity indices. The Sea surface temperature (SST) fronts commonly collocate with other oceanographic fronts and induce biological productivity. Owing to the variability of fronts over time and space, this paper focuses on the decadal changes in frontal dynamics in the BoB under a changing climate. High-resolution MODIS-Aqua Level-3 SST datasets at 4 km were obtained for the period 2003-2022. We evaluated frontal variability using the Cayula-Cornillon front detection algorithm (CCA) and trend analysis over the past two decades. A frontal displacement of ~ 1-2° with varying zonal shifts across the basin was observed during the decadal analysis. Additionally, seasonal observations show peak frontal activity during the pre-monsoon (March-May) and post-monsoon (October-December) periods, coinciding with bloom events in the BoB. Overall, the study highlights the functionality of SST fronts, maintaining a healthy and sustainable large marine ecosystem in the BoB. These findings emphasize the need for robust monitoring and comprehensive analysis of the hydrodynamic properties of fronts.

Keywords: Bay of Bengal, Cayula-Cornillon Front, MODIS-Aqua, Sea surface temperature, marine ecosystem

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Numerical Modeling of Wave Transmission and Reflection by Semicircular Armour Unit

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ABSTRACT

The current study focuses on the numerical modelling of semicircular wave energy dissiparing using the advanced computational fluid dynamics (CFD) tool REEF3D. The study aims to investigate the wave-structure interaction, specifically how semicircular energy dissipation blocks influence wave attenuation and energy dissipation in coastal environments. REEF3D, equipped with Reynolds-Averaged Navier-Stokes (RANS) equations and turbulence modelling, provides a robust platform to simulate complex wave dynamics and flow patterns around these curved blocks. Simulations cover various wave conditions, crest dimensions, and submergence levels to analyze the wave runup and wave reflection characteristics. The semicircular geometry is studied for its enhanced stability and hydraulic performance compared to conventional blocks shapes.

Semicircular blocks provide effective coastal protection by reducing wave energy and minimizing shoreline erosion. Numerical modelling consistently show that semicircular dissipation blocks effectively reduce wave runup and transmission.

Keywords: Semicircular dissipation blocks, Computational fluid dynamics (CFD),Wave runup, Reef 3D and Numerical Modelling.

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High-Resolution Time-Series Mapping of Shoreline Change at Kakinada Coast Using CoastSat and Multisensor Imagery

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ABSTRACT

The Kakinada Coast along the Bay of Bengal is highly dynamic and facing increasing risks of shoreline erosion due to natural coastal processes and human activities, a challenging problem for both natural and large-scale coastal infrastructure. CoastSat is an open-source satellite-based shoreline mapping tool kit that processes Landsat and Sentinel images to extract accurate, time-stamped shoreline positions for coastal change analysis.

This study utilized the open-source CoastSat Python tool kit to automatically extract a high-resolution time-series of Satellite-Derived Shorelines (SDS) from sattelite images obtained from Landsat (L7, L8, L9) and Sentinel-2 missions, spanning the period from January 2015 to November 2025. This study quantifies the decade shoreline dynamics of Kakinada Coast, a critically affected stretch located downdrift of the major Kakinada port structures and Rivers. All mapped shorelines were projected into UTM Zone 44N and visualised to examine their spatial spread over the study region. The dense clustering of multiyear shoreline traces highlights the dynamic nature of Kakinada Coast, where both natural monsoonal cycles and local anthropogenic influences shape the coastline. A significant short-term change was observed during and after Cyclone Montha in 28 October 2023, when strong waves and storm surge caused noticeable erosion along parts of the coastline. These cyclone-related shoreline shifts stand out clearly in the satellite-derived time-series and help demonstrate the sensitivity of the coast to extreme events.

To quantify cross-shore movement, five shore-normal transects were drawn perpendicular to shoreline, across the selected hotspot area. Time-series analysis for each transects revealed distinct spatial patterns. This study demonstrates the effectiveness of CoastSat as a low-cost, repeatable tool for long-term shoreline monitoring in highly urbanised coastal environments.

The decade-long shoreline dataset provides valuable insights into erosion–accretion cycles, long-term recession trends, and event-driven coastal responses along most active beach along Kakinada coast.

Keywords: Satellite-Derived Shorelines (SDS), Shoreline Change, Time-Series Analysis, Shoreline Extraction, Coastsat.

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Modeling the Extreme Wave Climate and Tide–Surge Interactions Induced by Cyclone Michaung Along the Nellore Coast

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ABSTRACT

Cyclone Michaung was a severe storm that impacted the Andhra Pradesh coastline in December 2023. It created extreme conditions along the Nellore coast, posing serious risks to coastal towns, infrastructure, and navigation. To assess coastal vulnerability and improve disaster readiness, it is important to understand how cyclone-driven waves, storm surges, and tides interact. This study offers a combined modeling framework to analyze the extreme wave climate and tide-surge dynamics caused by Cyclone Michaung in the Nellore coastal zone.The modeling system uses reconstructed cyclone wind fields, detailed underwater features, offshore boundary conditions, and tidal data to simulate how waves form, move, and change near the shore. By connecting surge modeling with wave simulations, the study assesses how significant wave height, wave periods, direction, surge elevation, and tide-surge interaction changed during the storm. Tidal boundaries were included to account for possible increases in water levels when surges coincided with high tide.

The results indicate that Cyclone Michaung produced significantly higher wave heights, with peak significant wave heights well above typical monsoonal levels. Nearshore transformations intensified wave energy as waves shoaled and refracted over shallow waters. The tide-surge model shows surge elevations of about 1.0–1.5 m above the astronomical tide along low-lying areas of the Nellore coast, resulting in localized flooding. The timing of surge peaks with rising tide further increased the risk of flooding, especially in estuarine and backshore areas. The results indicate that Cyclone Michaung produced significantly higher wave heights, with peak significant wave heights well above typical monsoonal levels. Nearshore transformations intensified wave energy as waves shoaled and refracted over shallow waters. Overall, the findings show that Cyclone Michaung significantly changed the coastal hydrodynamics of the Nellore region through extreme wave activity and strong tide-surge interactions.

Keywords: Cyclone Michaung; extreme wave climate; storm surge; tide–surge interaction; coastal hydrodynamics; numerical modeling

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Extended Modeling and Analysis of Cyclone Montha–Induced Extreme Wave Conditions and Their Effects on the Kakinada Coastal Zone.

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ABSTRACT

Cyclone Montha caused severe wave conditions along the Kakinada coast, which posed significant risks to coastal infrastructure, navigation, and shoreline stability. It is important to understand where and when these high-wave events occur to improve coastal preparedness and reduce hazards. This study presents an extensive modeling that evaluates the size, spread, and coastal impacts of the extreme waves generated by Cyclone Montha along the Kakinada coast. The analysis aims to simulate the extreme wave characteristics created during Cyclone Montha, including wave height, wave period, and direction patterns. It also looks at how these waves changed as they approached the shore and assesses the potential impacts on the coast, especially in high-energy zones that are likely to experience erosion and structural stress. The modeling framework used are cyclone wind fields and bathymetric data to recreate wave conditions both offshore and nearshore during the event.The results shows a clear increase in significant wave heights, with peak values far surpassing typical seasonal conditions. The northern and central areas of the Kakinada coast had the highest wave intensities, especially near exposed headlands and shallow areas where wave shoaling and refraction boosted wave energy. The distribution of wave parameters points out critical areas vulnerable to wave-induced erosion, flooding, and potential damage to port activities and coastal defenses.
Overall, the detailed modeling analysis demonstrates that Cyclone Montha significantly changed wave behavior along the Kakinada coastal zone, leading to extreme wave heights and high-energy areas that pose serious risks to the shoreline. The study highlights the need to include detailed wave modeling in coastal risk assessments to better predict the impacts of future cyclone-driven wave events.

***Keywords*:** Cyclone Montha, extreme wave conditions, wave modeling, high-wave events.

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Understanding The Role Of Boundary Layer- Land Surface Interactions In The Brown Ocean Effect-Driven Inland Reintensification Of The Tropical Storm Erin(2007) Using Wrf

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ABSTRACT

Tropical Storm Erin (2007) exhibited a rare phenomenon, the Brown Ocean Effect, where the storm re-intensified over Oklahoma, almost three days after making landfall, creating widespread damage. This study uses the Weather Research Forecasting (WRF-ARW) model to investigate the role of Planetary Boundary Layer (PBL) and Land Surface (LS) schemes in simulating Erin's inland reintensification. A sensitivity analysis was conducted with a nested domain (27km and 9km resolutions) with different combinations of PBL and LS parameterization schemes to understand the storm's evolution post landfall. The simulations focused on the spatio -temporal variability of different land surface variables like soil moisture, soil temperature, surface fluxes, surface winds, mean sea level pressure, particularly after landfall and during reintensification. Model outputs were compared with the observational and reanalysis datasets to assess the accuracy of different combinations of parameterization schemes in capturing the reintensification of the storm. Results show that the schemes maintaining higher soil moisture and soil temperature were better in representing the progression of Erin's intensity, supporting the significance of the land-atmosphere interactions consistent with the Brown Ocean Effect. The YSU(PBL scheme)-Unified Noah land surface model(LS scheme) provided the most realistic depiction of the surface fluxes and soil characteristics linked with the storm's reintensification.
Overall, this study highlights the importance of PBL-LS parameterization schemes in simulating the reintensification of tropical storms. By improving model representation, these schemes enhance the predictive skill for such storms, which can have significant impacts on both the environment and human society.

Keywords: Tropical Storms, Brown Ocean Effect, WRF-ARW, Planetary Boudary Layer, Land atmosphere interactions.

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Decadal Variability of Barrier Layer Thickness in the Bay of Bengal Under Global Climate Change

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ABSTRACT

The present study investigates the decadal variability of barrier layer thickness (BLT) in the Bay of Bengal and illustrates its dynamic response to recent global climate change using six decades of monthly mean Ocean Reanalysis System 5 reanalysis data (1958–2022). The barrier layer in the Bay of Bengal plays a critical role in modulating air-sea interactions and regional climate. This study investigates the decadal variability of the barrier layer thickness and its underlying forcing mechanisms. We find that this decadal variability is intrinsically linked to the remote influence of the Pacific Decadal Oscillation. The spatial pattern of barrier layer thickness variability exhibits a pronounced meridional dipole across the bay. The Pacific Decadal Oscillation indirectly modulates the barrier layer through an atmospheric bridge, by altering the Walker circulation and the associated wind patterns over the Bay of Bengal. During positive phases of the Pacific Decadal Oscillation, weakened winds enhance shoreward Ekman transport, deepening the isothermal layer and promoting a thicker barrier layer along the eastern and northern coasts. Concurrently, these weakened winds, along with changes in wind stress curl, lead to reduced oceanic mixing and enhanced upwelling in the southeastern bay, which shallows the isothermal layer and results in a thinner barrier layer. The opposite mechanisms occur during negative phases. Diagnostic analysis reveals that the primary physical drivers of decadal barrier layer variability differ regionally. In the northern Bay of Bengal, horizontal advection and freshwater flux-induced entrainment are the dominant processes. In contrast, in the southern Bay of Bengal, heat flux and freshwater flux-induced entrainment play the leading role. This study concludes that the Pacific Decadal Oscillation is a key remote driver of decadal barrier layer variability in the Bay of Bengal, with its influence mediated through distinct dynamical processes in different parts of the basin.

Keywords: BLT, ILD, PDO, Bay of Bengal, Kelvin waves, Rossby waves.

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Projected Changes In Storm Surge Characteristics Over The Arabian Sea And Bay Of Bengal Based On CMIP6 Models

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ABSTRACT

Storm surges are among the most destructive coastal hazards in the North Indian Ocean, particularly along the densely populated and low-lying coasts of the Arabian Sea (AS) and Bay of Bengal (BoB). This study investigates historical and future storm surge behaviour in the AS and BoB using high-resolution CMIP6 climate model outputs. Seasonal and annual mean storm surge residuals are analysed to assess projected changes under a near-future climate scenario (2021–2050) relative to a historical baseline (1985–2014). Results indicate a robust increase in mean surge levels across all seasons in the AS, with the highest amplification north of 15°N, particularly along the Gujarat coast, whereas no significant increase is projected for the BoB. Extreme surge events are evaluated using the Generalized Pareto Distribution (GPD) with the Peak-Over-Threshold (POT) method to estimate the 100-year return period (RP100). The projected RP100 surge heights show the largest increases along the east coast of India during the winter season (DJF) and along the west coast of India during autumn (SON). Additionally, the Gujarat coast exhibits a consistent increase in RP100 surge levels across all seasons, underscoring its enhanced vulnerability. These findings highlight regionally contrasting responses of storm surge hazards under future climate change and emphasize the need for region-specific coastal risk management and adaptation strategies.

Keywords: Storm Surge, Bay of Bengal, Arabian Sea, CMIP-6, GPD(POT)

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Rock Magnetic Properties, A Proxy For Delineating Sediment Source And Transport In A River-Estuarine Environment

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ABSTRACT

River and estuarine sediments from eight rivers across three states (Maharashtra, Goa, Karnataka) along the west coast of India were studied seasonally to determine the source, transport patterns, and the influence of human activities (mining or industry-related), if any, on the sediments using rock magnetic properties. The Maharashtra rivers (Gad and Jaigad) exhibited the highest average magnetic concentrations (zlf- 1419-3283 x $10^{-8}m^3kg^{-1}$) compared to the Goa (Terekhol, Chapora, Sal, Talpona; zlf- 27-421 x $10^{-8}m^3kg^{-1}$) and Karnataka (Nethravati, Gurupur; zlf- 32-48 x $10^{-8}m^3kg^{-1}$) rivers and reflected the Deccan traps as the main sediment source contributing to the magnetic concentration. The rivers in Karnataka had the lowest magnetic concentration. The seasons seemed to influence magnetic concentration, with higher values during the wet season than during the dry season. Among the rivers studied in Goa (Terekhol and Chapora), anthropogenic activities contributed to significant magnetic concentrations. Magnetite dominated the magnetic mineralogy in the Maharashtra and Goa rivers, while in the Karnataka rivers, a mix between Magnetite and hematite was seen. The present study highlights the effective use of rock magnetic properties as a proxy in characterizing and interpreting different environmental processes acting on the sediments in a river-estuarine system.

Keywords: estuary, sediments, magnetic properties, rivers

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Investigating Atmospheric And Oceanic Parameters For Possible Tsunami Signals

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ABSTRACT

Tsunamis, known for their immense destructive power, have been extensively studied in order to better understand their complex behaviour and mitigate their effects on coastal regions around the world. The atmosphere and ocean have interrelated systems with complex feedback mechanisms. The Earth's climate system consists of five interconnected components: the atmosphere, hydrosphere, cryosphere, lithosphere and biosphere. Both internal variations and external factors have the ability to influence the climate system. While most studies have focused on the geological mechanisms of tsunami generation and propagation, more attention is needed towards the interaction between tsunamis and atmospheric and oceanic parameters. The present study aimed at investigating possible links between tsunamis and these parameters in order to identify any precursor signals. Five significant tsunami events were examined i.e., Indonesia (1992), Java (1994), Indian Ocean (2004), Chile (2010) and Japan (2011), each with a magnitude of 7 Mw and causing widespread devastation. The findings reveal a constant pattern across all five cases. In most of the cases increasing trends in temperature, specific humidity and mean sea level pressure was observed. While a decreasing trend in geopotential height, sea surface temperature, salinity, net surface heat flux and mixed layer depth was found. These changes were detected 5 to 3 days before the tsunami hits. These findings highlight the dynamic interactions between atmospheric and oceanic parameters during tsunamis and can provide information about possible signals prior to the Tsunami. This study helps to improve understanding for the development of early warning systems and disaster preparedness plans.

Keywords: Tsunami, reanalysis data, atmospheric-oceanic parameter, predictive signals and disaster preparedness.

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Influence of the Madden–Julian Oscillation in Modulating Rainfall Extremes across different regions of India

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ABSTRACT

This research aims to investigate the influence of Madden-Julian Oscillation (MJO) on extreme rainfall events across India over a 50-year (1974-2024) high-resolution daily rainfall dataset and Real-Time Multivariate (RMM) MJO indices data set. The precipitation events were classified by their intensity, and before examining the relevant data for different MJO phases using composite mean, anomaly, and frequency methods. Based on the analyses, MJO Phases 1, 2, and 5 were linked to active convective activity and upward trends for extreme and very heavy rainfall events over the Indo-Gangetic Plain, central India, and some parts of northeast India. The active phases were found to be associated with the MJO convective envelope over the Indian Ocean, which supported more active convection and a higher probability of rainfall. While for MJO phases 6 to 8 tended to be associated with lower rainfall amounts, longer dry days and generally less-than-average rainfall anomalies across peninsular India and western India. The spatial distribution of peak rainfall intensity was again significantly lower in these later MJO phases. Therefore, the study finds a clear association between MJO and intraseasonal hydroclimatic extremes across India and its importance for operational forecasting by improving sub-seasonal to seasonal rainfall predictions.

Keywords: Madden–Julian Oscillation (MJO); Extreme Rainfall Events; Indian Monsoon; Composite Analysis

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Hydrodynamic Variability And Its Impacts On The Blue Economy In The Northern Bay Of Bengal

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ABSTRACT

The marine economy of Bangladesh is highly dependent on the Northern Bay of Bengal, where thousands of individuals rely on fishing, aquaculture, and coastal activities for their livelihoods. However, significant changes in hydrodynamic patterns have been observed in this region, driven by climate variability and increased anthropogenic activity along the coast. This study aims to assess the implications of these changes for the communities and industries dependent on these waters. The research investigates the variability of currents, tides, and water levels throughout the year and during major storm events, with a focus on Bangladesh's coastal and offshore zones, including the Swatch of No Ground. Hydrodynamic modelling was conducted using HEC-RAS 6.6, and spatial risk mapping was performed with QGIS 3.40. Data sources include bathymetry from GEBCO, tide measurements from INCOIS and NOAA, river flow records from the Bangladesh Water Development Board, and satellite imagery from Sentinel-3 and MODIS, covering sea surface temperature, chlorophyll-a, and turbidity. Simulations were run for both typical monsoon seasons and extreme cyclone scenarios to capture regular patterns and disaster impacts. Satellite data analysis revealed distinct seasonal trends. Sea surface temperatures range from 26°C in winter to approximately 30°C during the pre-monsoon period, aligning with local fishing season calendars. Sea surface height fluctuates by nearly 15–20 cm, with lower values during the northeast monsoon compared to the southwest monsoon. Chlorophyll-a concentrations indicate peak productivity in coastal waters (2–3 mg/m³) during the monsoon, coinciding with increased riverine nutrient input, while offshore concentrations remain below 0.5 mg/m³. Sea surface salinity exhibits substantial variation, from 32–33 psu in the dry season to 20–25 psu near river mouths during peak monsoon. These hydrodynamic and biogeochemical changes directly influence fish distribution and necessitate adaptive strategies for aquaculture operations throughout the year. Notably, these conditions are projected to threaten approximately 60% of existing fish farm infrastructure within the study area. Critical thresholds were identified: current velocities exceeding 0.8 m/s disrupt cage aquaculture, and tidal range variations above 2.5 meters challenge coastal fishing port operations. This research integrates oceanographic science with economic planning in an unprecedented manner for the region. The findings are intended to inform fisheries management decisions regarding aquaculture site selection, seasonal fishing regulations, and coastal infrastructure design under future climate scenarios, thereby supporting the implementation of SDG 14 in Bangladesh.

Keywords: Bay of Bengal, Blue Economy, Coastal hydrodynamics, Climate resilience, Fisheries management

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Hydrodynamic Variability And Its Impacts On The Biodiversity In The Northern Bay Of Bengal

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ABSTRACT

The northern Bay of Bengal exhibits remarkable oceanographic complexity where monsoon-driven circulation, river discharge, and mesoscale features collectively govern marine ecosystem dynamics. Understanding how physical processes translate into biological responses remains critical for predicting ecosystem resilience under climate variability. This study aims to: (1) characterise seasonal hydrodynamic variability and stratification patterns in the northern Bay of Bengal, (2) identify and quantify the spatiotemporal persistence of mesoscale cyclonic eddies and their influence on nutrient distribution, and (3) assess the relationship between eddy-driven upwelling and biological productivity across different trophic levels. We analysed multi-sensor satellite observations spanning 2022-2024 for the northern Bay of Bengal region (18°N-22°N, 88°E-92°E). Chlorophyll-a concentrations were derived from MODIS-Aqua, Sentinel-3 OLCI, and VIIRS ocean colour sensors using standard NASA algorithms. Sea surface height anomaly data from satellite altimetry enabled mesoscale eddy detection through the Okubo-Weiss parameter method combined with sea surface height contour analysis. Seasonal stratification dynamics were characterised using temperature and salinity profiles, while wind stress data quantified atmospheric forcing patterns across monsoon phases. Our analysis reveals that a persistent cold-core cyclonic eddy in the northern region maintains remarkable six-month stability from July through January.This mesoscale system begins to form under the influence of wind-stress curl during the summer monsoon and is later maintained by the westward movement of semi-annual Rossby waves. As it develops, the eddy triggers pockets of upwelling that lift nutrient-rich subsurface waters into the sunlit surface layer. In these eddy-affected zones, chlorophyll-a levels can rise to nearly eight times higher than those of the surrounding nutrient-poor waters, clearly showing its strong impact on local biological activity. Because the eddy remains stable for an extended period, it allows enough time for phytoplankton blooms to form and for energy to move upward to zooplankton communities, creating productive “hotspots’’ in an otherwise low-productivity environment. Ongoing work is exploring how year-to-year changes in eddy behavior influence the broader food web across the region. Overall, the results highlight how mesoscale eddies add essential spatial diversity to the northern Bay of Bengal’s seasonal productivity patterns. Their long- lasting cyclonic structures support the full development of local food webs, even in a basin where strong stratification usually limits biological growth.

Keywords: Mesoscale eddies, Monsoon dynamics, Ocean stratification, Primary productivity, Trophic interactions

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Phenophyto: A Python And R Package For Automated Detection And Visualization Of Phytoplankton Bloom Phenology

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ABSTRACT

Phytoplankton bloom phenology defines the timing, duration, and intensity of bloom cycles. These cycles drive marine ecosystem productivity and carbon cycling. However, anthropogenic rise produces harmful algal blooms threatening marine and human health. Monitoring phytoplankton bloom phenology is critical for detecting harmful events, managing ecosystems, and assessing climate-driven ocean changes. Ocean-color satellite observations provide large-scale coverage, yet existing automated tools for bloom phenology detection remain inadequate. Many tools cannot reliably detect bloom initiation, peak, termination, and duration. To address these gaps, this study presents PhenoPhyto, an open-source package in Python and R developed for automated detection and visualization of phytoplankton bloom phenology using remotely sensed chlorophyll-a data. PhenoPhyto integrates a modular workflow to process daily and weekly datasets from multiple sensors, generate long-term climatologies, and apply robust algorithms to detect bloom initiation, peak, termination, and duration, while offering interactive visualization functions for producing spatiotemporal phenology maps and publication-ready charts. The 19 years (2004-2022) of chlorophyll-a data was used to validate this package. The analysis with this package showed multi-seasonal blooms in the northern Bay of Bengal, with peaks during the pre-monsoon, monsoon, and post-monsoon periods. Phytoplankton Bloom frequency increased over the time, while duration declined, influenced by climate modes such as ENSO and IOD, with El Niño suppressing and La Niña enhancing blooms. Phytoplankton blooms commonly initiate near the Meghna estuary, Cox's Bazar, and Chattogram coasts and spread offshore. Coastal regions showed high chlorophyll-a (>5 mg m^{-3}), whereas offshore waters showed lower concentrations (<0.5 mg m^{-3}) but longer durations, indicating a strong coastal-to-offshore productivity gradient. PhenoPhyto increases accessibility and reproducibility in bloom phenology research, supporting global sustainability efforts aligned with SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 6 (Clean Water and Sanitation).

Keywords: Phytoplankton blooms, chlorophyll-a, remote sensing, phenology detection, Bay of Bengal.

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Characterisation of Differential Solar Radiation Pattern across Coastal and Island regions of India

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ABSTRACT

The study of solar radiation patterns over the region is crucial and plays a vital role in estimating Earth's energy budget, energy balance, and its impact on climate change variability and sustainability scenarios. In the present study, global solar irradiance data for the period from 1971 to 2020, spanning fifty years, have been analysed for Indian coastal and inland stations. Six stations on the East and West coasts and two inland stations, have been selected for the study, located near the Bay of Bengal and the Arabian Sea. Global solar irradiance data recorded by insitu observatories of India Meteorological Department (IMD) Network have been studied. Stations have been selected to represent different latitudinal region. Climatological normal data of monthly mean values for three different climatological periods, from 1971 to 2000, 1981 to 2010, and 1991 to 2020, have been analysed for Chennai, Goa, Vishakhapatnam, Thiruvananthapuram, Minicoy and Port Blair. Diffential analysis in terms of percentage departures and comparative analysis is carried our for all stations. All the coastal stations found a decrease in global solar irradiance and negative departures from one climatological period to the next climatological period whereas inland stations exhibit increasing trends and positive departures for the same climatological periods. The differential solar radiation pattern is found to be more pronounced from the tropical region to the equatorial region, with a decrease in global irradiance values. For the same period, positive departures are observed over the inland station. In addition, further analysis was carried out for the period from 2021 to 2024, using monthly data for each year and similar results were found. The decrease in global solar irradiance values helps to understand the differential solar radiation pattern, suggesting the energy exchange between Earth, Ocean, and Atmosphere and its impact on the climate change scenario. The results presented here for the Indian coastal and inland stations will provide important regional insights into future trends in solar radiation and be useful for planning in the green energy sector.

Keywords: Global solar irradiance, Indian coastal and island region, Climate Change, Energy Budget, Greeen energy sector

Theme: Ocean and Climate

Session Title: Polar climate variability and teleconnections

Session Convener: Dr. Suchithra Sundaram

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Impact Of Antarctic Ozone Depletion On The Accelerated Rise Of Indian Ocean Wave Heights In The Late Twentieth Century

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ABSTRACT

Ocean waves are a key Essential Ocean Variable vital for marine navigation, offshore operations, and oceanographic surveys. This study examines the multi-decadal evolution and drivers of significant wave height (SWH) across the Tropical Indian Ocean (TIO), Sub-Tropical Indian Ocean (STIO), and Southern Ocean (SO) from 1985 to 2024. The temporal analysis reveals a marked shift in the Indian Ocean wave climate from a period of a strong SWH increasing trend during 1985–2000 to a weakening or quasi-stationary phase after 2000. Statistically significant increases are observed from 1985 to 2000, with the strongest increase in the SO (1.78 cm yr^{-1}), followed by the STIO (1.65 cm yr^{-1}) and TIO (0.99 cm yr^{-1}). In contrast, the early 21st century shows declining or near-zero trends, significant only in the TIO (–0.20 cm yr^{-1}). A 10-year running mean of swell and wind sea components indicates that these variations are dominated by changes in swell height in the Indian Ocean, closely coupled with sea-level pressure anomalies and intensified westerlies between 40°S and 65°S, thereby amplifying swell generation from the Southern Ocean. This variability is closely linked with the pronounced positive phase of the Southern Annular Mode (SAM) in the late 20th century, linked to Antarctic stratospheric ozone depletion. Following the implementation of the Montreal Protocol, ozone depletion has slowed, and early signs of ozone recovery have emerged. This recovery has moderated the SAM toward weaker positive values since the early 21st century, contributing to the observed reduction or stabilization of SWH trends after 2000. Overall, the results show that ozone-driven SAM fluctuations largely control decadal SWH variability in the Indian Ocean and have a significant role in the Indian Ocean regions' wave climate

Keywords: Significant wave height, Ozone, Chlorofluorocarbon, Indian Ocean

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Polar Influence On The Extreme Rainfall Events In India.

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ABSTRACT

The Indian summer monsoon of 2013 covered the entire country by 16 June, one month earlier than its normal date. Around that period, heavy rainfall was experienced in the north Indian state of Uttarakhand, which is situated on the southern slope of Himalayan Ranges. This study investigates the scientific rationale behind the incidence of the extreme rainfall event in the backdrop of large scale monsoon environment.

It is found that cold-dry air from Arctic region moved southwards to the Indian region and intruded to the midlatitudes and interacted with the midlatitude westerly trough during 12-14 June 2013. 14 June onwards, the cold air intrusion started deepening the midlatitude westerly trough and by 16 June, the cold air anomaly got trapped within the upper tropospheric westerly trough, which further deepened the trough, to the northwest of India. The intrusion of midlatitude westerly trough might have destabilized the atmosphere over the Uttarakhand region during 16– 17 June. At the same time, a monsoonal low pressure system that generated over the Bay of Bengal moved northwestward towards the Indian land. It is found that the interaction between the low pressure system that provided increased low level convergence and abundant moisture, and the midlatitude westerly trough that generated strong upper level divergence, helped monsoon to cover the entire country and facilitated the occurrence of the heavy rainfall event in the orographic region.

Keywords: Indian Summer Monsoon, Polar Influence, Midlatitude Trough, Low Pressure System, Extreme Rainfall

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IMPACTS OF POLAR SEA-ICE MELT ON THE INDIAN SUMMER MONSOON AND WESTERN DISTURBANCES

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ABSTRACT

The influence of polar sea-ice loss on tropical and subtropical circulation remains poorly understood. Using fully coupled and high-resolution atmosphere-only simulations with the Community Earth System Model, we examine how idealized Arctic and Antarctic sea-ice melt affects the Indian Summer Monsoon (ISM) and winter Western Disturbances (WDs). Sea-ice albedo was reduced to enhance shortwave absorption and induce realistic melt, enabling a clean attribution of remote impacts.

The ISM exhibits a robust weakening under both hemispheric sea-ice melt, with a stronger response to Antarctic and combined melt than to Arctic melt alone. Monsoon circulation and continental rainfall decline, accompanied by an equatorward shift of the Intertropical Convergence Zone. These changes arise from weakened low-level monsoon flow and reduced synoptic activity.

Complementary high-resolution CAM5 simulations forced with sea-ice-melt SST and SIC fields show that winter WD activity also weakens substantially. WD frequency decreases by ~19% and intensity declines across all vorticity bands. The weakening is linked to a widening and equatorward shift of the subtropical jet, driven by a reduced lower-tropospheric and enhanced upper-tropospheric meridional temperature gradient. The resulting increase in baroclinic stability suppresses WD genesis and development. These jet adjustments closely resemble those projected under greenhouse-gas-induced warming, implying that sea-ice loss reinforces broader anthropogenic circulation changes.

Keywords: Sea Ice Melt, Indian Summer Monsoon, Western Disturbances

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Arctic to Tropics - two way teleconnection mechanism

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ABSTRACT

Arctic warms at least twice the Global rate of warming. At least in some location the rate is even more pronounced, leading to changes in atmospheric circulation. Some of these connect to distant locations even to tropics. On the other hand climate of the tropics is also changing. Are they interconnected. Studied indicate, Indian Monsoons are influenced by the Arctic Ocean changes. Sea-ice losses in Barents and Kara seas seems to be centre of action for such teleconnections. Pressure anomalies generated there has the potential to induce Rossby wave trains that can influence the moisture supply in the Northwestern part of the Indian sub-continent. Also the Warm Arctic Cold Europe (WACE) conditions also seems to influence tropics by modifying low level flow and cyclogenesis in the Arabian Sea. However, the Tropics have some of the intense ocean atmospheric processes, all these are modulated by intricate land ocean atmosphere dynamics, Eg. Madden Julian Oscillation to modulate the Arctic precipitation and temperature. These short term influences are also seems to be modulated by interannula to decadal events like ENSO and Inter decadal Pacific Oscillation.
Heat released during monsoon rains travels all the way upto the Bering strait melting the ice there. These suggest the a two way link in teleconections in the northern hemisphere. Studies also show the impact of sea-ice changes to the Pacific trade winds, Does this impact ENSO, more research is required. If it happen so, then the impact of Arctic changes are more than wha one can expect.

Keywords: Arctic, Monsoons, Teleconections.

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THE NEW ARCTIC STRATEGIC TRIANGLE: MILITARISATION, CRITICAL MINERALS AND CONTEST FOR NORTH – WEST PASSAGE

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ABSTRACT

The Arctic region encircling the North Pole, is a region of geostrategic significance. Once considered an inhospitable and remote frontier, is now recognized as a treasure trove of untapped energy resources , which is becoming increasingly accessible as the ice melts. As a result, the region has also led to the emergence of various maritime routes with shorter distance, and increased competition for these resources. This paper conceptualizes the "New Arctic Triangle" as an interplay between militarisation, critical mineral extraction, and geopolitical contestation surrounding the Northwest Passage (NWP) and role played by North Atlantic Treaty Organisation (NATO)in this region. As sea ice melts, the North West passage—which was earlier considered impractical for commercial navigation—will become increasingly viable, presenting shorter distance between the transpolar shipping routes connecting the Atlantic and Pacific. This shift elevates sovereignty claims, particularly between Canada, which views the route as internal waters, where the United States and European states regarding it as an international strait. The region , which was traditionally considered as peaceful and stable in High north, has turned out to be an area of geopolitical rivalaries, followed by the Russia- Ukraine invasion and the increasing Sino-Russian cooperation . The volatility of the Scandinavian region is shaped by geostrategic issues, such as dominance of the emerging maritime routes – Northern Sea Route (NSR) and Northwest Passage (NWP), changing position of NATO, and claims to seabed resource. By examining these three intersecting vectors—military strategy, mineral resource geopolitics, and maritime route competition—this paper argues that the Arctic is transitioning from a zone of scientific cooperation to a contested strategic frontier central to global power reconfiguration.

Keywords: Arctic region, Critical minerals, Militarisation, NATO, NWP.

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Direct Observations Of Antarctic Bottom Water Temperature Changes In Deep Channels Of The Atlantic Ocean

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ABSTRACT

Antarctic Bottom Water (AABW) is a major component of the abyssal layer of the global ocean contributing to the lower limb of the ocean meridional overturning circulation. Recent studies suggest a slowdown in AABW export which leads to warming and aging of the abyssal ocean. Three modes of AABW circulation are observed in the abyss of the world ocean: slow flows in wide large-scale ocean basins, relatively fast flows along the continental slope as a part of deep western boundary currents, and very fast gravity currents in narrow channels, troughs, and fracture zones of underwater ridges. These narrows are key points where the coldest component of AABW propagates between oceanic basins. Therefore, these passages are convenient for monitoring the long-term changes in abyssal waters. In this study, we report new observations of abyssal water temperature in several key points in the Atlantic Ocean, including the Vema Channel and fracture zones of the Mid-Atlantic Ridge. We also analyze deep-water temperature data collected during more than 40 years in the deep basins of the Atlantic Ocean. Repeated ocean-wide transects show that the mean potential temperature trends differ west and east of the Mid-Atlantic Ridge. Abyssal warming observed in the basins of the West Atlantic changes to cooling in the East Atlantic. Our measurements performed in the Vema Fracture Zone provide data on the evolution of the coldest abyssal AABW flow through the channels in the Mid-Atlantic Ridge to the deep basins of the East Atlantic. The signal of abyssal water warming observed west of the Mid-Atlantic Ridge does not propagate over the shallowest sill of the fracture zone, indicating possible change in abyssal mixing along the AABW flow.

Keywords: Decadal warming, gravity flows, in situ measurements, abyssal channels, bottom circulation

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Regional Polar Sea-Ice Biases in IITM-ERPAS and Their Implications for Teleconnections to the Indian Summer Monsoon

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ABSTRACT

Polar sea-ice variability plays a critical role in regulating the global climate by influencing atmospheric circulation, temperature gradients, and tropical climate behaviour. Rather than focusing on the entire Arctic or Antarctic as a whole, several studies highlight that regional sea-ice changes—particularly in the Barents–Kara Sea, Laptev–East Siberian–Chukchi sector, and the Indian Ocean sector of Antarctica—drive important teleconnections that affect Eurasian and monsoon-region climate (Prabhu et al., 2011; Sundaram & Holland, 2022; Kulkarni & Agarwal, 2023, 2025; Azhar et al., 2020, 2022). Therefore, understanding model performance in these sensitive regions is essential for improving climate prediction.

This study evaluates the sea-ice concentration (SIC) climatology of the IITM-ERPAS subseasonal prediction system against NSIDC observations over a 15-year period (2004–2018). The model reveals a consistent underestimation of sea ice across the central Arctic, particularly during summer and autumn. This agrees with observational research documenting enhanced melt and thinning under accelerated Arctic warming (Kumar et al., 2020; Yadav et al., 2020). In contrast, the model shows an overestimation of sea ice in the Barents–Kara region, one of the fastest-changing Arctic sectors (Kumar et al., 2021).The Pacific Arctic sector also exhibits persistent underestimation, despite earlier studies showing that sea-ice anomalies in this region are linked to strong and weak monsoon years (Sundaram & Holland, 2022; Kulkarni & Agarwal, 2025). Similarly, the model underestimates Antarctic sea ice, especially in the Indian Ocean sector, which is positively correlated with Indian Summer Monsoon Rainfall (Azhar et al., 2020, 2022).

In addition, recent literature points to several other sea-ice–climate linkages that require further investigation to fully understand how polar variability influences ISMR across different time scales.

Keywords: Sea-ice concentration (SIC), IITM-ERPAS, Arctic, Antarctic, ISMR teleconnections

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Relative Influence Of Zonal Wavenumber 3 On Antarctic Atmospheric Parameters And Sea Ice Concentration Through Phase Composite Analysis

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ABSTRACT

The Southern Annular Mode (SAM) serves as the leading pattern of atmospheric variability across the Southern Hemisphere. In contrast, the Zonal Wave-3 (ZW3) pattern constitutes another key mode, exhibiting a quasi-stationary and zonally asymmetric configuration marked by three pronounced ridges and troughs extending longitudinally through the mid-to-high latitudes of the Southern Hemisphere. This study examines the specific influence of the Zonal Wave-3 (ZW3) pattern on the Antarctic cryosphere using the European Centre for Medium-Range Weather Forecasts (ECMWF) Fifth Generation Atmospheric Reanalysis (ERA5) dataset, covering all Southern Hemisphere seasons over the period 1979–2020. Using the Marshall SAM Index along with a newly developed ZW3 index derived from 500-hPa meridional wind anomalies, the months characterized by strong ZW3 activity and weak SAM phases were identified. Composite anomalies of 500-hPa geopotential height, computed across the eight phases of the identified ZW3 months, reveal three distinct ridge and trough structures arranged in changing clockwise patterns. The barotropic nature of the atmosphere allows these patterns to influence surface wind fields. Corresponding surface wind maps show alternating southward and northward flows across three zonal bands, aligned along the isobars in accordance with geostrophic balance. These wind anomalies induce temperature variations that, in turn, affect the marginal sea ice zones, where poleward winds tend to reduce ice concentration while equatorward winds enhance it. This relationship is evident in the associated sea ice anomaly plots. Understanding the influence of ZW3 is crucial for improving Antarctic climate projections, particularly under future warming scenarios, given its significant role in modulating sea ice extent.

Keywords: Zonal wavenumber 3, quasi- stationary, barotropic, Sea ice, Antarctica

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Tree-Ring Based Climate Reconstructions In Western Himalaya: A Review

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ABSTRACT

Tree-ring studies from the Western Himalaya provide one of the few reliable means of reconstructing past climate in a region where instrumental data are sparse and short. This review synthesises findings from key dendroclimatological studies on *Cedrus deodara*, *Pinus wallichiana*, and other high-elevation conifers to evaluate their climatic sensitivity, reconstruction potential, and links to Himalayan glacier variability. Across multiple chronologies spanning 400-500 years, winter temperatures and pre-monsoon moisture emerge as the dominant controls on radial growth, while monsoon rainfall shows weaker and inconsistent influence. Warmer winters and reduced snowfall consistently enhance growth, whereas hot and dry pre- monsoon conditions suppress it. These growth-climate relationships have enabled robust reconstructions of winter temperatures, pre-monsoon moisture, and, indirectly, fluctuations in glacier mass balance. The reviewed studies also reveal coherent signals of recent warming and glacier retreat during the twentieth century. Despite strong proxy potential, major challenges remain, including limited high-altitude climate records, restricted spatial coverage, and insufficient multi-species or multi-proxy approaches. Overall, the collective evidence suggests that Himalayan conifers serve as powerful indicators of past climate variability, and expanding dendroclimatic networks across the region is crucial for enhancing the long-term understanding of Himalayan climate and cryosphere dynamics.

Keywords: Tree-ring, Western Himalaya, *Cedrus*, *Pinus*, dendroclimatology

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Advection and Thermodynamic Trapping of Absorbing Aerosols over the Indian Sector of the Southern Ocean During the Austral Summer

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ABSTRACT

Observations from two Indian Southern Ocean Expeditions (SOE-IX: 2016–17; SOE-X: 2017–18) during the austral summer were analysed to quantify the absorbing aerosol loading, vertical distribution, thermodynamic influence, and clear-sky radiative impacts over the Indian Sector of the Southern Ocean (ISSO). Shipboard measurements of aerosol optical depth (AOD), black carbon (BC) mass concentrations (M_B), size-segregated ambient aerosol mass, and radiosonde profiles of the lower atmosphere were combined with SBDART radiative transfer model simulations to derive the aerosol optical properties, Aerosol Direct Radiative Effect (ADRE), and atmospheric heating rate (HR). The open oceanic region between 50 and 60°S exhibited the highest mean AOD_{500} (0.156 ± 0.026) and M_B (90.78 ± 40.11 ng m^{-3}), leading to the largest atmospheric ADRE ($+3.10 \pm 0.38$ W m^{-2}) and HR (0.087 ± 0.011 K day^{-1}). Southern regions (60–69°S), despite exhibiting lower AOD_{500} (0.070 ± 0.017), had substantial M_B (68.81 ± 28.40 ng m^{-3}) and non-negligible ADRE ($+1.56 \pm 0.49$ W m^{-2}) owing to pervasive low-lying thermal inversions that inhibit vertical ventilation. CALIOP retrievals revealed multiple elevated and near-surface absorbing layers (polluted continental/smoke, dusty marine, polluted dust), indicating efficient long-range transport from southern Africa and Madagascar, as supported by HYSPLIT airmass trajectory analyses. Fossil fuel-derived BC dominated (> 80%) over biomass- burning-derived BC across the ISSO. Several radiosonde profiles documented multiple thermal inversions southwards of 50°S, which correlated with enhanced near-surface BC accumulation. Sensitivity simulations indicated that increasing M_B from 50 to 300 ng m^{-3} resulted in a □3–5- fold increase in the HR at three locations in coastal Antarctic waters, implying that modest increases in absorbing aerosol loading can significantly amplify local warming and potentially accelerate sea-ice melt. These observations underscore the crucial role of thermodynamic trapping and advective supply in shaping the impacts of absorbing aerosols in a climatically sensitive and pristine marine sector.

Keywords: Absorbing aerosols; Southern Ocean; Aerosol Direct Radiative Effect; Atmospheric Heating Rate; Thermal inversion

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Influence of sea-ice decline on long-term seasonal patterns of Arctic Dimethyl sulfide

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ABSTRACT

Dimethyl sulfide (DMS) is a volatile biogenic compound primarily produced through ecological interactions that include marine microbial food webs. Polar regions are major sources of seawater DMS, thereby playing a crucial role in global sulphur cycling. The Arctic Ocean, experiencing rapid warming and significant sea ice melt, is a hotspot for DMS production due to the presence of phytoplankton that produce DMS. In this study, we performed seasonal analysis of long-term (1850-2100) seawater DMS concentrations predicted by a machine learning model for the historical and future scenarios along with the predictor variables (Chl a, MLD, NO_3, PO_4, SiO_4, SOS, SST, Radiation) for the different water basins in the Arctic. In a changing climate, (from SSP126 to SSP585), we found that the Central Arctic shows the largest increase in the seawater DMS concentrations towards the end of the future scenarios. The empirical orthogonal function analysis of predictors and seawater DMS shows that radiation is a strong predictor, while sea surface temperature, mixed layer depth, chlorophyll, salinity and nutrients are secondary ones. The effect of sea-ice melting in the Arctic not only increases the DMS concentrations but results in a strong seasonal shift due to global warming. This shift is strong in the Central Arctic, Beaufort Sea, Kara Sea, Canadian Arctic and the Chukchi Sea. Most of the Arctic shows an increase in the seawater DMS concentration values except the Greenland, Iceland, Norwegian Seas.

Keywords: Dimethyl sulfide, Sea-ice, Arctic, Climate change, Seasonality

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Investigating The Role Of Arctic Sea Ice And Atlantic Sea Surface Temperature On The Variability Of Indian Summer Monsoon

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ABSTRACT

Polar sea ice plays a significant role in the Earth's climate system by regulating the exchange of heat, momentum, and moisture between the atmosphere and the ocean. However, Arctic sea ice has shown a rapid decline since the beginning of the 21st century. It is melting at a faster rate than anywhere else, making it highly susceptible to the impacts of global warming. Anthropogenic forcings, as well as the internal variability of the climate system, are considered the drivers of such rapid changes. It is noted that slight variations in ocean, atmospheric, and cryosphere parameters over the Arctic region have a significant effect on global climate. In this study, we examine one such impact of Arctic sea ice- the influence of spring Arctic sea ice on the Indian summer monsoon (ISM). For this study, we analysed multiple datasets from 1951 to 2020. Preliminary studies using the National Centre for Environmental Prediction (NCEP) and the National Centre for Atmospheric Research (NCAR) dataset, India Meteorological Department daily gridded rainfall data, Monthly Sea Ice Extent and Concentration, 1850 Onward, V2 data, and HadISST1.1 data indicate that during many of the spring (March-May) season, before a strong ISM year accompanied more sea ice near West Greenland near Labrador, and less over the Greenland-Iceland-Nordic Sea, along with North Atlantic SST patterns similar to that observed during the positive phase of North Atlantic Oscillation (NAO). More analysis is required to understand the interaction between Arctic sea ice, Atlantic SST, and their combined influence on ISM. The study demonstrates a new teleconnection between the Arctic and the tropics.

Keywords: Arctic Sea ice, Indian Summer Monsoon, Atlantic SST, North Atlantic Oscillation, Teleconnections

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Relationship of Indian summer monsoon rainfall with Antarctic sea ice

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ABSTRACT

Antarctic sea ice fluctuations have an immense capability to impose large-scale variations on the global climate. Physical processes underlying the polar-tropical linkages are complex in nature. Present study identifies a sector-based Antarctic sea-ice relationship with the Indian summer monsoon rainfall (ISMR). To address the objectives of this study, passive microwave satellite data of sea ice area (SIA), over five sectors of Antarctic archived by National Snow and Ice Data Center has been utilized for the period 1983–2015.

Out of the five sea-ice sectors of Antarctic considered along with total Antarctic, SIA variability over Bellingshausen and Amundsen Seas (BAS) and Western Pacific Ocean (WPO) is observed to have robust concurrent linkages with the ISMR. During the boreal summer, an in-phase (out-of-phase) significant relationship is observed between the WPO (BAS) SIA and ISMR. Next, a significant inverse relationship between the El Niño Modoki Index (EMI) and ISMR is observed to gradually strengthen from the month of June that persists for the entire boreal summer monsoon season. Further, lead-lag correlations demonstrate a significant direct (inverse) relationship of July SIA over BAS (WPO) with June-September (JJAS) season EMI of the concurrent year. Furthermore, regional aspects of rainfall over India with respect to the relation with SIA over BAS and WPO along with EMI are also investigated. A spatial correlation of rainfall over India with EMI and BAS SIA during JJAS shows a significant negative relation over northern and southern parts of India. On the other hand, the WPO SIA is positively correlated with rainfall over parts of central and northwest India. The chief features of a regional correlation pattern for concurrent July SIA with rainfall over India are similar to its counterpart during the July-September season for both BAS and WPO sectors.

Key words: Indian summer monsoon, Antarctic sea ice, satellite data, Bellingshausen and Amundsen Seas, Western Pacific Ocean

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Microbial community dynamics and their responses to climate-change induced variations in Kongsfjorden.

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ABSTRACT

The Arctic is warming at an alarming rate (four times faster than the global average), resulting in a decline in sea ice cover, glacier retreat, and permafrost thaw. The declining sea ice cover has led to increased primary production and the expansion of macroalgal beds in the coastal Arctic, resulting in the contribution of marine organic matter. The wet precipitation events have led to increased transport of sediments and terrigenous organic carbon from glacial and permafrost to the Arctic fjords. In addition, the intrusion of warmer Atlantic water and longer melt periods are expected to affect the magnitude and composition of export fluxes of biogenic matter in the high Arctic Fjords such as Kongsfjorden. Although microbes play a crucial role in biogeochemical processes, the effects of climate-change-induced variations on microbial community metabolism and composition are not well understood. To address this knowledge gap, we have conducted a series of studies over the past decade that evaluate the microbial community dynamics and their responses to various aspects of climate change in Kongsfjorden. Highlights of our results include

1) community composition and assembly mechanism of particle-associated (PA) and free-living (FL) microbes, crucial for particulate organic matter (POM) degradation and carbon flux to deeper depths, and 2) specific microbial groups respond to the increased supply of macroalgal- carbon during summers in Kongsfjorden.

Keywords: Microbial ecology, bacteria, Archaea, Arctic Fjord, macroalgae, particle-attached, free-living

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Marine Siderophores: Distribution, variants, and ecological significance in contrasting environments of the Indian Ocean basin.

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ABSTRACT

The primary productivity in the Indian Ocean Basin, including Bay of Bengal (BoB), Arabian Sea (AS), and the Indian sector of Southern Ocean (ISO), is co-limited either by seasonal availability of nutrients, trace metals like Fe, light, and oceanographic conditions like MLD. Iron is a major limiting factor in surface waters of BoB and ISO whose uptake by phytoplankton and microbes is facilitated by organic ligands like Siderophores. Siderophores are low molecular weight organic ligands with high affinity for iron, and are either cell membrane bound (amphiphilic) or exogenous (hydrophilic). Phytoplankton like diatoms do not produce siderophores but can take up iron bound to exogenous siderophores (xenosiderophores) to meet their Fe-demand. In this study, we present the first set of siderophore dataset collected from 3 depths (surface, Deep Chlorophyll Maxima-DCM, 200 m) at 8 stations in ISO and 1 station before and after a cyclone in BoB. Samples were also collected for chlorophyll *a*, nutrients, and total bacterial abundance. For siderophores, 100 L of <1 kDa fraction seawater was passed through XAD-16 column using a peristaltic pump. Adsorbed siderophores were eluted in Methanol (300 ml) and the eluent was analyzed using HPLC-ESI-Q-ToF-MS for characterization and quantification. Further, molecular docking was carried out to ascertain the binding energy of the major siderophores. More than 15 different siderophores were identified in both ISO and BoB waters. Ferrioxamines were dominant in both ISO and BoB. The binding energy was least in Ferrioxamine and high in Acinetoferrin, suggesting that Ferrioxamine-Fe complex was more stable than other major siderophores. In BoB, a sharp increase in the phytoplankton biomass (chl *a*) in DCM was observed post cyclone, with a concomitant change in siderophore concentrations. Our results show that distribution and composition of siderophores is influenced by biotic factors, vertical mixing, and hydrography.

Key words: Siderophores, Indian Ocean, Southern Ocean, Molecular Docking, Iron.

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Existence Of Rare Actinobacterial Forms In The Indian Sector Southern Ocean And Their Biosynthetic Potential

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ABSTRACT

Microbial communities in the Southern Ocean (SO) play a significant role in the global biogeochemical cycling. Actinobacteria, one of the major group of microbes in the SO and being the largest contributor of natural product discovery, still remains untapped in the ecosystems of SO. The focus of our study was to explore the diversity of Actinobacteria in different depths of water samples from the Indian sector of SO (ISO). During 11th expedition of ISO, water samples were collected from 3 depths (surface, DCM and 200m) at 10 different locations along the cruise track. Culture dependent and non-cultivable forms were studied to determine the diversity of actinobacterial genera. Metagenomic analysis revealed presence of numerous unknown genes. *Agromyces, Brachybacterium, Corynebacterium, Dietzia, Glutamicibacter, Gordonia, Microbacterium, Mycobacterium, Nocardioides, Psuedonocardia, Rhodococcus* and *Sva0996 marine groups* were the most prominent genus of Actinobacteria obtained from metagenomic analysis. Rare actinobacteria such as *Chryseoglobus indicus, Micrococcus luteus, Rhodococcus erythropolis, Brachybacterium* sp., *Microbacterium oxydans, Streptomyces harbinensis* and *Brevibacterium casei* were isolated by culture dependent approach and identified by 16S rRNA sequencing. Pigmented, non-filamentous actinobacterial genera are dominantly present in the Indian Sector of Southern Ocean (ISO). Whole-genome sequencing and comparative genomic analysis of one actinobacterial strain, *Streptomyces sp.* SOSIST-3 confirmed its taxonomic classification and unveiled a rich repertoire of biosynthetic gene clusters, including many with low or uncharacterized similarity to known pathways. These results revealed the existence of diverse rare actinobacterial forms in the ISSO, and the potential of the presence of diverse cryptic BGCs, coupled with functional genes associated with environmental resilience, positions SOSIST-3 as a strong candidate for bioprospecting and novel antibiotic discovery.

Keywords: Actinobacteria, Southern Ocean, Indian Sector, diversity, taxonomy, Biosynthetic potential

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The Drivers Of Under-Ice Phytoplankton Bloom In The Coastal Waters Of Prydz Bay, East Antarctica

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ABSTRACT

In the coastal waters of Prydz Bay, East Antarctica, the seasonal retreat of land-fast sea ice creates a critical window for phytoplankton growth, forming the base of the polar marine food web. To investigate the factors controlling these under-ice blooms, we conducted high-resolution temporal sampling over a month-long period during the austral summer of 2022/2023. We analysed water column parameters, including temperature, salinity, phytoplankton composition, chlorophyll *a*, macronutrient concentrations, and the dynamics of both particle-attached (PA) and free-living (FL) bacterial communities. Our time-series data revealed two distinct phytoplankton bloom events, characterised by a rapid drawdown of macronutrients and a corresponding surge in chlorophyll *a*, which peaked at 50.05 µg L^{-1}. The rapid depletion of surface nutrients would typically lead to a collapse of the bloom. However, we found that the system was sustained by a vital biotic interaction: bacterial nutrient recycling. Particle-attached bacteria performed the initial degradation of organic matter from the bloom, releasing dissolved nutrients that were subsequently utilised by free-living bacteria and, crucially, by the phytoplankton to fuel a second bloom event. This synergistic relationship allowed the ecosystem to maintain high productivity even under potentially nutrient-limited conditions. Our findings underscore that the development and persistence of under-ice blooms are not governed by a single factor but by a tight coupling between physical ice processes and a complex microbial loop, highlighting the essential role of these under-ice blooms in modulating Antarctic coastal productivity.

Keywords: Phytoplankton; free-living bacteria; particle-attached bacteria; under-ice bloom; Prydz Bay

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Arctic Fjord Bacteria as a Sustainable Source of Cold-Active Biocatalysts

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ABSTRACT

A total of 94 bacterial isolates obtained from Kongsfjorden and Krossfjorden were evaluated for cold-active hydrolytic enzymes, comprising 35 psychrophiles and 59 mesophiles. All isolates were screened for amylase, protease, lipase and cellulase activities using substrate-based plate assays incubated at 4–15 °C. Among the psychrophiles, 17 isolates showed clear hydrolysis zones at low temperatures, while mesophiles displayed minimal or no activity below 10 °C. Nine psychrophilic isolates exhibited multi-enzyme activity. Based on plate-screening performance, 12 high-activity isolates were shortlisted for secondary assays. Temperature–activity profiling confirmed that six isolates retained 40–70% activity at 10 °C, and three maintained measurable activity at 4 °C, indicating strong cold adaptation. Stability tests demonstrated that four isolates retained activity for up to 48 hours at 4 °C. A cold-water substrate-degradation test further validated functionality for two lead isolates under application-like conditions. Preliminary phenotypic and biochemical characterisation was completed, and 16S rRNA sequencing is ongoing. The results demonstrate significant cold-active enzymatic potential among Arctic psychrophilic bacteria and provide a basis for targeted purification, gene-level identification and evaluation for low-temperature industrial applications.

Keywords: Psychrophilic bacteria; Cold-active enzymes; Arctic fjords; Hydrolytic activity; Industrial biotechnology.

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Picophytoplankton succession under biophysical and chemical influences in the Indian sector of the Southern Ocean during the austral summer

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ABSTRACT

The Southern Ocean, a region characterized by high nutrient levels but often low productivity, hosts dynamic picophytoplankton communities crucial for its food web. This study investigated the spatial and inter-annual variability of picophytoplankton abundances and their environmental drivers in the Indian sector of the Southern Ocean during the austral summers of 2018 and 2020. Using flow cytometry for picophytoplankton quantification and standard oceanographic methods for environmental parameters (temperature, salinity, nitrate, phosphate, silicate), we employed descriptive statistics, inferential group comparisons (*t*-tests, analysis of variance), principal component analysis (PCA) and principal component regression (PCR) to analyse the dataset. Our analyses revealed significant differences in picophytoplankton abundances and environmental conditions across distinct oceanic fronts, between deep chlorophyll maximum and surface depths and, notably, between the two study years. PCA identified three major environmental gradients explaining over 93.5% of the variance in temperature, salinity, nitrate, phosphate and silicate. PCR confirmed our hypothesis: the abundance and carbon biomass of picoeukaryote II (PEUK-II) picophytoplankton was statistically significant overall (F-statistic = 3.415, P = 0.0290). The model explained 24.2% of the variance in PEUK-II abundance ($R2$ = 0.242), indicating its sensitivity to dynamic oceanographic conditions, with PC3 (primarily representing a salinity gradient) being a significant predictor. Conversely, *Prochlorococcus*- like/*Synechococcus* picophytoplankton abundance was not statistically significant overall (F- statistic = 2.068, P = 0.124), suggesting control by other, potentially non-linear factors. These findings highlight distinct ecological strategies among picophytoplankton groups and are vital for predicting their roles in the Southern Ocean's microbial food web amidst ongoing environmental change.

Keywords: Picophytoplankton, Southern Ocean, Principal Component Analysis (PCA), Environmental gradients, Carbon biomass

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EPS-Mediated Biofilm Formation On Glass And Polystyrene Surfaces By Polar Isolates

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ABSTRACT

Extracellular Polymeric Substances (EPS) secreted by microorganisms in polar environments play a vital role in enhancing survival under extreme conditions by facilitating biofilm formation and surface adhesion. EPS is essential for microbial colonization on diverse substrates such as rocks, sediments, and, increasingly, plastic debris. Understanding how EPS-producing microbes interact with various surfaces, including plastics, is critical for studying microbial surface dynamics relevant to both polar ecosystems and anthropogenic pollution. Microplastics (MPs) are one such group of anthropogenic pollutants that provide surfaces to be colonized by microorganisms, forming the "plastisphere." EPS plays a key role in microbial colonization of MPs by regulating initial adhesion, irreversible attachment, and subsequent biofilm maturation. Since the biochemical composition of EPS differs across microbial isolates, such compositional differences may influence the microbial interaction with different substrates. Moreover, different plastic types may favor different EPS-producing microbes. Therefore, it can be hypothesised that EPS–MP interactions in marine environments are substratum-specific, and shaped by different microbial communities. This study aims to demonstrate that EPS composition and surface material together shape microbial colonization on substrata including glass & polystyrene. A comparison of surface colonization experiments aims to investigate the factors that may influence surface colonization by diverse EPS-producing communities and its implications on pollutant transfer, and plastisphere persistence in polar marine environments.

Keywords: Extracellular Polysaccharides, Polar microbes, Microplastics, Biofilm, Microbial colonization

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Ferrioxamine Production And Iron Binding By *Stutzerimonas Stutzeri* From The Indian Sector Of Southern Ocean

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ABSTRACT

The Southern Ocean, rich in macronutrients, plays an important role in regulation of global climate and supporting marine ecosystems in the mid and lower latitudes. Despite the high concentrations of macronutrients, primary productivity in this region remains limited due to the scarcity of dissolved ferrous iron (Fe^{2+}). Iron predominantly exists in its ferric form (Fe^{3+}), making it unavailable for biological uptake and characterizing the Southern Ocean as a high-nutrient, low-chlorophyll (HNLC) zone. To overcome the demand for bioavailable Fe, bacteria produce siderophore (a low molecular weight iron chelating organic ligands) to enhance the binding and transport of iron. During 11th Indian Scientific Expedition to the Southern Ocean (ISESO-11) in 2019-20, one of the several siderophore producing bacteria isolated was identified as *Stutzerimonas stutzeri* by 16s rRNA Sanger sequencing method. This isolate was found positive siderophore by chrome azurol sulphonate (CAS) assay and showed a 75±0.3 % siderophore production in CAS liquid assay. During the optimization for siderophore production, it was observed that modified artificial seawater medium supplemented with starch as carbon source, incubation temperature of 20°C, pH 8 and Fe concentration of 1µM promoted maximum growth and siderophore production. Further, LC-ESI-MS (liquid chromatography-electronspray ionization-mass spectrometry) analysis of the siderophore extracted using XAD-2 & XAD-16 revealed hydroxamate type siderophores namely ferrioxamines as dominant siderophores. Molecular docking revealed thermodynamically stable complex with Fe^{3+} indicating strong binding affinity. This study sheds light on the role of ferrioxamines in iron acquisition by *S. stutzeri* in the iron limited Southern Ocean waters.

Keywords: *Stutzerimonas stutzeri*, Ferrioxamines, LC-ESI-MS, Docking, Southern Ocean

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Characterisation of Deep Chlorophyll Maxima in the Indian Sector of the Southern Ocean and their contribution to water column productivity

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ABSTRACT

The Deep Chlorophyll Maximum (DCM) represents a subsurface peak in phytoplankton biomass, commonly observed in stratified waters. While in tropical oceans the DCM is governed by the trade-off between light availability and nutrient limitation, its formation in the Southern Ocean (SO) is driven by a more complex interplay of factors, including iron availability, sea ice retreat, photoacclimation, and regional hydrodynamics. As climate-induced stratification is expected to intensify, understanding the vertical structure of net primary productivity (NPP) and the role of subsurface production is crucial for predicting future changes in ocean productivity and the biological carbon pump (BCP). This study investigates the spatial variability, structure, and drivers of the DCM across different frontal systems and the Seasonal Ice Zone (SIZ) in the Indian Sector of the Southern Ocean (ISSO), using *in situ* and satellite-based observations. The DCM depth ranged between 20 and 120 m, shaped by the interplay of light, nutrients, and water mass characteristics. Distinct regional characteristics were observed in the North of the Subtropical Front (NSTF), dual DCM peaks (30-100 m) formed under strong thermal stratification, contributing ~18% to the integrated primary production (IPP). In the Subtropical Front (STF), lateral nutrient divergence supported shallow dome-shaped DCMs, while near Kerguelen Island, shallow and intense DCMs aligned with the ferrocline due to island-derived iron inputs. In the Polar Front-1 (PF-1) region, weak multiple DCM peaks (40-120 m) coincided with the nitracline and contributed substantially (~31%) to the IPP. In contrast, the Polar Front-2 (PF-2) generally lacked DCM, except in 2016 when salinity stratification from meltwater entrainment facilitated its formation. In the SIZ near Prydz Bay, shallow, low-magnitude DCMs followed post-bloom conditions and accounted for ~31% of the IPP. Overall, DCM variability in the ISSO reflects the combined influence of stratification, nutrient-light balance, and regional biogeochemistry. Its depth and magnitude significantly impact regional productivity and carbon export, underscoring its crucial role in the Southern Ocean's carbon cycle.

Keywords: Deep Chlorophyll Maxima, Phytoplankton, Productivity, Southern Ocean

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Changes in the Arabian Sea oxygen minimum zone intensity: Inferences from a sediment core.

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ABSTRACT

The Arabian Sea encompasses one of the tropical open ocean oxygen minimum zones (OMZ) of the world ocean with denitrifaying conditions. Changes in water circulation, productivity, and water masses play an important role in the formation and sustenance of OMZ. For the present study, a sediment core of 2m in length was collected from the perennial Arabian Sea OMZ and studied for downcore variations in total organic carbon (TOC), total nitrogen (TN), $CaCO_3$, nitrogen isotopes, and rock magnetic properties to infer changes OMZ intensity off Goa. The TOC ranges between 1.5 and 4.1 % and $CaCO_3$ ranges between 28.5-62.2%. The nitrogen isotopic ratios ($\delta^{15}N$) exhibit variations between 5 and 7.3 ‰ suggesting changes in the denitrification in the intermediate waters at the core site. Magnetic susceptibility (z_{lf}) ranges between 4 and 59 $x10^{-8}$ m^3 kg^{-1} with lower values observed in core below 80 cm. There is an increase in z_{lf} above 80 cm suggesting an increase in oxygenation of water at core site. These results indicate that denitrification strength has undergone changes in the Arabian Sea, which suggests variations in the intensity of OMZ at the upper boundary. Whereas, changes in rock magnetic parameters suggest that there may have been changes in the intensity in OMZ at the lower boundary as well.

Keywords: Arabian Sea, oxygen minimum zones, sediment core, denitrification, Magnetic susceptibility

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Past Eight Million Years Of Paleoclimatic Variability From The Western Arabian Sea

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ABSTRACT

The Arabian Sea region is of particular importance in understanding the evolution of the South Asian monsoon (SAM), as monsoonal winds affect both the oceanic circulation pattern and biological activities across seasons in the Arabian Sea. The Arabian Sea oxygen minimum zone (OMZ) is inferred to be the third most voluminous OMZ in the world and covers the fourth largest area in the global ocean. Magnetic minerals, specifically biogenic magnetic minerals, are sensitive to the variability of the OMZ. In this work, we analysed natural remanent magnetization (NRM), magnetic susceptibility (□), anhysteretic remanent magnetization (ARM), and isothermal remanent magnetization (IRM) on sediment samples from the Ocean Drilling Program (ODP) site 728B in the Oman Margin. An increasing trend in magnetic mineral abundance between 7 and 5.8 Ma, 4.2 and 3.8 Ma, and 2 and 0.8 Ma indicated increased detrital content in response to increased erosion. The increased erosion of the catchment continental rocks implies strengthened SAM conditions during the ages mentioned above.

Keywords: Arabian Sea; Environmental Magnetism; Paleoclimate; South Asian Monsoon

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Paleoenvironmental Controls on the Abundance and Diversity of Magnetofossils in the Northern Indian Ocean

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ABSTRACT

Magnetofossils are nanometre sized magnetic fossil relict of magnetotactic bacteria (MTB) that are widely distributed in marine sediments. Previous studies have revealed that changes in the abundance and diversity of magnetofossils in marine sediments are closely linked with paleoenvironmental conditions. In this work, we applied suite of rock magnetic measurements followed by transmission electron microscopy on the marine sediment samples and separated magnetic fractions to identify and characterize the magnetofossils in the different areas of the northern Indian Ocean. Magnetic coercivity and mineralogy diagnostic proxies including first order reversal curve [FORC] diagrams, low temperature magnetic measurements, and magnetic hysteresis curves indicated large variability in the magnetic properties of magnetofossils, which appears to be site specific. Electron microscopy results confirmed that conventional and giant magnetofossil are abundant, more widespread and spatially distributed within northern Indian Ocean. The outcome of this work exploring the biomagnetism potentials of the northern Indian Ocean greatly expand our understanding on the environmental factors controlling the genesis and preservation of magnetofossils in the modern and ancient sediments.

Keywords: Magnetotactic Bacteria, Magnetofossil, Biomagnetism, Northern Indian Ocean, Rock Magnetism, Electron Microscopy

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Magnetic Stratigraphy of paleolakes in Himalayas: implications to the geomagnetic excursions and environmental changes

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ABSTRACT

The global climate system, particularly the climate of Southern Asia, is greatly influenced by the enormous Himalayas and Tibetan Plateau. The Indian Summer Monsoon and Winter Westerlies, which have various degrees of impact on the Himalayan region, are mostly to responsible for the shifting climate regime. Lakes that originated during previous glacial eras are known as paleolakes in the Himalayas. Understanding geomagnetic excursions and their effects on climate change can be aided by examining the magnetic stratigraphy (MS) of these paleolakes. In order to identify geomagnetic excursions, particularly the younger ones, and to comprehend historical climatic changes in the Himalayas, we conducted paleomagnetism, rock magnetism, and MS of five paleolakes (Bagwalipokar, Ramganga, Bhimtal, Spituk, and Lamayuru) in the western Himalayan belt. The main magnetic carrier mineral in these paleolakes appears to be magnetite/titanomagnetite, according to rock magnetic investigations. In the Bagwalipokar paleolake, two geomagnetic excursions were detected at younger levels [11.6–10.5 m (15.5–14.7 ka) and 15–11.7 m (8.0–2.85 ka)], which correlate with the previously documented younger Hawaiian lava flow excursions. The cooling event of an oxygen isotope record of biogenic carbonate from Palaeolake that started at 8.2 ka may be responsible for the youngest excursion from 8 ka.The history of the Indian Summer Monsoon from approximately 11 to 6 ka BP, the North Atlantic glacial outburst flood, and the slowdown of the Atlantic meridional overturning circulation may all be found at Riwasa in northwest India. Three geomagnetic excursions associated with global events have been identified by MS of the Ramganga paleolake: the Mono Lake Event (about 28.4–25.8 ka), the Gulf of Mexico Event (around 12.5–17 ka), and the Bagwalipokar Excursion Events (15.5–14.7 ka and 8-2.85 ka, respectively). Because of the wet and dry climates, the lower and middle sections of the Ramganga paleolake reflect the low and high energy depositional environments during sediment deposition.

Keywords: Magnetic Stratigraphy; Geomagnetic excursions; Paleomagnetism; Environmental changes

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Rock Magnetic Signatures Of Late Quaternary Terrigenous Influx And Monsoon Variability Off The South-Eastern Indian Margin

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ABSTRACT

A high-resolution record of rock magnetic variations from sediment core SK343/GC-02 retrieved from the continental margin off Kalpakkam, western Bay of Bengal, provides history of Late Quaternary terrigenous influx and monsoon variability. The core spans the last ~23 ka and records distinct rock magnetic changes associated with climatic transitions. Magnetic parameters such as magnetic susceptibility (χ_{lf}), anhysteretic remanent magnetization (χ_{ARM}), and saturation isothermal remanent magnetization (SIRM) indicate variations in ferrimagnetic mineral concentration linked to detrital input from the Palar River. Higher values of χ_{lf} and SIRM reflect increased terrigenous flux under strong monsoonal conditions and *vice versa*. Enhanced detrital influx from the Palar River to the continental shelf occurred during 22,000–15,000 cal. years B.P. (representing the later phase of the Last Glacial Maximum) and 11,000–7200 cal. years B.P. (Early Holocene Climatic Optimum), reflecting intensified northeast monsoon activity. In contrast, diminished riverine input around ~23,200–22,000 cal. years B.P. (initial phase of the LGM), ~14,800–12,900 cal. years B.P. (Bølling–Allerød), and 7200–4900 cal. years B.P. (Mid-Holocene Aridity) signifies periods of weakened monsoonal strength. The mid-Holocene interval (~5 ka BP) exhibits a distinct rise in magnetic mineral concentration, interpreted as increased sediment delivery associated with tectonic uplift and river rejuvenation within the Palar basin. Hysteresis and thermomagnetic analyses confirm magnetite as the dominant ferrimagnetic phase, with Curie temperatures of 570–580 °C. Day- Dunlop plots reveal predominantly pseudo–single-domain grain sizes, with minor contributions from superparamagnetic particles indicative of pedogenic inputs. The rock magnetic data collectively record alternating phases of fluvial intensification and climatic aridity to Late Quaternary monsoon variability. These results demonstrate the efficacy of environmental magnetism as a proxy for decoding climate-driven sedimentation processes in tropical continental shelf settings.

Keywords: Environmental magnetism, terrigenous influx, hysteresis, thermomagnetic curves, Late Quaternary.

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Environmental Magnetic Evidence for Marine–Lacustrine Transitions in a Coastal Antarctic Lake

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ABSTRACT

Coastal lakes in Antarctica serve as valuable archives of past climatic and environmental changes. Their evolution is closely linked to relative sea-level (RSL) variations driven by deglaciation, making them ideal natural laboratories for investigating marine–lacustrine transitions and reconstructing paleo–sea-level histories. This study presents a high-resolution reconstruction of mid- to late-Holocene paleoenvironmental changes from Heart Lake, a low-elevation coastal lake in the Larsemann Hills, East Antarctica. Accelerator mass spectrometry (AMS) ^{14}C dating of bulk organic matter indicates that the sediment core spans from 6.37 to 0.25 cal ka BP. Downcore diatom assemblages and magnetic susceptibility parameters were analyzed to delineate the marine–lacustrine transition and infer past environmental conditions. Based on these results, the core was divided into three zones: Zone 1 (112.5–18 cm; 6.37-3.07 cal ka BP) representing marine conditions of a former submarine basin, Zone 2 (17–9 cm; 3.07-1.75 cal ka BP) marking a transitional phase, and Zone 3 (8 cm to core top; 1.75-0.25 cal ka BP) reflecting freshwater conditions. Zone 1 exhibits elevated values of magnetic concentration–dependent parameters (χ_{lf}, χ_{ARM}, and SIRM), likely reflecting enhanced input of glacially-derived sediments from the nearby Dalk Glacier (~2.5 km). In Zone 2, a marked decrease in these parameters, accompanied by higher χ_{fd}% indicates intensified pedogenesis and relatively warmer climatic conditions. The mixed diatom assemblages of marine and freshwater taxa in this zone signify progressive isolation of the basin due to glacio-isostatic uplift. Zone 3 is characterized by dominant freshwater diatoms and low magnetic mineral concentrations, reflecting the establishment of a stable freshwater environment. This reconstruction enhances our understanding of Holocene deglacial dynamics in the Larsemann Hills and offers a baseline for future paleoclimate and sea-level studies across East Antarctica.

Keywords: Environmental magnetism, diatom, marine-lacustrine transition, coastal lake, East Antarctica.

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Charting the effects of multi-components and magnetostatic interactions on sediment magnetism

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ABSTRACT

One timeless challenge in rock and environmental magnetism is to characterize magnetic minerals before linking their type or abundance to geological or environmental processes. This is particularly critical in paleoclimatic and paleoenvironmental studies of marine sediments, where magnetic assemblages always comprise multiple components of often unknown origin. Subsequently, the estimation and use of bulk magnetic parameters largely underestimate the underlying fundamental diversity in magnetic property changes with size, arrangement, anisotropy, concentration, and mineralogy, which many times leads to incomplete or sometimes ambiguous interpretation of crucial climatic events or diagenetic processes. To examine how these complexities affect bulk magnetic parameters, this study uses first-order reversal curve (FORC) diagram simulations based on fundamental principles of micromagnetic modelling. We obtain solutions for basic and simplistic geometries such as random, cluster, and chain of single domain particles with anisotropy and separation controls capturing variability mostly observed in marine sediments. Magnetic anisotropy variations (uniaxial to cubic) provide indirect representation of high coercivity minerals. Our results show that overlapping coercivities and strong magnetostatic interactions, characteristic of collapsed magnetotactic bacterial chains or framboidal greigite clusters, cannot be resolved using bulk magnetic parameters such as susceptibility and remanent magnetization. We conclude with few examples of natural samples including marine sediments to showcase the real experimental counterparts and provide recommendations for the regularization of FORC diagrams and integration of multi-method magnetic approaches for robust mineralogical interpretation and independent confirmations.

Keywords: Sediment Magnetism, Multicomponents, Magnetostatic Interactions, FORC Digram, Magnetic Ansiotropy, Bacterial Chains

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Environmental Magnetism for Tracing River Sediment Sources from a Debris-Covered Himalayan Glacier, Central Himalaya

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ABSTRACT

Glacial sediments derived from the Gangotri Glacier, a prominent debris-covered glacier in the Himalaya, were investigated using environmental magnetism to characterise their magnetic mineralogy, grain-size (domain-state) distribution, and probable provenance. Suspended sediments were sampled continuously over the full ablation season, complemented by sediment samples collected from the glacier's debris cover. The sediments were subjected to an array of environmental magnetic analyses involving measurement of low- and high-field (χlf and χhf) magnetic susceptibility, Isothermal remanent magnetisation (IRM) acquisition curve, coercivity spectra, hysteresis loops and thermomagnetic (χ-T) curves. The mean of χlf values is 5.22 $\times 10^{-8}$ m^3/kg, while the mean of χhf values is 5.23 $\times 10^{-8}$ m^3/kg, which are in line with each other, suggesting minor frequency dependence of magnetic susceptibility. The IRM acquisition curves and coercivity spectra of most of the samples have saturation below 400 mT and coercivity below 60 mT (i.e., low coercivity), respectively, implying probable dominance of magnetite. The hysteresis measurements show S-shaped narrow loops, which justify the fine-grained magnetite's presence in samples with very low contribution of para-/diamagnetic component. The domain state characterisation suggests that most of the studied samples are of a single- domain (SD) nature. Further, the χ-T curves of most of the studied samples displayed a well- defined Curie temperature (Tc) at ~580 °C, supporting the predominance of magnetite in these glacial sediments. The near identical mean χlf (5.22 $\times 10^{-8}$ m^3/kg) and mean χhf (5.23 $\times 10^{-8}$ m^3/kg) values and consistent environmental magnetic properties inferring dominance of SD magnetite in samples, suggesting the sediments derived from a less weathered unit. This provides evidence for the subglacial mechanical origin of sediments, which might have come from the same lithological unit.

Keywords: Environmental magnetism, Magnetite, Glacial sediments, Central Himalaya

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Magnetic signatures of sediments along the Carlsberg Ridge: Insights into hydrothermal activity

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ABSTRACT

Hydrothermal activity at mid-ocean ridges (MORs) is well known for its association with metalliferous deposits in the sediments. Both hydrothermal vent (active/extinct) distribution and sediment studies along the Carlsberg Ridge (CR) remain limited. We have collected eight spade cores from the valley and flank regions of the CR and analysed for magnetic susceptibility (χlf) and laboratory-induced remanent magnetizations. Results indicate that sediments from the ridge valley exhibit higher χlf values compared to the ridge flank. Sediments closer, as well as ~250 km away to the identified vent site display high χlf, Saturation Isothermal Remanent Magnetisation (SIRM), Hard Isothermal Remanent Magnetisation (HIRM), and low anhysteretic remanent ratio (χARM/SIRM), with the signature of coarse Stable Single Domain (SSD) and fine SSD & Mixture grains with magnetite as the dominant mineral, suggesting new active/relict site/sites in the vicinity. Low magnetic mineral concentration with SSD/SP transitional grainsize observed in flank sediments and in two cores from the ridge valley may indicate the absence of hydrothermal activity. Conventional methods for locating hydrothermal vents along MOR are typically costly and require much time. As a non-destructive and rapid technique, rock magnetic properties can identify magnetic signatures in the sediments linked to hydrothermal activity and guiding the selection of sites for detailed exploration. We demonstrate rock magnetic analyses can be used to characterize sediments near and away from hydrothermally active/extinct areas at the CR.

Keywords: Sediment, Magnetics, Hydrothermal, Carlsberg Ridge, Mid Ocean Ridge

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Application Of Mineral Magnetic Techniques For Detecting Ash Layers In The Andaman Sea Sediments

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ABSTRACT

The Andaman Sea encompasses the trench - volcanic arc – back arc system extending from Myanmar in the north to Sumatra in the south. The Andaman – Sumatra - Java volcanic arc consists of several subaerial and submarine volcanoes. Several sedimentary records collected from the Andaman Sea have reported the presence of volcanic ash layers offering valuable clues to past volcanism and tectonism of the region. Despite its significance, identifying and characterizing these ash layers within marine sediment cores remains a challenging and time-consuming process. In this study, a sedimentary record from the Andaman Sea is utilized to reconstruct the eruptive history of a submarine volcano using mineral magnetic and geochemical properties. The glass shard abundance throughout the sediment core was determined by manually counting the coarse fraction of the sediments. The abundance of glass shards of the core reveals the presence of three ash layers (AL-1, AL-2 and AL-3). Geochemical analyses of the glass shards show that ash layer 1 is rhyolitic in composition while ash layers 2 and 3 are andesitic and dacitic. Magnetic concentration parameters display a threefold increase in the values in sedimentary layers containing mafic volcanic ash (AL-2 and AL-3) relative to background sediments illustrating the utility of magnetic properties in unambiguously identifying ash layers even in regions with a very high background volcanoclastic sedimentation. However, magnetic properties do not show considerable variation in AL-1 as felsic ash layers are rich in feldspar glass and poor in magnetic minerals and are difficult to detect using magnetic properties alone.

Keywords: Mineral Magnetism, Andaman Sea, Submarine Volcanism, Subduction Zone, Volcanic Glass

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Magnetic Fingerprinting Of The Bedload Sediments From The Estuaries Of Tiracol, Chapora, Sal, Talpona & Galgibag Rivers - West Coast Of India

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ABSTRACT

The present study sets out to elucidate how magnetic minerals derived from wide array of source regions respond to source to sink processes in complex estuarine systems along goa westcoast. Characterizing magnetic minerals in the Goa estuarine zone is made easier by the region's varied geology, climate, and oceanography. The environmental factors that impact magnetic materials during transportation often leave an imprint on the mineral from the point of origin to the sink. Total of 140 samples collected from five estuarine systems from goa west coast were analyzed for magnetic measurements including dual frequency magnetic susceptibility, anhysteretic remanent magnetization (ARM), isothermal remanent magnetization (IRM), grain size analysis, and total organic carbon (TOC). Magnetic susceptibility of all rivers showed discrete zones of enrichment and depletion of magnetic mineral distribution throughout, relatively high S-ratio of sediments suggest the presence of ferrimagnetic minerals throughout whereas low S-ratio indicative of dominance of antiferromagnetic minerals. Cyclic variations in magnetic grain size diagnostic proxy (Fd% and ARM/SIRM) revealed the changes in the distribution of fine and coarse grained magnetic particles linked with weathering and erosion of catchment rocks. Temperature dependence of magnetic susceptibility (χ-t) curves confirmed the presence of magnetite, titanomagnetite and titanohematite particles. Scanning electron microscopy data indicated the presence of varying size, sharp edge magnetic particles at the river catchment and sub rounded to rounded particles at nearshore indicates the varying morphology due to transportation of grains from source to sink. Bivariant plots plotted against magnetic susceptibility and other magnetic parametrs helped in discriminating over grain size and coercivity of minerals as a comparative study for five rivers.

Keywords: estuarine systems, susceptibility, anhysteretic remanent magnetization (ARM) , titanomagnetite , morphology

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Tracking of Source-to-Sink Processes in a Tropical Estuarine System Using Environmental Magnetism

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ABSTRACT

Tropical estuarine systems represent complex and dynamic environments where sediment transport and deposition are driven by fluvial input derived from diverse catchment lithologies, hydro-and sediment dynamic, and climatic factors. In this study, we employed magnetic mineral fingerprinting method to investigate source-to-sink sediment dynamics in two contrasting tropical estuaries of Goa, India; The Chapora (mesotidal) and Sal (microtidal) estuaries. A comprehensive set of environmental magnetic parameters were measured on surficial riverine bedload sediments, riverbank soil profiles, hinterland rocks, and marine sediments to identify and characterize the magnetic mineral assemblages for tracking the sediment provenance. The bulk estuarine and soil magnetism was mainly dominated by ferri (magnetite, titanomagnetite), and antiferromagnetic (hematite, goethite) minerals. Scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS) further confirmed the presence of such complex magnetic mineralogy. Comparison of magnetic data representing different depositional environment revealed distinct magnetic signatures linked to lithological sources such as laterites, basalts, and granitic gneisses, and highlight differential sediment contributions originating from riverbank (top-and sub soils), catchment, and marine environment. The integration of magnetic properties with mineralogical composition underscores the effectiveness of environmental magnetism in discriminating sediment sources and unravelling transport pathways. This work contributes to a deeper understanding of estuarine sediment dynamics in tropical settings and offers a robust methodological framework for sediment provenance studies critical for coastal management and geomorphic evolution assessments.

Keywords: Environmental Magnetism, Source-to-Sink Processes, Tropical Estuaries, Provenance, Hydro-and Sediment Dynamics.

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Establishing the inventory of magnetic minerals for Bay of Bengal and Ninety East Ridge sediments

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ABSTRACT

Magnetic minerals are widespread in deep-sea sediments originating from large number of potential sources including terrigenous, biogenic, diagenetic, authigenic, volcanic, cosmogenic, and hydrothermal mineralization.The present study focusses on establishing a magnetic mineral inventory of the deep-sea sediments from the two contrasting depositional sites (Bay of Bengal-BoB, Ninetyeast Ridge-NER) in the Indian Ocean region. The sediment samples were collected by using a box core and subsampled at every one cm interval immediately after collection and stored at -20°C until further analysis. After sediment processing, we employed suite of rockmagnetic and grain size measurements to identify and characterize the magnetic mineral assemblages for developing the inventory of magnetic minerals in terms of their concentration, grain size and mineralogy.The bulk sediment magnetism of the studied sediment cores is constrained by ferrimagnetic- and antiferromagnetic minerals, which exhibit broad grain size and coercivity distributions. Overall, the magnetite content varies over two orders of magnitude and showed large variations in their distribution throughout the core. Two contrasting patterns in the magnetic and clastic grain size distribution are evident. The BoB core showed the downcore increase in the concentration of fine (SP-SD) sized magnetic particles and dominance of well-sorted unimodal type silt sized clastic sediments, while opposite pattern in magnetic grain size and clastic (multi-modal type clay and silt) is noticed in the NER core. Specialized magnetic (thermomagnetic curves, hysteresis loop) data and electron microscopy data helped to identify different magnetic mineral phases at each studied site and evaluate the relative contribution of each magnetic mineral phase to the bulk magnetic properties. Inventory of magnetic minerals and clastic sediment of the BoB and NER sediments was established in this study. The downcore variability of inorganic carbon (%) in these sediments showed no temporal variability from surface to bottom but significant spatial variation with low concentration (~ 2%) in the BoB and high (~8%) in the NER.This data provided crucial insights on the distribution of magnetic minerals, characteristics of magnetic carriers, and their potential sources.

Keywords: Indian Ocean, Environmental Magnetism, Magnetic Minerals, Provenance, Depositional Environment.

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Rock Magnetic Study of a Channel-Dominated Gas Hydrate System in the Bay of Bengal

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ABSTRACT

In this study, we present the magnetic properties of a 196.45 m long sediment core (NGHP-01-15A) retrieved from the Krishna - Godavari [K-G] basin under the aegis of Indian National Gas Hydrate Program. Based on the down-core variations in rock magnetic properties, the sediment core was divided into five distinct sedimentary magnetic zones (I-V). The uppermost Zone I (0.74-29.36 mbsf) shows reducing values of magnetic concentration dependent parameters - magnetic susceptibility (□lf), anhysteretic remanent magnetization (ARM) and saturation isothermal remanent magnetization (SIRM). This implies a decrease in the abundance of magnetic minerals. A sharp drop in □lf and ARM is observed at around 22.86 mbsf, marking the sulphate-methane transition zone (SMTZ). Below the SMTZ, all the sulphate is consumed and methanogenesis leads to increased methane concentrations. Zone II (30.86-41.91 mbsf) is marked by a sharp drop in the concentration dependent parameters χ_{lf}, ARM and SIRM indicating the presence of weakly magnetic minerals. These values remain constantly low throughout this zone. Sulphate values are observed to be near zero throughout this zone. Low susceptibility values combined with the near zero sulphate values indicate intense pyritization processes taking place in this zone. Zone III (42.57-111 mbsf) is marked by a spike in the abundance of magnetic minerals while zone IV (111.05-140.3 mbsf) displays a marked intensification in the abundance of magnetic minerals. The bottom simulating reflector (BSR) observed to be at 125 mbsf falls in this zone. The BSR denotes the changeover between the gas hydrate stability zone and the free gas zone. Zone V (140.35-196.45) is marked by a pronounced drop in the abundance of magnetic minerals. The magnetically enhanced zone IV dominated by higher magnetite content represents a prominent mass transport deposit (MTD)-rich sedimentary layer formed during the period of higher sedimentation events in the K-G basin.

Keywords: Rock magnetism, Bay of Bengal, mass transport deposit, Krishna-Godavari basin, gas hydrate

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Unravelling the impact of mass transport deposit and diagenesis of magnetic minerals on the rockmagnetic record of sediment core from the Bay of Bengal

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ABSTRACT

In this study, we employed suite of rockmagnetic, geochemical, mineralogical and sedimentological analyses on a sediment core recovered from a marine sedimentary environment of Krishna-Godavari (K-G) basin. The aim of this study was to elucidate the impact of mass transport deposits (MTD's) and magnetic mineral diagenesis on the sediment magnetic properties. Based on rockmagnetic and geochemical record, we classified the sediment core into four distinct sediment magnetic zones. Bulk sediment magnetism is mainly constrained by the detrital (titanomagnetite, titanohematite) and diagenetic (pyrite) minerals. Rock magnetic and electron microscopy data indicated that the magnetic properties of the sediment core is highly controlled by large scale variability in the detrital input (magnetic particles), varying degree of diagenesis, and onset of MTD's. Several sediment intervals exhibiting depletion in magnetic susceptibility coupled with selective loss of finer ferrimagnetic magnetic particles can be attributed to presence of magnetic iron sulfides (pyrite), which were produced as a result of diagenetic dissolution triggered by anaerobic oxidation of methane coupled to sulfate reduction. A marked increase in total organic carbon (TOC) content in the lowermost zone of sediment core can be very well linked to the efficient preservation of labile organic matter due to rapid sediment deposition. We have developed a conceptual model which explain the control of mass transport deposit and magnetic mineral diagenesis on the sediment magnetic record of the Bay of Bengal

Keywords: Rock magnetism, Magnetic Minerals, Sedimentation, Diagenesis, Methane Hydrates Bay of Bengal

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Climatic Control on the Magnetic Properties of Bay of Bengal Sediments

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ABSTRACT

The sediment composition along the northeastern Bay of Bengal varies due to changes in monsoon-driven and fluvial sedimentation processes. However, the mechanisms controlling the distribution and deposition of magnetic minerals in this regions is not well understood. To address this, a detailed environmental magnetic study was carried out on a 2.27 m long sediment core collected from the outer continental shelf off Dhamra Port, Odisha, Bay of Bengal to reconstruct variations in sediment provenance and depositional processes. Sedimentation in this region mainly originates from major rivers such as Brahmani, Baitarani, Mahanadi, and Subarnarekha, which flow through Precambrian igneous and metamorphic terrains that serve as the primary sources of iron (Fe)-rich sediments. Room-and high temperature environmental magnetic measurements were conducted on sediment core samples, which yielded information on the magnetic mineral concentration, grain size and mineralogy. The magnetic stratigraphy of the core delineates four distinct zones characterised by systematic variations in c and SIRM, indicating differences in magnetite content, mineralogy and crystal size. Electron microscopy data further confirmed the presence of magnetic minerals comprising of mixed mineralogy (soft and high coercive).The cyclic variations of magnetic proxies within these sedimentary zones coupled with major changes in magnetic mineralogy suggest large fluctuations in sediment contribution from the major river systems feeding the study area. Higher S-ratio in these zones indicate the dominant magnetic mineralogy is magnetite/titanomagnetite. A decrease in magnetic intensity and the appearance of coarser grains upwards indicate enhanced fluvial discharge and a rise in catchment-derived sediment flux. The lower-most sediment magnetic zone is characterised by a low S-ratio and magnetic concentration, indicating the enrichment of titano- hematite/goethite resulting from oxidation of detrital minerals originating from the metamorphic terrains. Overall, these magnetic variations indicate alternating stages of sedimentation driven by changes in fluvial discharge and reflect a coupling between catchment erosion, sediment transport, and depositional processes.

Keywords: Environmental Magnetism, Fluvial Sediment Processes, Source-to-Sink Processes, Continental shelf, Bay of Bengal

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Rockmagnetic Investigation of Sediment Core from the northern Andaman Sea

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ABSTRACT

The Andaman Sea is a tectonically active marginal basin situated in the eastern part of the Indian Ocean and plays a significant role in regulating regional sediment dynamics and monsoon-driven depositional processes. In this study, we conducted rockmagnetic investigation on a ~ 2.7 metre long sediment core from northern Andaman Sea to elucidate the control of provenance and climate on the evolution of sediment magnetic record. Bulk sediment magnetism is mainly constrained ferri-and antiferromagnetic minerals, which occur in varying proportion throughout the core. The magnetic record of this sediment core was classified into three distinct magnetic zones (Z-I, Z-II, Z-III) based on the changes in the magnetic susceptibility. An anomalous sediment zone (Z-II) exhibiting high magnetite content is constrained by coarser ferrimagnetic particles, which were abundantly found in this zone. Such enhancement in magnetite content from 2.20 - 2.45 metre can be attributed to the period of increased terrigenous input and transport controlled by regional climatic conditions. The sediment magnetic zones Z-I and Z-III showed relatively low and uniformity in their magnetic characteristics interms of magnetite content, coercivity and crystal size. Grain size record of the sediment core showed large variability in the distribution and sizes of clastic sediments. End member modelling of grain size and magnetic remanence data helped to identify the different end members and unravel their contribution to the sedimentary evolution of magnetic and grain size record.

Keywords: Andaman Sea, Rock Magnetism, Grain Size, Magnetic Remanence, End-Member Modelling.

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Magnetic Properties of Ocean Floor Basalts from the Andaman Sea.

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ABSTRACT

Rock magnetic and mineralogical analyses were conducted on ocean floor dredged basalt samples from the Andaman Sea to identify and characterize the magnetic mineral phases. A spatial distribution map of ocean floor basalt in the central Andaman Sea was developed based on their magnetic characteristics (content, coercivity, grain size). The analysed basalt samples exhibit high magnetic susceptibility (χlf) and strong saturation isothermal remanent magnetization (SIRM), indicating a significant concentration of ferrimagnetic minerals. Selected dredge samples display distinctive magnetic signatures, offering valuable insights into mineralogical freshness and alteration processes. Bulk of the basalt samples exhibit higher magnetite content constrained by fine-grained (single-domain [SD] to pseudo-single-domain [PSD]) ferrimagnetic particles as seen through elevated χARM/SIRM ratios (characteristic property of fine-grained and relatively unaltered magnetic assemblages). This suggest that the studied basalt samples have experienced minimal chemical alteration, thereby preserving their original mineralogical characteristics since formation. Furthermore, Mineralogical data of ocean floor basalt samples confirmed the presence of magnetic (titanomagnetite, magnetite, chromite) and non-magnetic (plagioclase feldspars & pyroxenes group) minerals.

Keywords: Ocean floor Basalts, Andaman Sea, Magnetic Minerals, Genesis and Distribution.

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Session Title: Teleconnections of South Indian Ocean and climate of Indian subcontinent

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2.	Variability Of Drought/Flood Characteristics Over Six Homogeneous Regions Of India: Historical & Future Perspective
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Potential of HighResMIP Models in Simulating the Relationship between D20 based Global-ENSO index and Indian Summer Monsoon Rainfall

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ABSTRACT

The accurate prediction of Indian Summer Monsoon Rainfall (ISMR) is crucial for effective water resource management and food security planning over the Indian region. The seasonal and long-range predictability of the ISMR depends on its slowly varying predictable drivers. In this study, the robustness of a newly discovered depth of the 20°C isotherm (D20) based predictor (referred to as Global-ENSO i.e. G-ENSO) towards skillful long-range prediction of the ISMR is demonstrated. Using the observed, reanalysis, and HighResMIP model data, it has been shown that the G-ENSO index provides useful skill in forecasting the ISMR even at a lead time of 18-24 months. It is found that the inter-model variability in G-ENSO and ISMR relationship is not very high. The future projections suggest that the relationship between the G-ENSO and ISMR remains strong and does not change significantly in a warming climate, indicating very good prospects for the skillful long-range forecasts of the ISMR.

Keywords:ISMR, D20, Isotherm, HighResMIP, Predictability

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Variability Of Drought/Flood Characteristics Over Six Homogeneous Regions Of India: Historical & Future Perspective

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ABSTRACT

The drought and flood are well-known hydro-climatic extremes as well as important natural hazards that have a detrimental effect over India and its six homogeneous regions. The key point of this research paper is that we investigate historical as well as future drought and flood characteristics, such as frequency, duration, severity, and Intensity across India and its six different homogeneous regions. Drought and flood events are identified with the help of the Standardized Precipitation Index (SPI). For historical study, utilize 13 General Circulation Models (GCMs) from the Coupled Model Intercomparison Project Phase 6 (CMIP6) from 1985 to 2014 and their Multi-Model Ensemble (MME) while for future estimation of flood and drought in two Shared Socioeconomic Pathways, i.e., SSP245 and SSP585, scenarios for the near future (2030-2059) and far future (2070-2099). In this study, the quantile mapping method is used for bias correction of CMIP6 data. Furthermore, we are examining historical and future emission scenarios, and our results found that the frequency of severe drought events has increased over AI, EPI, NWI, WPI regions while decreased over the NCI, SPI regions, from the near future to far future timeslices under the SSP585. The region NWI emerges as a hotspot for drought and flood, having high severity in NF and FF time slices under the SSP245 and SSP585 scenarios, while the NCI region has depicted nearly constant drought severity in NF and FF under the SSP245 and FF under SSP585 scenarios. The SPI3 indicates significantly increasing trends observed over the AI, NEI, EPI, and SoPI regions in the near future (NF) under the SSP245. Overall, AI, NWI, NCI, NEI, WPI, EPI, and SoPI depicted a significantly increasing trends of SPI3 in the near future under the SSP585.

Keywords: SPI, CMIP6, MMEs, SSP, Bias Correction

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Understanding The Spatio-Temporal Variability Of The Peak Indian Summer Monsoon

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ABSTRACT

The Indian Summer Monsoon (ISM) reaches its peak intensity typically in the month of July and August and contributes to major amount of annual precipitation across all over the Indian subcontinent. This is driven by complex interactions of ocean and atmosphere, large- scale circulation patterns, and regional topography. In the peak monsoon month, a low-pressure systems build up with huge amount of moisture transport from the Arabian Sea and Bay of Bengal which result in heavy precipitations. This helps in agriculture and maintain water table balance, but it also risks floods and landslides. The seasonal and interannual variability in rainfall distribution during the month of July and august is strongly influenced by phenomena like El Niño–Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). Therefore, it is necessary to understand the spatial and temporal patterns of rainfall during the peak monsoon month for improving seasonal forecasts, water management, and climate adaptation strategies. In this study, ERA5 reanalysis dataset has been used for tricadal comparison (1961–1990 and 1991–2020) which shows marked shifts in Indian monsoon dynamics, with warming over northwestern India, the Arabian Sea, and Bay of Bengal, and cooling over central and northeastern regions. Rainfall decreased over the Arabian Sea and Bay of Bengal but increased over the East Indian Ocean and this is influenced by high-pressure anomalies linked to reduced rainfall over southern India.

Keywords: ISM, Monsoon Variability, Meteorological parameter, ERA5

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Theme: Ocean and Climate

Session Title: The spatio-temporal manifestations of the Indian Ocean variability, change and modelling

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3.	Pre-Conditioning Of The Indian Ocean By Triple Dip La-Nina: Impact On Indian Summer Monsoon And The Multi-Year Negative Indian Ocean Dipole Of 2021-22
4.	Spatial Variability Of Aerosols And Their Radiative Influence Over The Tropical Indian Ocean During The Iind International Indian Ocean Expedition.
5.	Validation Of Swot Observed Significant Wave Height And Its Impact On Wave Simulation In The Indian Ocean.
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Diversity of MJO initiations over the Indian Ocean basin

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ABSTRACT

This study investigates the diversity of Madden Julian Oscillations (MJO) initiations within the IO basin focusing on the influence of background state and the preconditioning processes which drive the convection initiations. ~60% of MJO initiations are observed over the western equatorial Indian Ocean (WEIO), while ~40% of MJO initiations are observed over the eastern equatorial Indian Ocean (EEIO) and they exhibit stronger convective amplitudes compared to the western counterpart. The Indian Ocean SST background state is observed to influence the frequency of occurrence of initiations over the two domains during boreal summer. During boreal winter, the IOD is typically in a neutral or decaying phase, and only about 40% of the MJO initiations are observed during positive or negative IOD phase. About 70% of the summer MJO initiations are observed during active positive or negative phase of IOD. While nearly half of the WEIO initiations occurred during positive IOD phase, relatively fewer WEIO initiations occurred during a negative IOD phase. On the other hand, EEIO initiations were found to be more favored during negative IOD phase. Investigation of the preconditioning associated with winter MJO initiations reveal a more rapid and stronger destabilization over the EEIO. Plantary boundary layer (PBL) moisture budget analysis reveal that while the moistening over EEIO results from the competing effects of horizontal and vertical advection processes, horizontal advection together with cloud evaporative processes together drives the moistening of the PBL over the WEIO. Stronger zonal gradient in the mean moisture field and the larger amplitude Rossby response to the suppressed state over the Maritime Continent contribute to strong horizontal advection of moisture over the EEIO, which leads to the rapid destabilization and stronger convection development over the domain.

Keywords: Madden Julian Oscillations, Convective initiations, Indian Ocean, moisture budget, planetary boundary layer

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Emerging influence of the Australian Monsoon on Indian Ocean interannual variability in a warming climate

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ABSTRACT

The Indian Ocean Dipole (IOD) and Tripole (IOT) represent primary modes of interannual variability in the Indian Ocean, impacting both regional and global climate. Unlike the IOD, which is closely related to the El Niño-Southern Oscillation (ENSO), our findings unveil a substantial influence of the Australian Monsoon on the IOT. An anomalously strong Monsoon induces local sea surface temperature (SST) variations via the wind-evaporation-SST mechanism, triggering atmospheric circulation anomalies in the eastern Indian Ocean. These circulation changes lead to changes in oceanic heat transport, facilitating the formation of the IOT. Our analysis reveals a strengthening connection between the Australian Monsoon and the IOT in recent decades, with a projected further strengthening under global warming. This contrasts with the diminished coupling between ENSO and IOD in recent decades from observations and model projections, illustrating evolving Indian Ocean dynamics under the warming climate.

Keywords: Climate variability, climate change, Indian Ocean Modes

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Pre-conditioning of the Indian Ocean by triple dip La-Nina: Impact on Indian Summer Monsoon and the multi-year negative Indian Ocean Dipole of 2021-22

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ABSTRACT

The Indian Ocean Dipole (IOD) a strong modulator of the Indian Summer Monsoon (ISM), as positive (negative) IOD conditions are often associated with above (below) normal ISM. IOD events can arise due to internal variability or can be forced by the conditions in the tropical Pacific Ocean. In this study, we study the interaction of the Pacific Ocean state in with the Indian Ocean for multi-year La-Nina events. It is found that prolonged La-Nina-type conditions suppress the seasonal cycle of winds in the tropical Indian Ocean. As a result, large westerly wind anomalies ensue in the central equatorial Indian Ocean and the along-shore easterlies along the Java-Sumatra coast during boreal summer and fall are suppressed. Reduced wind-evaporation-SST feedback and weakening of the mean upwelling in the eastern tropical Indian Ocean causes warming of SST in the eastern Indian Ocean. Such warming is observed to peak in boreal summer during peak monsoon months. A simultaneous cooling of western Indian Ocean SST by a strong cross-equatorial monsoonal flow associated with a strong monsoon can thus cause peak IOD conditions during summer, further complicating the non-linear IOD-monsoon association's prediction. Long-lead forecasts of tropical Pacific conditions are more skillful than IOD. Better simulation of such association in dynamical models will improve the long-lead forecasts of the Indian Monsoon. The frequency of consecutive La-Nina events is projected to increase in a warming world, which can intensify negative IOD type conditions, therefore, compounding the climate risk associated with such events.

Keywords: Indian Ocean Dipole, triple La-Nina, Indian Monsoon

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Spatial Variability of Aerosols and Their Radiative Influence Over the Tropical Indian Ocean during the IInd International Indian Ocean Expedition.

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ABSTRACT

The Tropical Indian Ocean (TIO) is a distinct region where atmospheric processes primarily govern aerosol dynamics. Aerosol optical depth (AOD), black carbon (BC) mass concentration (M_B), along with radiosonde launches were conducted during the IInd International Indian Ocean Expedition (IIOE-II) in December, 2015, spanning between 15°N to 20°S. CALIOP aerosol subtypes, atmospheric stability parameters, and SBDART based radiative transfer simulations were further analysed. The resulting dataset provides a comprehensive aerosol dynamics across the TIO, allowing quantification of Aerosol Direct Radiative Effect (ADRE), Atmospheric Heating Rates (HR), and linkages between aerosol loading and atmospheric stability. At 12.97°N, aerosol loading was highest (AOD_{500}: 0.630 and M_B : 1382.21 ± 209.10 ng m^{-3}) due to advection of continental aerosols. Aerosol subtype data revealed dominant polluted continental/smoke and dusty marine layers extending up to ~2.5 km over the northern TIO, advected from the Indian subcontinent and Arabian region. Southward, both AOD and M_B decreased sharply; M_B declined from 990.95 ± 184.79 ng m^{-3} at 11°N to to an average of 39.63 ± 14.40 ng m^{-3} south of the Inter-Tropical Convergence Zone (ITCZ), emphasizing the ITCZ's role as a hemispheric barrier. In open ocean region, $AOD_{870} > AOD_{380}$, indicating coarse-mode sea-salt dominance. Variations in aerosol distribution corresponded to strong spatial heterogeneity in atmospheric stability, with Convective available potential energy ranging from 0.0274 to 2535.2 J kg^{-1} and convective inhibition energy from 0 to −387.5 J kg^{-1}. Highly unstable conditions near ~6°S (ITCZ) supported deep convective uplift of aerosols to ~10 km, whereas stable conditions in northern TIO enhanced near-surface accumulation. Clear-sky ADRE (+17.98 W m^{-2}) and HR (0.540 K day^{-1}) were highest near the coast, while offshore region showed much lower heating rates (0.063 ± 0.017 K day^{-1}), an ~87% reduction, attributed to the prevalence of scattering aerosols (SSA_{500} : 0.997± 0.002) in the region. The elevated ADRE and heating rates near the coast can warm the lower troposphere, reduce static stability, and weaken the land–sea thermal contrast that drives the Indian Summer Monsoon.

Keywords: Tropical Indian Ocean, Aerosols, Continental outflow, Atmospheric Stability, Atmospheric Heating

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Validation Of Swot Observed Significant Wave Height And Its Impact On Wave Simulation In The Indian Ocean

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ABSTRACT

Understanding and accurately forecasting ocean surface waves is vital for coastal safety, maritime operations, fisheries, port and harbour construction and recreation. This study presents a comprehensive validation of significant wave height (SWH) observations from the newly launched Surface Water and Ocean Topography (SWOT) satellite mission in the Indian Ocean. SWOT provides Ka-band radar measurements with high spatial resolution, delivering sea surface height and SWH observations along its nadir track and across a 120 km swath on either side of the nadir in its interferometric (KaRIn) mode. KaRIn and Nadir observations of SWH are validated against independent Jason-3 and SARAL/AltiKa satellite observations and in-situ measurements, including Moored and Wave Rider buoys. Results showed that SWOT SWH estimates had high agreement with traditional satellite and buoy data, with RMSE ranging between 0.25 m and 0.45 m. SWOT Nadir observed SWH showed higher accuracy than SWOT KaRIn observations. The validated SWOT Nadir data were then assimilated into the WAVEWATCH III numerical wave model, forced with ERA-5 winds. Assimilation of SWOT Nadir data led to enhanced model performance, with improvements of up to 4.35% in wave height and 8.69% in wave period compared to the non-assimilated model runs.

Assimilation was limited to SWOT Nadir data due to challenges in defining the observation error covariance matrix for the spatially correlated SWOT KaRIn data. This highlights the need for future work in developing error models for full-swath assimilation. This study emphasizes the importance of satellite-based wave observations for advancing operational oceanography.

Keywords: Data Assimilation, Significant Wave Height, SWOT Satellite, Validation, WAVEWATCH III

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The Development Of A High-Resolution Regional Ocean Model Using MOM6 For The North Indian Ocean Towards Improved Ocean State Forecast

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ABSTRACT

The Indian National Centre for Ocean Information Services (INCOIS) provides ocean state forecasts for coastal communities and other stakeholders. The current forecasting system employs a 1/12° ocean model based on Regional Ocean Modelling System (ROMS). However, as part of the unified modelling framework, INCOIS plans to use Modular Ocean Model version 6 (MOM6) as its future workhorse for the modelling framework on a global and regional scale at a very high resolution. Considering MOM6 is a new-generation ocean circulation model which employs the Arbitrary-Lagrangian-Eulerian (ALE) method for hybrid vertical coordinates, it is anticipated that it would better represent fine-scale processes, including coastal currents off the east and west coast of India and the non-linear-regions such as the western Arabian Sea. Accurately capturing these currents, especially at sub-inertial timescales, is crucial for reliable ocean state forecasts. Accordingly, INCOIS is leveraging high-performance computing (HPC) to develop a high- resolution (1/36°; ~3 km) regional ocean circulation model for the North Indian Ocean (NIO) offline nested with an eddy-permitting (1/12°) global model. The regional model domain spans 32°E to 108°E and 8°S to 30°N, with open boundaries to the east and south. Boundary conditions are sourced from the global MOM6 configuration and forced by interannual atmospheric fields from the Japanese 55-year reanalysis (JRA-55do). Initial hindcast simulations indicate that both the 1/12° and 1/36° configurations reproduce the large-scale seasonal cycle of currents and sea surface height along the Indian coasts reasonably well. Additionally, the higher-resolution 1/36° setup provides significant improvements in resolving non-linear, dynamically driven features; particularly mesoscale and sub-mesoscale eddies associated with regions such as the Somali Current system and the northern Bay of Bengal, and variability at sub-inertial and intraseasonal timescales.

Keywords: Regional Ocean Modelling, MOM6, Ocean forecast, climate change

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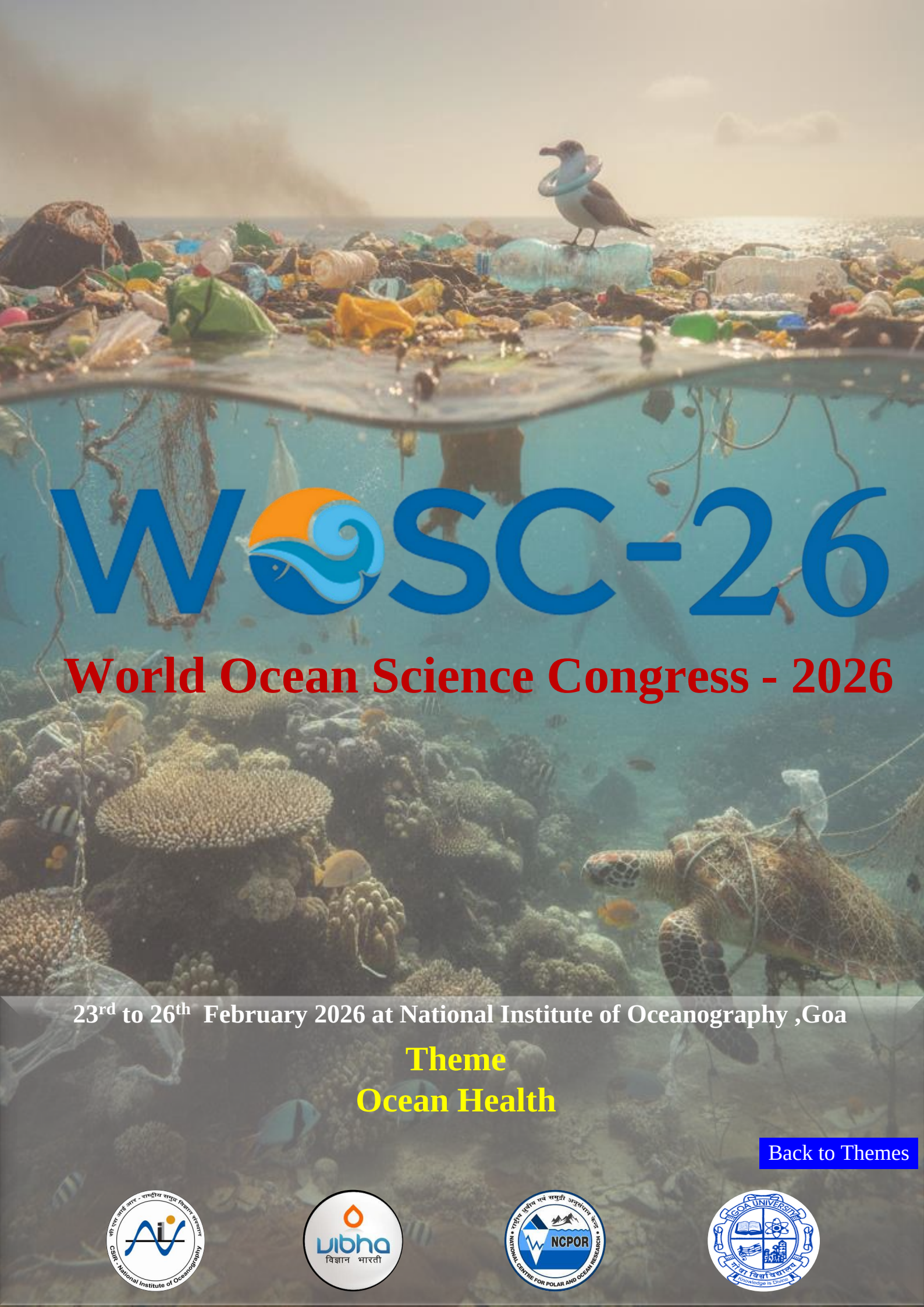

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Session Title: Biogeochemistry of the Indian Ocean: Present understanding and the way forward

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Controls On DMS Production In The Arabian Sea

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ABSTRACT

Dimethylsulfide (DMS) is the predominant volatile sulfur compound present in the surface waters of the ocean. It is generated from dimethylsulfoniopropionate (DMSP), an osmolyte that is primarily synthesized by marine phytoplankton. Interactions between the air and sea release DMS into the atmosphere, where it is oxidized to produce sulfate aerosols, which affect atmospheric acidity and contribute to the heat budget by forming cloud condensation nuclei. Due to its role in climate regulation, DMS is commonly referred to as an 'anti-greenhouse gas. Since marine phytoplankton are crucial for DMS production, seasonal productivity is expected to have a significant impact on DMS distribution and flux. The open Arabian Sea experiences seasonal productivity characterized by upwelling during the southwest monsoon (SWM) and winter mixing during the northeast monsoon (NEM), while the coastal Arabian Sea (the west coast of India) also experiences upwelling during the SWM but faces severe deoxygenation towards the end of this period. Sampling for DMS and related compounds was carried out along the II- transect in the Open Arabian Sea and at the Candolim Time Series (CaTS-G5) as part of the SIBER-India and INDIAS_IDEA projects. In the open ocean, elevated concentrations of DMS, DMSP, and DMSO were observed during the SWM and NEM, associated with productivity driven by nutrient input from wind-induced upwelling and winter convection, as well as mesoscale eddies and the dominance of small phytoplankton taxa with high DMSP content. In contrast, the concentration at the coastal G5 station was influenced by the annual phytoplankton regime and succession, along with the seasonal anoxia that occurs towards the end of the SWM. This study investigates the similarities and differences in DMS production and assesses the contribution to DMS flux from both regions of the Arabian Sea.

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Carbon Dynamics And Sea-To-Air Carbon Dioxide Fluxes Of The Southeastern Arabian Sea With A Special Emphasis On The Wadge Bank Region

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ABSTRACT

This study investigated the carbon dynamics in the southeastern Arabian Sea, including the wadge bank and adjacent Gulf of Mannar, to understand the factors influencing the carbonate system and to compute the sea-to-air carbon dioxide (CO2) flux. Discrete samples from 8 cross-shore transects [Ervadi (T1), Tuticorin (T2), Uvari (T3), Wadge Bank (T4), Colachel (T5), Kollam (T6), Alappuzha (T7), and Kochi (T8)] were collected during September 2024, the waning phase of the Southwest Monsoon, onboard FORV Sagar Sampada. Hydrographical and biogeochemical parameters measured, including wind speed, temperature, salinity, dissolved oxygen (DO), pH, nutrients, and total alkalinity (TA). The carbonate system parameters were computed using the CO_2SYS program, and sea-to-air CO2 fluxes were calculated based on gas exchange parameterization equation. Wind speed was maximum on the wadge bank region (≤10 m/s), which decreased northward (≥1.36 m/s) with localised highs in the nearshore zones of Kollam and Colachel (T6-T7). The southeastern Arabian Sea was influenced by upwelling and associated subsurface hypoxia (oxygen ≤ 25µmol/L), whereas transects in the GoM (T1 to T4) did not exhibit subsurface hypoxia. The vertical pH distribution exhibited strong stratification in upwelling zones, with surface values of ~8.2 and 7.91 at depth. In contrast, T1 to T4 maintained uniformly high pH (~8.23) due to a well-mixed water column and enhanced photosynthetic activity (Chl- a > 0.4 µg/L). Upwelling-driven CO_2 enrichment was evident in the subsurface waters of the southeastern Arabian Sea (T6 to T8), where subsurface pCO_2 concentration was ~ 600 µatm and the bottom concentration reaches ~1000 µatm. However, CO_2 fluxes to the atmosphere remained low (<5 mmol m^{-2} d^{-1}) in the southeastern Arabian Sea (T6-T8) due to weak winds and pronounced salinity stratification that restricted vertical mixing. In contrast, the Gulf of Mannar (T2-T5) exhibited higher fluxes (>10 mmol m^{-2} d^{-1}), associated with enhanced wind speeds and higher temperature, facilitating enhanced air–sea exchange.

Keywords: carbonate system, upwelling, sea-to-air co2 fluxes, gulf of mannar, wadge bank

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Excerpts from a recent study: Is there a shift in nitrogen cycling in the North Indian Ocean?

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ABSTRACT

The Arabian Sea (AS) and the Bay of Bengal (BoB) lie along similar latitudes, and both house low oxygen conditions at their intermediate depths. However, unlike the AS, the redox conditions in the BoB are just above the required levels of suboxia to support denitrification. Suboxic environments are ideally suited for enhanced production of nitrous oxide (N_2O), and as the BoB has widespread depletion of oxygen at mid-depths, it can be an important site for the cycling of this important greenhouse gas. The well-defined Oxygen Minimum Zone (OMZ) in the AS displays a bimodal peak of N_2O within the OMZ and acts as a major contributor of N_2O to the atmosphere. The BoB also contributes to N_2O production within the OMZ, however, it is a single peak with no consumption happening as the region is non-denitrifying unlike the AS. In the present study we present N_2O data collected between 2010 and 2023 from two fixed sites, the Arabian Sea Time Series (ASTS) station and the Bay of Bengal Time Series (BoBTS) station, and, compare the data with those collected during the 1990s. In the AS, within the OMZ, the N_2O profile was characterized by a pronounced minimum between two maxima, also seen in the Eastern Tropical Pacific Ocean which experiences similar conditions. While the primary peak is at a depth of ~100m and records ~40 nM, the maximal concentrations of N_20 (~80 nM) occur at the deeper depths (~600 – 1000 m) beneath the zone of intense denitrification. In the Bay of Bengal, the N_2O max was recorded at ~200 m with a Dissolved Oxygen (DO) of ≤ to 4 µM. The N_2O measurements in the BoB during 1990's showed the highest concentrations of N_2O at the primary peak, recorded between 60 – 80 nM at ~ 200 m depth with a DO < 4 µM (Naqvi et al. 1994). In the recent data we measured almost double concentrations of N_2O ranging between 120 and 163 nM within the OMZ of the BoB. While the recent set of measurements indicates no major change in the AS, there seems to be a massive shift in the redox conditions in the BoB, and warrants a detailed study on N_2O (nitrogen) cycling from this important region which is known to contribute to nearly 30% of the global marine nitrogen loss.

Keywords: nitrous oxide, nitrogen cycling, suboxia, Bay of Bengal, Arabian Sea

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Phytoplankton pigment composition in the Eastern Arabian Sea: Insights from a 10-Year Time Series Study

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ABSTRACT

The Arabian Sea (AS) is the most biologically productive region of the Northern Indian Ocean and sustains one of the largest subsurface Oxygen Minimum Zones (OMZs). Previous studies have identified upwelling during the southwest monsoon (SWM) and winter cooling during the northeast monsoon (NEM) as the primary drivers of high productivity in this basin. Productivity declines during the inter-monsoon periods (spring and fall), when the microbial loop becomes more active. Here, we present time-series observations (2015–2025) of phytoplankton pigment composition and size classes (micro-, nano-, and pico-plankton contribution) along a meridional transect (8-21°N, 68°E) in the Eastern Arabian Sea (EAS). During the NEM, convective mixing lowered sea surface temperature (SST) in the northeastern Arabian Sea, enriching surface waters with nutrients and enhancing microplankton contributions, whereas pico- and nano-plankton dominated in the southeastern Arabian Sea. The spring inter-monsoon (SIM) was characterised by elevated SST and nitrogen limitation, favouring picoplankton proliferation. During the peak SWM, microplankton were dominant in the central EAS in July 2021; however, picoplankton dominated throughout the transect in the July 2020 observation. During late SWM/fall inter-monsoon (FIM), phytoplankton biomass (chlorophyll a) was consistently low, with picoplankton contributing 70-80% at the surface, nanoplankton dominating subsurface layers, and microplankton accounting for only 10-20%. The mixed layer depth, Si/N ratios, and mesoscale processes generally influence the phytoplankton distribution and their inter-annual variability. Secondary chlorophyll maxima (SCM), primarily formed by *Prochlorococcus*, were observed at the southern boundary of the OMZ during NEM and SIM. SCM development was associated with a shallow OMZ upper boundary, sufficient light, and secondary nitrite availability, enabling *Prochlorococcus* proliferation. Overall, our decade-long observations highlight the persistent ominance of picoplankton in oceanic waters of the Arabian Sea and their critical role in carbon export and OMZ maintenance, despite their small cell size.

Keywords: Arabian Sea, OMZ, pigment composition, size classes, secondary chlorophyll maxima

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Coupled Physical-Biogeochemical Model Based Analysis On Submesoscale Variability Of Chlorophyll In The Bay Of Bengal

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ABSTRACT

The Bay of Bengal (BoB) is a dynamic region where submesoscale processes significantly influence oceanic circulation and biological activity. In this study, we explore the impact of submesoscale filaments on Chlorophyll-a (Chl-a) distribution and examine the broader implications of submesoscale activity on marine productivity in the BoB region. By utilizing high-resolution model simulations (2 km) and biological tracer data, we analyze key physical parameters such as temperature, salinity, vertical velocity, and vorticity, along with their interaction with biological tracers.Our analysis reveals distinct submesoscale filaments, characterized by sharp gradients in Sea Surface Temperature (SST) and Sea Surface Salinity (SSS), that develop from late summer to winter months, a period of heightened submesoscale activity. These filaments are closely associated with regions of intense vertical vorticity and strain, suggesting a coupling between physical forcing and biological responses. We identify multiple instances where increases in vorticity and vertical velocity correlate with significant changes in Chl-a concentrations, providing insights into the dynamics driving biological variability at submesoscale resolutions.Our analysis extends to a comprehensive evaluation of submesoscale dynamics across the northern BoB, where we generate area-averaged time series of vorticity, vertical velocity, and Chl-a concentrations. This approach reveals distinct periods of intensified submesoscale activity, during which significant responses in physical parameters precede changes in biological productivity. Our research is focused on elucidating the mechanisms responsible for these observed interactions, with the goal of enhancing our understanding of how small-scale physical processes influence the biogeochemical dynamics of the BoB.

Keywords: submesoscale, Chl-a, vorticity, vertical velocity, primary production

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Mesoscale eddy dynamics shape Coccolithophore biogeography in the Arabian Sea

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ABSTRACT

Mesoscale eddies play a pivotal role in modulating ocean biogeochemistry and plankton community dynamics, yet their influence on coccolithophore assemblages remains underexplored. Here, we investigate how cyclonic (cold core) and anticyclonic (warm-core) eddies influence the structure of coccolithophore communities in the Arabian Sea, based on a meridional transect along 68°E. *Gephyrocapsa oceanica* dominated across all sampled stations, comprising over 50% of the total coccolithophore abundance in surface waters, with a maximum abundance in the northern Arabian Sea. However, species such as *Emiliania huxleyi*, *Syracosphaera* sp., and *Florisphaera profunda* exhibited marked increases in abundance, indicating an increase in species diversity within the cold-core eddy region. Within the cold-core eddy, *E. huxleyi* accounted for up to 44% of the coccolithophore assemblage, coinciding with peak dimethyl sulfide (DMS) concentrations of 2.5 nM. These findings indicate that low temperature and nutrient enrichment via eddy-driven upwelling—particularly of nitrogen (NH_4^+) promote *E. huxleyi*. Additionally, the low-pH, low-temperature and high-nutrient water brought to shallow depths by the cold-core eddy led to the development of different morphotypes of *E. huxleyi*. Our results highlight mesoscale eddies as critical regulators of coccolithophore distribution and their climatic feedbacks through DMS emissions.

Keywords: Eddy; Coccolithophore; nutrients; DMS; pH

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Hydrothermal, OMZ, and Climate Forcing on the Dissolved Iron and Manganese Dynamics in the Indian Ocean

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ABSTRACT

This study investigates the distribution and controlling processes of dissolved iron (dFe) and manganese (dMn) across the GEOTRACES India cruise transects GI10 in the Arabian Sea and GI09 in the Bay of Bengal, extending through the Central Indian Ocean Basin (CIOB) and the southern Indian Ocean up to 30°S. Dissolved iron concentrations range from 0.02–3.5 nM in the Arabian Sea and 0.02–4.6 nM in the Bay of Bengal (BoB), while dMn exhibits a characteristic scavenging-type profile, enriched within the Oxygen Minimum Zones (OMZs) and decreasing with depth. Coastal advection dominates dFe supply to the Arabian Sea, whereas atmospheric deposition with higher dust solubility plays a major role in the BoB. In contrast, dMn variability in the BoB closely follows salinity gradients associated with large riverine influxes, with dMn concentrations reaching ~25 nM on the shelf due to dissolution of Fe–Mn oxyhydroxide-rich sediments delivered by the Ganga–Brahmaputra system. Within OMZs, processes like remineralization and reductive dissolution enhance both dFe and dMn, though dFe in the BoB is partly scavenged in the upper OMZ before release at depth. Geological features—including the Carlsberg Ridge, Central and Southeast Indian Ridges, and the Java–Sumatra Subduction Zone—supply dFe (typically 2–3 nM; up to ~20 nM near Rodrigues Triple Junction) and dMn (1–2 nM) to deeper waters. Climate-driven OMZ expansion, enhanced shelf inputs, increasing anthropogenic aerosols and recent changes in the climate of the southern sector of the Indian Ocean are projected to intensify the release, redistribution, and ecological impacts of both micronutrients, ultimately influencing productivity and biogeochemical cycling across the Indian Ocean.

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Gephyrocapsa oceanica is the predominant nanocalcifier in the western Indian continental shelf waters during the summer monsoon

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ABSTRACT

Coccolithophores (Haptophyceae), unicellular calcifying nanoplankton, play a key role in the global carbon cycle via photosynthesis and calcification. Despite the presence of plenty of studies on microphytoplankton from the Indian continental shelf, very few studies are available on the community ecology of coccolithophores, and they need further attention. Western Indian continental shelf possesses contrasting biogeochemical features during summer monsoon when upwelling occurs along the southwestern shelf, bringing cold nutrient-rich low oxygen water to the surface, supporting diatom-dominated phytoplankton bloom. However, at the same time, the northwestern shelf remains warm, nutrient-deplete and high saline. In this study, we present the distribution pattern of coccolithophores, collected during the summer monsoon (August 2018) onboard *RV Sindhu Sadhana* along the western Indian continental shelf covering a total of 13 stations from 9°N to 21°N (at 1° interval; and 6 depths at 200 m isobaths). The results revealed that coccolithophores constitute a significant part of the nanoplankton community in these shelf waters, with a predominance of *Gephyrocapsa oceanica*, with high spatial variability from south to north. It was observed that the warm, nutrient-depleted, and high saline waters in the north were occupied by a higher abundance of coccolithophores compared to the cold, nutrient-rich, low oxygen waters in the south. Diversity was also high towards the north of the shelf compared to the south. The upwelling-dominated area seemed to be unfavourable to the majority of the other species, whereas *Gephyrocapsa oceanica* was well-adapted, suggesting their ability to grow under such conditions, making them the dominant extant coccolithophore genus in the tropical Indian Ocean. Their distribution, abundance, and diversity were correlated with other ancillary parameters, including nutrients, temperature, salinity, mixed layer depths, etc.

Keywords: Coccolithophore, Eastern Arabian Sea, Physicochemical parameters, Upwelling, nanophytoplankton

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Influence Of Monsoonal Forcing And Coastal Upwelling On Nutrient Dynamics In The Southeastern Arabian Sea

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ABSTRACT

The present study examines the temporal variations in biogeochemical variables along the Kochi Time Series Transect (KoTS), located on the southwest coast of India, a region strongly influenced by coastal upwelling during the southwest monsoon. Monthly time series measurements of biogeochemical parameters in 2023 revealed the interplay between monsoonal forcing, upwelling intensity, and nutrient dynamics in the southeastern Arabian Sea. The onset of annual rainfall in May, followed by its intensification in June and a peak in July, coincided with the intrusion and persistence of hypoxic upwelled waters into the coastal zone. These upwelled waters, rich in nutrients, resulted in a marked enhancement of primary productivity, as reflected by elevated chlorophyll-*a* levels in the study region. During the transition from the Southwest Monsoon (SWM) to the Northeast Monsoon (NEM), nitrate levels exhibited distinct seasonal variability. A sharp decline was observed towards the end of NEM, followed by a gradual increase during the Spring inter monsoon (SIM) period, reaching concentrations exceeding 8 µM in bottom waters during active SWM upwelling. After SWM, nitrate levels decreased slightly but subsequently increased again during NEM, indicating the intrusion of Bay of Bengal water into the region. Nitrite concentrations followed a similar trend, reinforcing the influence of upwelling in controlling nitrogen species. Ammonium exhibited relatively limited spatial and temporal variations, particularly at offshore stations during SWM, indicating its rapid utilisation or oxidation under oxygen-depleted conditions. Phosphate concentrations began to rise prior to the onset of SWM, peaked during mid-SWM, and dropped significantly as the upwelled water mass weakened. A secondary increase in phosphate was observed during mid- NEM, coinciding with the intrusion of water from the Bay of Bengal into the region. Silicate concentrations showed pronounced enrichment during SWM and mid-NEM, particularly in deeper waters, highlighting the contribution of upwelled subsurface waters. Overall, the study underscores the pivotal role of monsoonal forcing and coastal upwelling in regulating nutrient cycling and biogeochemical variability in the nearshore waters off Kochi.

Keywords: Coastal upwelling,Monsoonal forcing,Nutrient cycling,Biogeochemical variability

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Seasonal Monsoon Controls on Phytoplankton Photosynthetic Efficiency in the Arabian Sea: A Fluorescence-Based Assessment of Ocean Health

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ABSTRACT

The Arabian Sea is a dynamic marine ecosystem strongly influenced by monsoon-driven hydrography and seasonal transitions, which regulate nutrient availability, water column structure, and primary productivity. As one of the world's largest oxygen minimum zone systems, the region exhibits pronounced post-monsoon and pre-monsoon variability, making it an ideal natural laboratory for assessing the physiological responses of phytoplankton to environmental change. Fluorescence-based observations offer a sensitive means of evaluating phytoplankton photosynthetic performance and ecosystem health under such shifting conditions.

This study investigates seasonal and spatial variability in key Photosystem II fluorescence parameters, including minimum fluorescence (Fo), maximum fluorescence (Fm), variable fluorescence (Fv), photosynthetic efficiency (Fv/Fm), and functional absorption cross-section (σPSII). Samples were collected along the 68°E transect during two RV Sindhu Sankalp cruises in November 2023 (post-monsoon) and February 2024 (pre-monsoon), representing transitional phases influenced by monsoon-driven hydrographic changes.

Distinct seasonal patterns emerged. During the post-monsoon period, the northernmost and southernmost stations exhibited higher Fv/Fm values (>0.3 at intermediate depths), indicating favourable physiological conditions, while intermediate stations showed reduced efficiency (<0.3). By the pre-monsoon period, this pattern reversed, with elevated Fv/Fm (>0.3, peaking at chlorophyll max depth) at intermediate stations and signs of physiological stress at terminal stations (<0.3)—likely reflecting seasonal differences in nutrient supply, stratification, and mixed-layer dynamics. Higher surface Fo and more heterogeneous σPSII profiles during pre- monsoon further indicated greater biomass and physiological diversity under dry-season conditions.

Overall, these fluorescence-based observations reveal strong monsoon-driven seasonal controls on phytoplankton photo-physiology and underscore the value of integrating optical diagnostics for assessing productivity, environmental responses, and ocean health in monsoon-influenced regions.

Keywords Phytoplankton Photophysiology, Photosystem II Efficiency, Fluorescence Measurements, Seasonal Variability, Monsoon-Influenced Hydrography, Arabian Sea

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Redox-driven sedimentary phosphorus speciation and the potential for benthic Prelease over the Western Indian Continental Shelf

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ABSTRACT

The Western Indian Continental Shelf (WICS) undergoes extreme changes in its oxygen regime over the course of a year, transitioning from normoxic during November to May to hypoxic- anoxic during June to October, with a particularly euxinic condition prevailing during September to October. Despite perennially N-limited conditions (N: P<16), shelf waters remain P-replete (PO_4^{3-} >0.5 µM) year-round, indicating significant benthic P input to the water column. This study investigated the seasonality of phosphorus speciation and assessed its potential for benthic release at the inner shelf station (G5), off Goa, in response to contrasting bottom water oxygen regimes. Short sediment cores and porewater samples were collected during near suboxic (10 µM O_2) conditions (October 2024), and normoxic (203 µM O_2) bottom water conditions (February 2025). The study of phosphorus speciation by the SEDEX method revealed distinct seasonal patterns: the lower concentration of Fe-bound P during suboxic conditions (0.16 mg/g) compared to normoxic (0.21mg/g), indicates greater P release to the water column during suboxia. Detrital P was elevated during the suboxic period (0.43 vs 0.19 mg/g), while authigenic apatite-bound P remained the dominant fraction in both seasons, confirming active diagenetic mineral formation. Organic-bound P showed minimal seasonal variation, consistent with comparable primary productivity inputs during intermonsoon periods. Porewater PO_4^{3-} concentrations were higher during suboxic conditions (2.7 µM) compared to normoxic periods (1.4 µM), supported by elevated dissolved Fe (2900 ppb) under suboxia in contrast to 950 ppb under normoxia. Interestingly, sediments under normoxic conditions exhibited a higher biopolymeric carbon content (23–27 mg/g) than those under suboxia (20–24 mg/g). The benthic P release over the WICS seems to be tightly controlled by the interplay between the oxygen regime of the bottom water and redox Fe cycling and phosphorus speciation in sediments. During suboxia, lower Fe-P in the sediments and higher porewater PO_4^{3-} suggested its potential for significant benthic release to the water column, which can trigger frequent cyanobacterial blooms during normoxic intermonsoon periods. Our study attempted to understand the coupled P-Fe-C biogeochemistry in WICS sediments, which is crucial for predicting ecosystem responses to changing oxygen regimes in this productive shelf system.

Key Words: Phosphorus speciation, SEDEX, Suboxia, Normoxia, WICS

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Influence of Prey Type on DOM Release, Cellular Physiology, and Bioluminescence-Relevant Status of Red *Noctiluca scintillans* in Coastal Waters

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ABSTRACT

Noctiluca scintillans (red type) is a major heterotrophic dinoflagellate whose blooms influence coastal biogeochemical processes through grazing, DOM release, and bioluminescent activity. To investigate how diet regulates these functions, bloom-derived *N. scintillans* were maintained under controlled laboratory conditions and fed three prey types: *Dunaliella salina*, *Thalassiosira* sp., and *Paraphysomonas* sp. DOM characteristics were assessed using fluorescence indices, while cellular physiological responses were quantified using AquaPen chlorophyll-fluorescence parameters. DOM profiles showed clear prey-specific patterns. *Thalassiosira*-fed cultures produced the highest microbial-associated DOM signal (BIX-7.49), whereas *Paraphysomonas* induced elevated β/α ratios, indicating fast turnover of fresh, protein-like components. Low HIX across all treatments confirmed that *N. scintillans* consistently released fresh, labile DOM that is readily available for microbial utilization and short-term carbon cycling. Photophysiological measurements revealed strong diet-dependent variability. *Dunaliella* supported the highest photochemical efficiency (Fv/Fm-0.705), suggesting improved cellular performance, while *Thalassiosira* increased energy dissipation (DIo/RC-5.84), reflecting greater metabolic stress. Increases in Area and Sm across treatments indicated enhanced electron storage capacity as cultures matured. Because bioluminescence in *N. scintillans* is closely tied to cellular metabolic state, these physiological differences highlight prey-driven shifts that may influence bloom bioluminescence intensity. Overall, the study demonstrates that prey identity strongly regulates DOM quality and cellular function in red *N. scintillans*, providing new insights into its ecological role and contributions to microbial carbon processing in coastal waters.

Keywords: Dissolved Organic Matter (DOM), *Noctiluca scintillans* (red type), Feeding physiology, Chlorophyll fluorescence, Coastal biogeochemical processes

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Chemoautotrophic CO_2 fixation over the Western Indian Continental Shelf

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ABSTRACT

Chemoautotrophy plays a globally significant role in oceanic carbon cycling, contributing ~0.77 Pg of new carbon (C) annually which can rival the photoautotrophic (algal) primary productivity (PP). Despite its global importance, its role in coastal anoxic systems remains poorly understood. The Western Indian Continental Shelf (WICS), the largest seasonal coastal anoxic system and a major biogeochemical hotspot, undergoes a pronounced transition from normoxic to suboxic/ anoxic/euxinic conditions, creating steep redox gradients that can favour metabolically versatile chemoautotrophic communities. However, the contribution of chemoautotrophic (dark) CO_2 fixation (DCF) to the total column productivity (0.35-3.39 g C m^{-2} d^{-1}) has remained unknown, which can be significant, given the high availability of reduced metabolites (i.e. NH_4^+, H_2S, CH_4, NO_2^- etc) during seasonal anoxia. Our ^{13}C-labelled incubations in the WICS waters off Ratnagiri, Goa, and Mangalore during September-October 2024 and February-March 2025 showed the rates and its seasonality of DCF to be significant. The DCF rates were very high (3.35 to 733 mg C m^{-3} d^{-1}), particularly in the shelf bottom waters off Goa during suboxia/anoxia but decreased significantly (0.52 to 14.18 mg C m^{-3} d^{-1}) during normoxia. During suboxia/anoxia, the bottom waters exhibited higher DCF rates (7.55-733 mg C m^{-3} d^{-1}) than surface layers (3.35- 119 mg C m^{-3} d^{-1}), possibly due to enhanced availability of reduced substrates e.g. NO_2^-, H_2S, NH_4^+ and CH_4 that could fuel chemoautotrophy via sulfide-driven denitrification, anammox, and anaerobic methane oxidation. During the normoxia, measurable DCF rates suggested active nitrification-driven chemoautotrophy by ammonia- and nitrite-oxidizing microorganisms independent of light. Despite lower DCF rates during normoxia, they signify a persistent new carbon input to the system, particularly in subsurface layers which receives incessant benthic NH_4^+ input. The mean column-integrated DCF rate varied from 3709 mg C m^{-2} d^{-1} during suboxia/anoxia to 379 mg C m^{-2} d^{-1} during normoxia which suggested 52% contribution of DCF to the total column productivity during both the seasons. Our study underscores the significance of dark carbon fixation as a substantial yet previously underestimated source of new organic carbon sustaining microbial communities in the coastal oxygen minimum zone of the Arabian Sea.

Keywords: chemoautotrophy, carbon fixation, normoxia, anoxia, shelf, India

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Seasonal Coastal Deoxygenation And Tropical River Plumes Enhances Nitrogen-Fixing Cyanobacteria In The Western Indian Continental Shelf During The Fall-Intermonsoon And Early Winter Monsoon.

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ABSTRACT

N_2-fixing cyanobacteria are ubiquitous in oligotrophic waters and represent a major source of new nitrogen in marine systems. In the western Indian continental shelf (WICS), *Trichodesmium* spp. typically form extensive blooms during the warm spring inter-monsoon (March–May) period. However, surface waters remain nitrogen-limited during other seasons except the peak summer monsoon, and the dynamics of N_2-fixers in the WICS remain poorly understood. We investigated inter- and intra-annual variations of cyanobacterial diazotrophs at a coastal station (27 m depth; G5, CaTS) between 2023 and 2025, covering the fall inter-monsoon (FIM), winter monsoon (WM), and spring inter-monsoon (SIM). Our results revealed that diatom–diazotroph associations (DDAs), particularly *Hemiaulus–Richelia* (H–R) symbioses, dominated nitrate- depleted surface waters during the FIM, with markedly higher abundances in October 2023 compared to October 2024. Interannual data (October 2020–2024) and spatial observations (15– 100 m depth; October 2021) across the WICS indicated recurrent DDA occurrences, with extreme peaks in 2021 and 2023 associated with intense anoxic/euxinic conditions. Coastal anoxia during the FIM, likely remobilizes sedimentary iron-bound phosphate, enriching surface waters with phosphate and Fe(II), thereby favoring diazotroph proliferation. Additionally, tropical riverine plumes deliver nutrients, and when nitrogen becomes limiting, the remaining excess phosphate and iron promote DDA growth in inner-shelf regions compared to outershelf regions. During the WM and SIM, variations in phosphate and iron dynamics could regulate the succession and ecological niches of N_2-fixers. The WICS represents a unique ecosystem where one of the world's largest seasonal deoxygenation events fuels nitrogen loss through subsurface denitrification and nitrogen gain via surface N_2 fixation, thereby coupling both processes spatially within the same region. However, N_2 fixation rates of DDAs in the eastern Arabian Sea remain largely unexplored, warranting focused investigation in future biogeochemical studies.

Key words: N_2 fixing-cyanobacteria, Diatom-diazotrophs, Coastal anoxia, nutrient dynamics, Western Indian continetal Shelf

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Phytoplankton size class response to monsoonal forcing in the Cochin coastal waters

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ABSTRACT

The southwest monsoon strongly influences the bio-optical properties and biogeochemical dynamics of the west coast areas of India. This study investigates how monsoonal forcing modulates the optical properties, biogeochemistry, and phytoplankton size structures in the Cochin coastal waters. Weekly *in situ* observations were conducted at 20 stations during August 2024 in the coastal waters off Kochi. Measured parameters include nutrients, Chl-a, phytoplankton size, total suspended matter, coloured dissolved organic matter, and secchi depth. The Secchi depth was comparatively lower in the Barmouth stations than north and south stations. TSM ranged from 3 to 37 mg L^{-1}. Chl-a concentrations showed considerable spatial and temporal variation (0.483–32.06 mg m^{-3}) throughout the sampling period, with the highest concentrations observed in the second week (avg 12.42 ± 8.69 mg m^{-3}). Nutrient concentrations also varied during the sampling time. The phytoplankton size class analysis revealed spatial and temporal trends. Microphytoplankton dominated mostly in the north and south stations, where the water was clear. Nanophytoplankton dominated at many stations, particularly in the Barmouth region, likely due to the limited light availability due to turbidity, despite the nutrient rich conditions. The pico phytoplankton concentration was low, but was slightly higher at the offshore stations. A *Chaetoceros* bloom was observed during the second week of August, which coincides with high chl-a and nutrients. In the following weeks (third and fourth), a significant decrease in the N/P ratio was evident, which was likely due to the nitrogen loss that took place as a result of the anoxic conditions formed due to the decaying of the bloom. Weekly principal component analyses showed a distinct shift from nutrient rich pre-bloom conditions in the first week to diatom bloom in the second week, driven by high nitrate and silicate availability. The following weeks exhibited nano plankton dominance with lower nitrate and phosphate influence, suggesting a transition to post bloom, regenerated nutrient regimes that favour small phytoplankton size class. This study demonstrates that monsoonal forcing modulates light availability, turbidity, and nutrient enrichment and thereby shapes phytoplankton size structure.

Keywords: Microplankton, Turbidity, Nutrients, PCA, Chlorophyll

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Validation Of Cmip6 Models For Ocean Biogeochemistry In The Tropical Indian Ocean

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ABSTRACT

The Tropical Indian Ocean plays a key role in regional climate, monsoon dynamics and marine ecosystems. It influences weather and monsoon patterns over South Asia, East Africa, and Australia and is a major driver of the Indian summer monsoon. Beyond its physical processes, the Indian Ocean is a key region for marine productivity supporting biogeochemical interactions which regulate regional fisheries and nutrient cycling. Despite the growing use of CMIP6 Earth System Models to simulate climate variability, the comprehensive evaluation of their biogeochemical components remains limited compared to the extensive assessments of physical variables such as sea surface temperature and sea level. This research aims to bridge that gap by validating the performance of CMIP6 models for key biogeochemical variables such as chl-a and nutrients alongwith selected physical variables in the Indian Ocean. Using Multi-source observational datasets and satellite products, the study compares model data with observations through statistical skill metrics including correlation coefficient, standard deviation and root mean square error. The analysis will add to the existing knowledge of biogeochemical simulations, reveal model biases, and rank the best-performing models for this region. It will demonstrate how effectively these models capture key oceanic processes such as upwelling, oxygen minimum zones, and primary productivity. These results will contribute to a better understanding of the physical dynamics and the biogeochemical behaviour of the Indian Ocean and implications for future projections.

Keywords: Ocean Biogeochemistry, CMIP6, Tropical Indian Ocean, Chlorophyll, Net primary productivity

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Quantification of pCO_2 and CO_2 Gas Exchange in the Bhitarkanika Estuary, East Coast of India

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ABSTRACT

Estuaries are defined as a transition zone at the land-sea interface, and is characterized by strong geochemical gradient due to the mixing of fresh and saline water. It represents a unique biogeochemical setting where fate of carbon has been modified drastically due to large scale variation in different physio-chemical properties. Estuaries, despite their comparatively small surface area (~0.3% that of the global ocean), serve as an important component of the global carbon cycle. It has been found that estuaries play an important role in modulating the global CO_2 budget. Wide variation of CO_2 flux has been observed depending on the environmental setting of an estuary. Therefore, it is important to estimate the pCO_2 and CO_2 fluxes in different estuaries on a spatial and temporal scale. In this work, an attempt has been made to evaluate the variation of pCO_2 and CO_2 flux at air-water interface in the Bhitarkanika estuary which is formed by the Brahmani and Baitarani rivers that drain into the Bay of Bengal. The annual average surface water pCO_2 in the Bhitarkanika estuary is estimated to be 2036 µatm, which is higher than that of the atmosphere (□400 µatm). Such a high pCO_2 is attributed to intense organic matter decomposition that suggests a net heterotrophic environment prevailing in the estuary. Seasonal variation of pCO_2 is significant. The highest average pCO_2 was observed during monsoon (3079 µatm), and lowest one was during summer (298 µatm). Overall, the super-saturation of pCO_2 makes this estuary a significant source of CO_2 to the atmosphere with an annual flux of 17.5 ± 9.6 mol C m^{-2} yr^{-1}. Therefore, this study shows the importance of small-scale estuaries in the global carbon budget, and signifies the predominance of mangroves on significantly high pCO_2 and its flux to the atmosphere.

Keywords: Surface water, pCO_2, CO_2 efflux, Bhitarkanika estuary

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Real-Time Monitoring Reveals Urbanization-Driven Degradation of Coastal Waters off Visakhapatnam

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ABSTRACT

The coastal water qualities of many tropical countries are being significantly impacted by rapid urbanization and industrial growth, but there are still few real-time measurements. By combining traditional field sampling with high-frequency buoy observations, this study investigates the spatial and short-term temporal variability of physico-chemical, and microbiological parameters of the coastal waters off the urbanized Visakhapatnam coast.. Temperature, salinity, dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TSS), nutrients (NO_2^-, NO_3^-, NH_4^+, PO_4^{3-}, SiO_4^{4-}), chlorophyll-a, and microbiological indicators were measured in surface-water samples taken from 13 coastline stations during February 2023. The findings showed high BOD (mean 5.09 mg L^{-1}) and significant nutrient enrichment (NO_3^- up to 14.15 µM; PO_4^{3-} up to 4.75 µM; NH_4^+ up to 34.58 µM), indicating strong eutrophic tendencies. Near harbor-influenced zones, dissolved oxygen decreased below 3 mg L^{-1}, indicating localized hypoxia associated with organic loading. Untreated sewage discharge was reflected in microbial contamination, such as faecal coliforms and Klebsiella spp. Dynamic diel variations in DO (4.0–11.24 mg L^{-1}) and chlorophyll-a (0.25–27.13 µg L^{-1}) were recorded by real-time buoy observations (10-minute intervals), emphasizing bloom-driven oxygen supersaturation during daytime and nocturnal depletion. Nutrients, suspended particles, and microbial loads were found to be the main causes of water- quality variations by multivariate analysis. Critical ecological stress was highlighted by the CCME-WQI's "poor" to "very poor" ratings for every station. In addition to providing crucial baseline data for regulating eutrophication and microbiological pollution in fast urbanizing tropical beaches, this work highlights the benefits of combining sensor-based monitoring with conventional sample for near-real-time assessment. These results are expected to encourage government authorities to build data-driven, adaptable coastal strategies.

Keywords: Coastal water quality, real-time buoy, eutrophication, microbial contamination, hypoxia, CCME-WQI, Bay of Bengal, urban coastal systems, environmental monitoring, Visakhapatnam coast

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Benthic-pelagic coupling over the Western Indian Continental Shelf

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ABSTRACT

The Western Indian Continental Shelf is a productive coastal ecosystem which sustains a large fishery, economy and livelihood of the coastal regions. The coastal upwelling sustains high primary productivity (PP) (0.24-3.39 g C m^{-2} d^{-1}) during the summer monsoon (June-September). However, the PP still remains modest (0.1-0.63 g C m^{-2} d^{-1}) during the post-monsoon period (October-May), despite the prevalence of oligotrophy (N-limitation). To understand the prime reason, we studied the benthic exchange rates of O_2 and nutrients at 3 innershelf stations off Ratnagiri, Goa, and Mangalore during normoxia (February-March) and anoxia (September- October) between 2013 and 2025. The benthic respiration (BR) during normoxia (22.86 mmol O_2 m^{-2} d^{-1}) suggested 100% mineralization of C_{org} equivalent of pelagic PP which decreased to 48% during anoxia although BR increased by 2 fold. Significant (3 fold) decrease in benthic NH_4^+ efflux from anoxia (3.47 mmol m^{-2} d^{-1}) to normoxia with concurrent benthic NO_3^- efflux (0.46 mmol m^{-2} d^{-1}) indicated the occurrence of benthic nitrification (1.55 mmol N m^{-2} d^{-1}). During normoxia, lower net DIN efflux (1.56 mmol m^{-2} d^{-1}) compared to anaerobic NH_4^+ efflux (2.66 mmol m^{-2} d^{-1}) suggested massive (40%) loss of diffusing NH_4^+ via coupled benthic nitrification-denitrification. During anoxia, the shelf sediment was still a net source of DIN (2.81 mmol N m^{-2} d^{-1}) despite significant benthic NO_3^- influx (0.81 mmol m^{-2} d^{-1}) feeding the benthic denitrification. Benthic PO_4^{3-} efflux increased by 11 fold from normoxia (0.06 mmol m^{-2} d^{-1}) to anoxia (0.67 mmol m^{-2} d^{-1}) apparently due to non-Redfieldian P release through reductive dissolution of sedimentary ferric minerals. Benthic Si efflux increased by ~2 fold from normoxia (1.85 mmol m^{-2} d^{-1}) to anoxia possibly due to higher biogenic Si availability. Benthic nutrient fluxes potentially met 51% of N, 31% of P and 64% of Si demand of pelagic primary producers during February-March which increased to 67% of N, 68% of P and 78% of Si during September- October, indicating a strong benthic-pelagic coupling which sustained the pelagic productivity and ecosystem functioning during oligotrophic non-monsoon period. These results also match with the fishing catch during the post-monsoon period lending support to the importance of benthic-pelagic coupling in sustaining the fishery of this region.

Keywords: sediments, oxygen, nutrients, flux, productivity, shelf, India

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Long-Term Carbon And Nitrogen Accumulation In A Tropical Estuary: Implications For Global Blue Carbon Accounting And Nitrogen Pollution

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ABSTRACT

While the role of tropical estuarine mangroves in climate mitigation through carbon sequestration is well established, the broader estuarine ecosystems that receive significant carbon and nitrogen inputs from land, ocean, and adjacent wetlands have been less explored for their potential in carbon sequestration and mitigating atmospheric warming. Here, we report that a large tropical estuary, while being a significant source of atmospheric CO_2, CH_4, and N_2O, also serves as a major carbon reservoir, sequestering approximately 38.4 ± 33.4 Gt C yr^{-1}. This dual role underscores the vital contribution of estuaries in in managing the global carbon budget. The estuary showed a 53-year record of carbon and nitrogen accumulation and displayed a robust carbon burial rate (127.9 ± 111.4 g cm^2 yr^{-1}), comparable to nearby mangroves and exceeding other coastal ecosystems. Physicochemical parameters like pH, redox potential, water content, and dry bulk density influenced organic matter preservation across sites. The $\delta^{13}C$ signatures indicated a mix of marine and terrestrial carbon sources, whereas the $\delta^{15}N$ signatures revealed significant pollution from anthropogenic nitrogen across many study sites, with enrichment observed in the surface sediment layer (0-2 cm) and extending several centimeters deeper into the core. It was also evident from sediment cores that the N pollution from anthropogenic sources existed since 1972. The study emphasizes that the role of estuaries in carbon sequestration cannot be ignored in the perspectives of global carbon and nitrogen budget. The study also recommend that tropical estuaries that are undergoing rapid degradation as a result of rising urbanization needs to be protected to ensure the ecosystem services they render.

Keywords: Carbon sequestration, Anthropogenic nitrogen, Estuaries, India, Climate mitigation

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Geochemical Partitioning And Ecological Risk Assessment Of Heavy Metals In Restricted Mangrove Areas Of Indian Sundarbans: Insights From Contrasting Hydrodynamic Regimes

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ABSTRACT

The Sundarbans mangrove delta, a UNESCO World Heritage Site, is a critical blue carbon reservoir, threatened by escalating heavy metal (HM) pollution from upstream industrial activities. While previous studies focus on accessible regions, understanding HM dynamics in restricted areas remains unstudied.

This study presents the first comprehensive geochemical assessment of HM speciation across three hydrodynamically distinct zones in protected Indian Sundarbans: (1) calm mangrove interior, (2) erosional tidal-active regions, and (3) cyclone-protected creek margins. Sediment cores (up to 73 cm) were analyzed for total HM (ICP-OES), organic carbon (CHNS), grain size, and HM speciation via BCR sequential extraction. FTIR spectroscopy revealed organic matter binding sites controlling metal-OM interactions.

Results show distinct patterns: calm zones displayed higher total HM accumulation with dominant Fe-Mn oxyhydroxide association, indicating protected deposition. Erosional zones exhibited lower total HM but elevated exchangeable fractions, suggesting active remobilization during monsoon stress. Silt-dominated sediments (≥75%) preferentially retained fine-associated metals, while clay fractions showed highest metal loading per unit surface area. FTIR indicated carboxylic and phenolic groups as primary HM binding sites, with variations reflecting terrestrial versus marine organic matter inputs.

Contamination indices (Enrichment Factor, Geo-accumulation Index, Potential Ecological Risk Index, and Risk Assessment Code) classified sites as moderately high pollution levels. Hydrodynamic regime fundamentally controls HM partitioning and bioavailability—critical for predicting metal cycling under monsoon intensification and sea-level rise.

This first dataset from restricted Sundarbans areas establishes a baseline for monitoring contamination changes and supports ecosystem-based management strategies in this biodiversity hotspot.

Keywords: Heavy metal speciation, Mangrove sediments, Ecological risk assessment, Coastal geochemistry, Estuary hydrodynamics

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Dynamics of Dissiolved Carbon in the Mandovi and Zuari Estuaries of Goa.

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ABSTRACT

Estuaries are dynamic ecosystems characterized by complex land-sea interaction that influence a variety of biogeochemical parameters. While these systems play significant roles, from sustaining biodiversity to supporting regional economies. Their natural buffering abilities makes it more concern to understand its carbon cycle in this ecosystem. With the continuous rise in the atmospheric Carbon dioxide (CO_2) concentrations estuaries can function as either a net source or a sink for CO_2. The study explores the potential of estuaries to sequester increased anthropogenic CO_2 emissions, a critical greenhouse gas. This is done in wide concern to understand the distributions of partial pressure (pCO2) in the surface waters of the Mandovi and Zuari estuaries. The study deals with temporal and spatial distributions to reflect this the physical-biogeochemical factors including temperature, salinity, pH, alkalinity, dissolved oxygen (DO), etc. are analyzed. Based on the measured marine carbonate system parameters, pCO_2 in the estuarine water is studied using PyCO2SYS. Quantifying air-water CO_2 exchange provides critical insights into estuarine health and CO_2 flux throughout the different regions of estuaries, as these estuaries originate in the Western Ghats of India, flow through urbanized regions, and eventually drain into the Arabian Sea.

Keywords: Mandovi and Zuari Estuaries of Goa, Carbon dioxide, pCO2, PyCO2SYS

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Distribution Of Coloured Dissolved Organic Carbon Along The Cochin Estuary And Its Effect On The Biogeochemistry Of Phytoplankton.

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ABSTRACT

The Cochin Estuary, a dynamic and eutrophic tropical estuarine system in southwestern India, exhibits strong seasonal variability driven by monsoonal freshwater inputs and salinity intrusion. Coloured Dissolved Organic Matter (CDOM) influences aquatic ecosystems by controlling underwater light availability, shaping microbial and phytoplankton dynamics, and regulating nutrient bioavailability. This research explores the spatiotemporal dynamics, sources, and optical properties of chromophoric dissolved organic matter (CDOM) at 17 stations over three seasons (monsoon, post-monsoon, and pre-monsoon) during 2022–2023. CDOM was described in terms of absorption coefficients (0.09-0.92m^{-1}), spectral slope parameters (S275–295 (0.00-0.04), S350–400 (0.004-0.016) and absorbance ratios (E2/E3 (3.14-33.2), E2/E4 (3.41-41.56), Spectral Ratio (0.05-2.38), in addition to physicochemical and biological parameters. Seasonal fluctuations were significant, with maximum aCDOM(440) values occurring during the monsoon season, indicating high allochthonous input, and the post-monsoon and pre-monsoon seasons showing high autochthonous contributions. Multivariate analysis, such as PCA and nMDS, revealed that CDOM dynamics were inextricably linked to hydrological and nutrient loading, with changes in source signatures controlled by freshwater inflow, microbial activity, and phytoplankton productivity. Significantly, an anomalously low-rainfall monsoon in 2023 shifted the composition and origin of CDOM, further emphasising the estuary's sensitivity to seasonal change. Overall, these results emphasise the central role of CDOM as both an indicator and a driver of estuarine biogeochemistry and suggest important implications for water-quality monitoring and carbon cycling in monsoon-influenced coastal environments.

Keywords: Cochin Estuary, CDOM, Spectral slope, Monsoon variability, Ecosystem impact

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Spatio-Temporal Trends in Mangrove Cover Following the 2004 Tsunami and Coastal Uplift in the North and Middle Andaman Islands, India

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ABSTRACT

The 2004 Sumatra-Andaman earthquake (9.2 Mw) caused an acute land uplift of up to 1.35 m in the North Andaman Islands. The resultant relative sea level drop triggered extensive mangrove die-off; while it also created new intertidal zones along the seaward edge, which are suitable for mangrove colonisation.

We assessed the mangrove degradation and colonisation trajectory in the North and Middle Andaman over the last two decades (2004 – 2024) using time-series analysis of Landsat 5/8 and Sentinel-2 imagery processed in Google Earth Engine.

Mangrove extent significantly decreases from 453 km² in 2004 to 270.2 km² in 2024 (40 % decrease). Degradation peaked in 2005–2016 at 14.9 km² yr^{-1} but slowed to 2.2 km² yr^{-1} in 2020–2024. Meanwhile, the land uplift created 150 km² of new intertidal zones in the North Andaman, of which, 13.9 km² (9 %) is currently colonized by mangroves. Colonisation rates increased from 0.4 (in 2010) to 1.4 (in 2024) km² yr^{-1} over the study period. Extreme land uplift (> 1 m) and coral rubble substratum across the west coast of North Andaman likely resulted in slower colonization compared to the east coast with less uplift (<0.6 m) and sand and muddy substratum.

The inventory of 150 km² new intertidal zones with potential for mangrove colonization provide a foundation for adaptive management towards large scale recovery and restoration of mangroves. Also, our findings provide a basis for assisted mangrove restoration to sustain long-term ecological resilience and ecosystem services in the Andaman Islands.

Keywords: Mangrove mapping; Sea level change; Sea level drop; Mangrove colonisation; Mangrove degradation; Mangrove succession

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Mangrove carbon stock recovery following the major vegetation loss after the 2004 Indian Ocean tsunami and coastal subsidence in the Nicobar Islands

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ABSTRACT

Large-scale disturbances play a crucial role in shaping ecosystem characteristics. The massive 97% mangrove loss in Nicobar Islands due to the coupled effects of 2004 Indian Ocean tsunami and coastal subsidence is a recent example for this. The new intertidal areas created by coastal subsidence had provided conducive environment for natural colonization of mangroves, offering an opportunity to study vegetation recovery and carbon stocks of the pre and post-tsunami timescales. We collected mangrove vegetation data of dead and remnant standing stumps from six tsunami affected sites in 2011 (pre-tsunami period) and standing live mangroves from 13 sites in 2022 (post-tsunami). The species composition and density have significantly differed between pre and post-tsunami timescales ($p<0.05$); where species of *Rhizophora* L., and *Bruguiera gymnorhiza* (L.) Lam. ex Savigny dominated during pre-tsunami; while *Sonneratia lanceolata* Blume and *Lumnitzera racemosa* Willd. have dominated in post-tsunami timescales. Meanwhile, the carbon stocks have also shown a significant change ($p<0.05$) between the pre and post-tsunami timescales. The average total biomass in 2022 was 37.25±7.44 Mg/ha^{-1}, with a mean carbon stock of 16.88±3.38 Mg/ha^{-1}, which is nearly six folds lesser than pre-tsunami values (Biomass = 205.03±22.52 Mg/ha^{-1}; Carbon stock = 91.56±9.58 Mg/ha^{-1}). Our study established a crucial baseline information in understanding mangrove recovery and carbon stock after the 2004 natural disturbances.

Keywords: Blue carbon; Coastal Ecosystem; Ecosystem recovery; Mangrove succession; Mangrove biomass

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Distribution and variations in mangrove carbon stocks along the Maharashtra coastline

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ABSTRACT

Mangroves are globally recognized as blue carbon ecosystems that play a vital role in climate change mitigation by storing nearly 47% of the total carbon buried in marine sediments despite covering only 0.3% of the ocean's surface. Baseline information on mangrove carbon stock availability has become a critical aspect of climate agenda. The current study assessed vegetative biomass and carbon stock in major mangrove sites across the Maharashtra coastline. Distribution of carbon among different pools and species-level contributions was also determined.

Using non-destructive sampling protocols, tree density, basal area, and species composition were measured for live trees, dead trees, and saplings across eight major mangrove sites in Maharashtra. Biomass was estimated through species-specific allometric equations, and standard carbon conversion factors were used to determine carbon stock. Woody debris was quantified using the planar intersect method.

The mean biomass and vegetation carbon stock in mangroves of Maharashtra were 222.00 ± 78.49 Mg/ha and 99.56 ± 35.20 Mg C/ha, respectively. Live trees represented the major carbon pool (91%). Among 8 mangrove species, *R. mucronata* contributed the most to the total biomass (566.90 Mg /ha), with a carbon stock of 268.79 Mg C/ha. The highest carbon stock was recorded in Achara (284.64 ± 88.89 Mg C/ha). Carbon stock was strongly correlated with basal area ($r = 0.98$, $p < 0.001$), indicating the influence of structural attributes on carbon stock.

Our findings highlighted the site and species level variations in the mangrove carbon stocks across the Maharashtra coastline and provided a critical baseline for strengthening the management and protection of the mangrove ecosystem. This will be particularly important for national climate mitigation frameworks (e.g., REDD+) and greenhouse gas reduction commitments.

Keywords: Carbon dynamics, Vegetation biomass, Mangrove conservation, Allometric equations, Climate change mitigation

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Seasonal Dynamics Of Radiatively Active Gases And Carbonate System Processes In The Mangrove Estuaries Of The Indian Sundarbans

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ABSTRACT

India's coastal blue carbon ecosystems play a pivotal role in regulating greenhouse gas exchanges and sustaining biodiversity. The Indian Sundarbans, the world's largest contiguous mangrove forest, offers a unique lens to study these dynamics under strong seasonal and tidal influences. This study integrates five years (2016–2020) of carbonate chemistry and greenhouse gas data from three estuaries across the Indian Sundarbans to elucidate biogeochemical linkages underpinning carbon sequestration and emission. Total alkalinity (TA), dissolved inorganic carbon (DIC), and pH showed marked seasonal variation, with maxima during pre-monsoon (TA up to 2506 µmol kg^{-1}; DIC up to 2203 µmol kg^{-1}) and minima during monsoon dilution. Post- monsoon recovery, coupled with elevated chlorophyll a and dissolved oxygen, revealed enhanced primary production as a key driver of inorganic carbon buildup and suppressed CO_2 efflux. Despite intense organic matter recycling, CO_2 fluxes remained modest (0.4 ± 0.61 to 1.62 ± 1.74 mmol m^{-2} h^{-1}), suggesting efficient carbon retention within the estuarine continuum. Simultaneous measurements of CH_4 and N_2O fluxes revealed strong spatial–temporal variability, governed more by substrate availability and microbial decomposition than by salinity or physical mixing. CH_4 fluxes (0.4–18.4 µmol m^{-2} d^{-1}) and N_2O fluxes (−0.6–5.4 µmol m^{-2} d^{-1}) were seasonally asynchronous with CO_2, highlighting complex feedbacks within the mangrove carbon cycle. Together, these findings position the Indian Sundarbans as a resilient yet vulnerable Blue Carbon hotspot—acting alternately as a carbon sink and a modest greenhouse gas source. Strengthening protection, monitoring, and valuation of such ecosystems through Blue Carbon markets and nature-based solutions is crucial for advancing India's Net Zero 2070 goals.

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Carbonic Anhydrase-Mediated CO_2 Sequestration by Marine Bacterial Communities

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ABSTRACT

Marine bacteria are reported to be promising candidates for enzyme-mediated biomimetic CO_2 sequestration, as they exhibit unique properties, including salt tolerance, the ability to function under elevated pressure, broad pH stability, and sustained catalytic activity under extreme environmental conditions. Carbonic anhydrase, a ubiquitous metalloenzyme catalyzing the reversible hydration of CO_2, offers a promising biocatalytic approach for industrial carbon capture, utilization, and storage. In this study, bacterial isolates obtained from coastal habitats in Goa were evaluated for carbonic anhydrase activity and their ability to induce calcite formation. Several strains exhibited high carbonic anhydrase activity, resulting in rapid pH elevation and a marked decrease in free calcium concentration during the incubation period. The morphology and composition of the precipitated minerals were characterized using X-ray diffraction and scanning electron microscopy, confirming the presence of distinct calcite polymorphs. Controlled-chamber experiments were further conducted to simulate CO_2 absorption conditions and assess the sequestration efficiency of these isolates. The setup enabled quantification of CO_2 uptake under regulated environmental parameters, thereby reflecting the enzymatic potential of coastal bacteria to facilitate CO_2 hydration and carbonate conversion in controlled systems. Overall, the findings highlight the potential of coastal region-associated bacterial communities from Goa as efficient, low-cost, and sustainable biocatalysts for enzyme-assisted carbon capture and mineral storage applications.

Keywords: Biocatalyst; Carbonic anhydrase; Calcite; CO_2 sequestration; Marine bacteria

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Variability of Physico-Chemical Parameters in Ribandar Creek and Ourem Creek from June 2025

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ABSTRACT

Coastal creeks form an essential component of Goa's estuarine network, playing a significant role in maintaining ecological balance, supporting biodiversity, and sustaining local livelihoods. Among these, Ribandar Creek and Ourem Creek, located in the Tiswadi taluka of North Goa district, are vital tidal water bodies influenced by both natural and anthropogenic factors. Ribandar Creek lies along the left bank Mandovi River. It is influenced by tidal flow and there are nearby salt-pans. Ourem Creek, situated to the east of Panjim, is characterized by tidal currents and mangrove-fringed channels, receiving substantial runoff from surrounding urban areas. The ecological functioning of these creeks is crucial for nutrient cycling, flood regulation, and maintaining water quality.The present study focuses on assessing the physico-chemical water quality of Ribandar and Ourem creeks to understand the seasonal and spatial variations in water characteristics. Water samples were collected monthly from multiple sampling stations, seven along Ourem Creek or its tributaries and three along Ribandar Creek based on accessibility and representativeness of the study area. The collected samples were analyzed for various physico-chemical parameters such as pH, salinity, temperature, electrical conductivity, turbidity, water hardness, oxidation-reduction potential (Eh), and dissolved oxygen (DO) using standard laboratory procedures. Seasonal variations, particularly between the monsoon and post-monsoon periods, were also studied to determine their influence on the overall water quality and ecological stability of the creeks.Continuous monitoring of these creeks is essential, as they are increasingly exposed to urbanization, waste discharge, and tidal influences that can alter their natural water chemistry and ecological functioning. The findings of this study contribute baseline data for future environmental assessments and emphasize the urgent need for sustainable monitoring and protection of Goa's fragile estuarine ecosystems to preserve their ecological and socio-economic importance.

Keywords: Creeks, Water Quality, Physio-chemical Parameters, Anthropogenic impacts

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Non-Native Species Recorded Along The Artificial Coastal Defence Structures Of Tamil Nadu Coast, India

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ABSTRACT

Human beings are greatly dependent upon natural ecosystems for the wide range of service provided essential for endurance (Holmulund and Hammer, 1999), chiefly the marine resources. The rise in coastal population leads to a proliferation of artificial coastal defense structures (ACDS), thus protecting them from sea level rise and increased storm frequency (Hinkel *et al*., 2014). ACDSs deployed in marine environments are always colonized by epibiotic sessile species which in turn create biogenic habitats for additional fauna of mobile species (Clynick *et al*., 2007). Though the ACDSs support the growth of various marine biota, including non-native species. Therefore, it was aimed to study the settlement of non-native species in the ACDSs of entire Tamil Nadu coast. Despite the variations in structures, the non-native species (Cryptogenic, and Introduced) occupied almost all the types of structures. The ascidians are the most dominant species in case of the non-native species. Among the 84 stations comprising the ACDSs along the Tamil Nadu coast recorded the total of 29 non-native species. Almost 26 species belonging to the ascidians, 2 species belonging to the bryozoan and 1 species to the gastropod have been reported. Eighteen species belonged to cryptogenic. The two species namely *Polyclinum isipengense* and *Diplosoma variostigma* were reported for the first time in the Indian coastal waters. The ACDSs serve as an asylum for the Non-Indigenous Alien species (NIAs). The sheltered boulder-pile breakwaters of fishing harbour were the preferred habitat for bryozoans, except north of Mandapam jetty, where *A. verticillata* colonized the concrete pile structures supporting the fishing jetty. The invasive ascidians are the serious threat to the

Shellfish and aquaculture industries. The outcome of this study can also help the governing bodies to formulate or redefine the policies in the maritime activities to avoid the invasion of species.

Keywords: Artificial Coastal Defence Structures, Tamil Nadu Coast, Epibiota, Non-native species, Fouling Organisms, Ship hull; Marine Policies

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Molecular Identification And Bioprospecting Of Tunicates Of Indian Coastal Water.

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ABSTRACT

Molecular characterization and bioprospecting of tunicates from Indian coastal waters were undertaken to establish a robust taxonomic framework and evaluate their potential as sources of high-value marine biomolecules. A total of 65 ascidian species were identified using mitochondrial cytochrome oxidase I (COI) sequencing, and diagnostic DNA barcodes were generated and deposited in BOLD, while nearly 400 partial COI sequences were submitted to NCBI, substantially enriching global ascidian barcode coverage and facilitating species-level resolution in a region of high but under-documented diversity. This molecular baseline provides a critical resource for future biodiversity assessments, invasive species surveillance, and conservation planning in the Indian Ocean realm.

Bioprospecting of selected colonial and solitary ascidians revealed a comprehensive nutritional profile, including favorable proportions of essential amino acids, polyunsaturated fatty acids, and key micronutrients, underpinning their promise as novel functional marine foods and nutraceutical candidates. Crude extracts exhibited pronounced anticancer activity against human cancer cell lines MCF7, HCT 116, and HeLa, in line with emerging evidence that ascidian- derived metabolites can inhibit tumor cell proliferation with limited toxicity to normal cells. In silico screening of ascidian-derived compounds further identified a novel candidate drug-like molecule with predicted inhibitory activity against multiple human pathogenic bacteria and major aquaculture pathogens, including White Spot Syndrome Virus (WSSV), highlighting prospects for next-generation anti-infectives in both clinical and aquaculture settings.

By integrating large-scale DNA barcoding with targeted bioactivity discovery, this study positions Indian tunicates as dual assets for ocean biodiversity inventories and blue biotechnology pipelines, directly supporting global One Ocean and sustainable blue economy objectives.

Keywords: Molecular taxonomy, DNA barcoding, Tunicates (Ascidiacea), Anticancer and antimicrobial potential, Indian coastal waters.

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First evidence of Microplastic Uptake from solitary ascidian Phallusia arabica with HighResolution Single-Particle Characterisation from South Andaman Islands

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ABSTRACT

Suspended Particulate Matter Microplastics (SPM-MP) have arisen as a critical environmental concern for the marine reef ecosystem, driven by their pervasive nature in growing magnitude. Filter and Suspension feeder organisms are the primary water processors affected first by the suspended microplastics for their continuous water filtration and the sessile mode of feeding mechanism. The sessile solitary ascidian Phallusia arabica was sampled from the subtidal reef habitat of Fish Point Dive Site using SCUBA (Self-Contained Underwater Breathing Apparatus) diving surveys to assess the prevalence of Suspended Particulate matter and diffused microplastics at Chidiyatapu, South Andaman. Microplastic particles were recovered from the specimen on dissection of the gut loop and mild alkaline digestion. Stereo microscopy combined with Sudan Black B staining confirmed the polymeric composition of the recovered microplastic particles. Micro-Raman spectroscopy was adopted for the characterisation of the polymer types of the microplastic particles. Complementary FTIR analysis was carried out for the identification of the polymer category. SEM imaging of microplastics revealed morphological features along with surface abrasion. The combined spectroscopic and microscopic approaches enabled complete multi-modal characterisation of each particle. This study presents the first evidence of microplastic uptake by Phallusia arabica from the Andaman Islands, depicting the species' vulnerability to particulate pollution. The singleparticle Raman–FTIR–SEM workflow contributes key baseline data for future monitoring in ecologically sensitive zones of the Andaman Islands.

Keywords: Phallusia arabica, Microplastics, Micro-Raman spectroscopy, FTIR, Andaman Islands

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Oxidative Stress Response In Coelomocytes Of The Tropical Seastar Astropecten Indicus Under Polystyrene Microparticle Exposure

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ABSTRACT

Microplastics are pervasive and persistent pollutants in estuarine and coastal ecosystems, with well-documented potential to disrupt the immunophysiological homeostasis of marine organisms. This study examines the oxidative stress responses induced by polystyrene (PS) microparticles in the coelomocytes of the tropical seastar Astropecten indicus, a benthic suspension feeder inhabiting the coastal waters of West Bengal, India. Industrial-grade PS microparticles, a common component of regional marine litter, were characterised using optical microscopy, Fourier transform infrared (FTIR) spectroscopy, and micro-Raman spectroscopy to confirm polymer identity and surface weathering. Sea stars were exposed to environmentally relevant concentrations of PS microparticles (0.25, 0.5, and 1 mg L^{-1}) for 7 and 14 days under controlled laboratory conditions. Immunophysiological responses were evaluated through total coelomocyte count, cell viability, cytotoxicity assays, and quantification of reactive oxygen and nitrogen species. PS exposure resulted in a significant decline in coelomocyte abundance and viability, accompanied by disruption of the antioxidant–prooxidant balance. Prolonged (14-day) exposure further elevated superoxide anion production while suppressing nitric oxide generation, indicating oxidative stress–mediated impairment of coelomocyte cytotoxic function. These responses demonstrate that A. indicus is highly susceptible to microplastic-induced immunotoxicity. Given its benthic, suspension-feeding lifestyle and ecological relevance, this species serves as a promising bioindicator of microplastic contamination in tropical coastal ecosystems. Overall, the findings underscore that escalating microplastic pollution may impose chronic oxidative and immunophysiological stress on marine invertebrates, signalling broader deterioration of environmental health and the ecological integrity of coastal habitats.

Keywords: Microplastics, Polystyrene, Seastars, Oxidative stress, Coastal pollution

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Eco-immunological diversity of sea stars of West Bengal coasts

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ABSTRACT

The origin, diversity, cellular lineage, and fate of echinoderm coelomocytes remain unresolved despite their functional parallels with vertebrate myeloid cells and their value as biomarkers in ecotoxicology. Although the pharynx and axial organs of echinoids have been proposed as hematopoietic analogues, the precise sites of coelomocyte production in asteroids are still unknown. Sea stars rely entirely on an innate immune system mediated by free-circulating coelomocytes within the coelomic fluid; however, the morphology, ultrastructure, and functional specialization of these cells are insufficiently characterized, particularly in tropical species. India hosts twelve known species of sea stars, including several occurring along the West Bengal coast, yet detailed immunobiological studies from this region are scarce. Our previous work on Astropecten indicus demonstrated distinct antioxidant and cytotoxic capacities in its coelomocytes, highlighting the importance of species-specific immune traits. A review of global literature further indicates that morpho-functional diversity among sea star immune cells and their relationships with habitat characteristics and environmental stressors remain poorly understood. The present study aims to advance knowledge of asteroid ecoimmunology by examining the ultrastructure, cellular differentiation patterns, and functional attributes of coelomocytes extruded from sea stars collected along the West Bengal coast. Special emphasis will be placed on antioxidant and pro-oxidant responses, which are central to innate immune defence and sensitive to environmental perturbations. By integrating morphological, ultrastructural, and functional immune assays, this study will provide new insights into the diversity, plasticity, and ecological significance of coelomocytes, contributing to a more comprehensive understanding of innate immunity and environmental adaptation in tropical echinoderms.

Keywords: Immunobiology, Evolutionary immunology, Echinoderms, Seastars

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Nereidids (Polychaeta, Annelida) as potential biomonitors of coastal mudflat: A taxonomy-based ecological perspective from Gulf of Khambhat, India

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ABSTRACT

Gulf mudflats represent one of the vulnerable ecosystems on earth. Due to its unique geomorphology and tidal circulation pattern, an extreme ecological condition prevails in the nearshore coastal areas. Gulf of Khambhat (GoKh), known as the largest intertidal mudflat along the western coastline of India, surrounded by heavy industrialized zone and experiences possible deep-sea discharges of harmful contaminants from various sources. Besides, its large intertidal zone is highly prone to coastal erosion. The establishment of world largest ship-recycling yard at Alang has made this mudflat more significant in ecology and biodiversity view point. The cumulative effect of extreme environmental conditions as well as anthropogenic stress resulted in low macrobenthic diversity however with high abundance of a particular polychaete family called Nereididae (Polychaeta, Annelida). This family represents low species richness with higher abundance that control majority of the resources in this mudflat. This benthic phenomenon indicates an alarming ecological situation for this area. Our morphological as well as molecular investigations revealed two possibly new species of nereidids from the Alang and adjacent coastal mudflats. They share two distinct ecological niche along the horizontal stratification of the intertidal zone. Further investigations have also revealed their potential in bioaccumulating harmful pollutants like POPs (Persistent Organic Pollutants) at significant concentration. Moreover, their potential in biodegradation of such pollutants established their high resilience through long-term ecological adaptation in this mudflat. Adaptation and implementation of biomonitoring strategies in the mudflats surrounding Alang ship-recycling yards is the need of the hour. Based on our research evidences, the study aims to establish these new species as potential biomonitors as well as sentinel taxa to represent the mudflat status and its vulnerability. They can also become an effective tool towards integrative monitoring programs to classify mudflat vulnerability along pollution gradient.

Keywords: polychaetes, sentinel taxa, new species, pollutants, gulf mudflats

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Assessment of Vegetative Biomass and Carbon stored in mangroves along the south-western coast of India

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ABSTRACT

Mangroves are an important blue carbon ecosystem that plays a significant role in the global carbon cycle and climate change mitigation. The present study aims to assess the vegetative biomass (above-ground and below-ground) and the potential of current carbon stocks stored in the mangrove forests along the south-western coast of India. IPCC Tier 3 sampling methodology was followed across eight sites to assess vegetative biomass and carbon. Biomass was calculated by general allometric formulas that were specific to the Asian region. The study revealed the presence of 15 mangrove species belonging to 12 genera and 8 families. The mean living biomass of the mangrove forest was found to vary with a range from 245.3 Mg ha-1 to 1363 Mg ha-1. The highest biomass was found in Dakshin Kannada, while the lowest was recorded in the Udupi district. In terms of the overall biomass composition, AGB comprised approximately 47-60%, whereas BGB accounted for about 40-53%. The research indicated that the importance of the mangrove areas in Madila and Karwar is largely attributed to the presence of mature A. officinalis trees with substantial basal areas. In contrast to the planted mangrove forest sections, the natural mangrove regions exhibited higher levels of carbon storage. The data assessed from the present research highlights the significant climate mitigation capacity of mangrove forests along the western coast and their vital contribution to India's efforts in fulfilling Sustainable Development Goals (SDGs).

Key words: Mangrove; Vegetative Biomass; West coast of India; allometric equation; Blue carbon

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Preliminary Exploration of Seagrass-Linked Blue Carbon in Kaliveli Lake Tamil Nadu

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ABSTRACT

Seagrasses play an important role in coastal blue-carbon dynamics. They can sequester significant amounts of organic carbon in their biomass and underlying sediments. Despite India's long coastline and the fact that seagrass has been found in a number of areas, little is known about the distribution of seagrass and how it stores blue carbon. One such understudied ecosystem is Kaliveli Lake, a sizable semi-enclosed coastal wetland on India's southeast coast that has never had its seagrass occurrence, species composition, or capacity to sequester carbon evaluated.

Rise in anthropogenic activities such as hydrological changes, land use alterations and pollution that establishing the baseline information on sediment organic matter and potential seagrass presence is critical. As part of preliminary investigations, the sediment cores (0 – 30 cm) were analysed using the loss on ignition method to estimate the organic matter content of the sediment. The Total Organic Carbon was determined using CHNS elemental analyser (Flashsmart CHNS/O) indicated a value of 65 gm C kg^{-1}. These findings highlight the ecological relevance of Kaliveli lake's sediment environment, even though its seagrass habitats have not yet been mapped or documented. The present study aims to evaluate seagrass distribution using remote sensing, assess potential habitat zones, and examine associated sedimentary carbon characteristics. The outcome will contribute the first baseline dataset on seagrass linked blue carbon in Kaliveli lake, supporting future conservation planning and climate resilience strategies.

Keywords: Blue carbon, Sediment analysis, Kaliveli lake, Sediment organic matter, Carbon sequestration.

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Preliminary studies of blue carbon reserve in Pulicat lake, Tamil Nadu

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ABSTRACT

Seagrass meadows are among the most productive coastal ecosystems, offering critical services such as shoreline stabilization, erosion control, water quality enhancement, nutrient cycling, and habitat provision for ecologically and commercially important marine species. They are also key contributors to climate mitigation through the sequestration and long-term storage of coastal blue carbon. Together with mangrove and saltmarsh ecosystems, seagrasses store nearly half of the ocean's organic carbon within their sediments. Despite this importance, blue carbon research on Indian seagrass ecosystems remains limited even though the country harbours extensive and diverse seagrass habitats.

Pulicat Lake, the second-largest brackish water lagoon in India, supports rich mangrove and seagrass ecosystems but faces increasing anthropogenic pressures, including industrial pollution from the Ennore estuary and Kosasthalaiyar River. As part of a preliminary effort to assess seagrass-associated carbon stocks in the Tamil Nadu sector of Pulicat Lake (115.2 km²), sediment samples were collected from sites harboring *Halophila ovalis* and *Halodule pinifolia*. Organic matter in surface sediments (0–15 cm) was quantified using Loss on Ignition yielding 7.78%. Direct Total Organic Carbon (TOC) analysis using a CHNS/O elemental analyser (Flashsmart CHNS/O) indicated a value of 60.9 g/Kg sediment. These preliminary sample results highlight the potential of Pulicat's seagrass sediments as important carbon reservoirs.

This study provides an initial baseline for blue carbon assessments in the southern sector of Pulicat Lake and underscores the need for comprehensive spatial sampling and long-term monitoring to strengthen India's coastal blue carbon research framework.

Keywords: Blue carbon, Pulicat lake, Seagrass, *Halophila ovalis*, Total organic carbon

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Multi-decadal Variation in Mangrove Forest Cover using Space-borne Multispectral Data Along the Maharashtra Coast (1990–2024)

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ABSTRACT

Mangrove ecosystems are important blue carbon reservoirs that help maintain coastal stability, store carbon, and protect biodiversity. This study looked at the changes in mangrove cover area over time in the coastal districts of Maharashtra from 1990 to 2024. We used multi-decadal dataset from Landsat (1990, 2003, 2015) and Sentinel-2 (2024) to identify mangrove areas. We mapped mangroves using vegetation normalized difference vegetation index (NDVI) and water-based spectral indices modified normalized difference water index (MNDWI), and the modular mangrove recognition index (MMRI). The results show a significant increase in mangrove cover in most districts. The largest area growth occurred in Raigad, Palghar. moderate increases were seen in Thane and Mumbai Suburban, while Ratnagiri, Sindhudurg and Mumbai city had relatively low increase in area. We validated the classification results using Google Earth imagery, Global Mangrove Watch (GMW) data, and India State of Forest Reports (ISFR) to ensure accuracy. This increase in mangrove area indicates successful natural regeneration and conservation efforts along Maharashtra's coastline. The expansion enhances blue carbon storage potential, emphasizing the need for long-term monitoring and conservation. The study highlights the benefits of using multi-sensor remote sensing with spectral indices for long-term assessments of mangroves and carbon stock in coastal ecosystems.

Keywords: Mangrove, Landsat, Sentinel, NDVI, MNDWI, MMRI.

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Evaluating Organic Matter and Trace Metal Dynamics Across Mixed Coastal Habitats of Kutch for Improved Blue Carbon Accounting

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ABSTRACT

Mixed coastal habitats of the Kutch region—including mangrove fringes, salt marshes, and tidal mudflats—are important but under-assessed components of India's blue carbon system. This study examines sediment organic matter (TOM) and related physicochemical variables across five sites (Luni, Modhva, Mandvi, Jakhau, Navlakhi) using averaged values from three sampling locations per site. TOM showed low but noticeable variation (0.20–0.84%), indicating patchy organic deposition typical of heterogeneous coastal settings. Strong negative correlations between sand and silt–clay fractions influenced trace metal behaviour, with finer sediments retaining higher Zn and Cr, while sand-rich zones showed elevated Hg. TOM displayed weak correlations with metals and texture, reflecting complex habitat-driven controls. Overall, the results emphasize the need for multi-parameter, habitat-specific approaches to improve blue carbon assessments in mixed coastal environments. This baseline dataset supports better blue carbon accounting and contributes to strengthening climate-resilient coastal management in India.

Keywords: Mixed coastal habitats, sediment organic matter, blue carbon, trace metals, Kutch coast

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Blue Carbon Ecosystems of Kachchh Coast, Gujarat: Faunal Diversity, Ecosystem Services, and Emerging Threats

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ABSTRACT

Blue carbon ecosystems (BCEs) are commonly known as coastal ecosystems (mangroves, tidal marshes, seagrass meadows, etc.), which are widely thought to be both mitigating and adaptive in climate change. These ecosystems are also important in maintaining biodiversity and supporting livelihood in the coastal areas besides their ability to capture carbon. A patchwork of such coastal habitats, comprising mangroves, mudflats, salt marshes and related intertidal zones is found in the Kachchh district of Gujarat, India. They are also essential ecosystems in biodiversity conservation, stabilization of the shoreline, and socio-economic prosperity of the coastal populations. Though BCEs in Kachchh are important in terms of ecology and socio-economics, not much research has been conducted on them. This paper will focus on their spatial distribution, biodiversity characteristics and some of the largely understudied ecosystem services but especially key habitats of both marine and terrestrial fauna. Mangrove ecosystems that constitute the dominant BCEs in the area receive specific treatment, as well as the relatively little-researched role of mudflats, salt marshes, and seagrass beds. Moreover, the paper highlights the interdependences between these ecosystems and immediate communities, including fisherfolk and pastoralists, whose livelihood depends on coastal ecosystems in complex ways. The current paper deals with the increasing anthropogenic and environmental risks that are facing these BCEs in the recent times.

Keywords: Coastal ecosystem, Mangroves, Salt marshes, Mudflats, Kachchh biodiversity

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Blue Carbon Ecosystems of Kachchh Coast, Gujarat: Faunal Diversity, Ecosystem Services, and Emerging Threats

Deep D. Dudiya[#1], Subhash I. Parmar[2] and Pranav J. Pandya[3*]
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ABSTRACT

Blue carbon ecosystems (BCEs) are commonly known as coastal ecosystems (mangroves, tidal marshes, seagrass meadows, etc.), which are widely thought to be both mitigating and adaptive in climate change. These ecosystems are also important in maintaining biodiversity and supporting livelihood in the coastal areas besides their ability to capture carbon. A patchwork of such coastal habitats, comprising mangroves, mudflats, salt marshes and related intertidal zones is found in the Kachchh district of Gujarat, India. They are also essential ecosystems in biodiversity conservation, stabilization of the shoreline, and socio-economic prosperity of the coastal populations. Though BCEs in Kachchh are important in terms of ecology and socio-economics, not much research has been conducted on them. This paper will focus on their spatial distribution, biodiversity characteristics and some of the largely understudied ecosystem services but especially key habitats of both marine and terrestrial fauna. Mangrove ecosystems that constitute the dominant BCEs in the area receive specific treatment, as well as the relatively little-researched role of mudflats, salt marshes, and seagrass beds. Moreover, the paper highlights the interdependences between these ecosystems and immediate communities, including fisherfolk and pastoralists, whose livelihood depends on coastal ecosystems in complex ways. The current paper deals with the increasing anthropogenic and environmental risks that are facing these BCEs in the recent times.

Keywords: Coastal ecosystem, Mangroves, Salt marshes, Mudflats, Kachchh biodiversity

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Blue Carbon Stock of Indian Seagrass meadows: A review

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ABSTRACT

Seagrass ecosystems along the Indian coast are vital marine habitats, characterised by significant species diversity, ecological functions, and carbon sequestration potential. A toal of 16 seagrass species are recorded over an estimated area of 500-520 km², spanning diverse regions including the Andaman and Nicobar Islands, Lakshadweep Islands, Palk Bay, Gulf of Mannar, Gulf of Kutch, and various coastal lagoons in India. Major seagrass meadows of species include *Cymodocea serrulata, Enhalus acoroides, Thalassia hemprichii,* and *Halophila ovalis.* Seagrass meadows reported to cover only about ~0.02% of the marine environment, but they absorb ~18% of the carbon from surrounding waters. Their distribution is influenced by environmental factors such as climate, sediment type, and hydrodynamics, and they commonly form dense, species-rich meadows in shallow, sheltered areas with silty to clay substrates. The present study is a review that focuses on the evaluation of Blue Carbon stocks documented in various Indian seagrass meadows, which serve as crucial blue carbon sinks, storing carbon in both biomass and sediment. A meta-analysis conducted by Akhand et al. in 2022 indicates that approximately 63 x 10^3 Mg C is stored in the seagrass beds of the Indian region. Our review shows that there have been only six published studies in India providing blue carbon stock data from seagrass. We observed a significant lack of research of blue carbon data for numerous seagrass meadows and beds. Carbon stocks in seagrass meadows from coastal lagoons were reported to range from 0.49 ± 0.15 to 9.52 ± 0.15 Mg C ha^{-1} in their biomass, while sediment carbon varied between 1.29 ± 0.04 and 11.94 ± 0.15 Mg C ha^{-1}. In Palk Bay, seagrass meadows are reported to have biomass carbon values ranging from 0.91 ± 0.06 to 0.97 ± 0.10 Mg C ha^{-1}, with sediment carbon levels between 2.51 ± 0.31 and 2.91 ± 0.26 Mg C ha^{-1}. In certain areas, sediment carbon storage was found to reach 2.02 ± 0.67 Mg C ha^{-1} at depths of up to 30 cm. Through this review, we aim to underscore the critical shortage of scientific research regarding blue carbon assessment from seagrass meadows and beds in the Indian region.

Keywords: Seagrass ecosystem, Carbon sequestration, Arabian Sea, Palk Bay, Gulf of Mannar, Blue carbon.

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Inhabiting Anthropogenic Seas: A Habitat Study Of Coastal Cetaceans Of Mumbai

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ABSTRACT

The nearshore waters of Mumbai are some of the most intensely used areas in the country with partially treated effluent discharge being a major polluter in the region. While highly degraded, these waters host populations of the Indian Ocean humpback dolphin (IUCN: endangered) and the Indo-Pacific finless porpoise (IUCN: vulnerable). As coastal species, inhabiting an extremely polluted seascape, these populations are prone to bioaccumulation and health risks. Profiling the habitat quality and understanding species-habitat relationships in such regions is critical for understanding their conservation needs. To address this gap for the population of humpback dolphins of Mumbai, a multi-method assessment was conducted between 2022-2025. As part of the habitat study, *in-situ* sampling of surface temperature, salinity, dissolved oxygen, distance to shore/creeks and depth was undertaken at fixed stations, within the known dolphin habitat. Sources of effluent discharge and offshore outfalls were also mapped. Presence of hypoxic(<2mg/l) surface waters were observed in all survey months with oxygen levels ranging from 0.25mg/l-8.83mg/l (SD+/-1.23). Salinity and temperature ranged between 28.5ppt - 36.9ppt (mean 34.15ppt, SD+/-1.38) and 24.8°C - 30.2°C (mean 26.9°C, SD+/-1.32) respectively. We further used factor analysis and GAM approach to understand intervariable relationships and factors influencing cetacean distribution in the study area. Our study shows that environmental parameters within the humpback dolphin habitat of Mumbai are influenced by sewage release in its nearshore waters; posing direct threats to the species prey bases and exposing the population to long-term health concerns.

Keywords: Coastal cetaceans, pollution, Mumbai, habitat, health

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Untangling Pollution Pathways: Metal Exchange And Biological Risk In A Turbid Estuary

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ABSTRACT

Coastal aquatic ecosystems have undergone increasing metal enrichment over recent decades due to rapid urbanization, land-use/land-cover (LULC) change, and unregulated point and non-point discharges. The Ulhas River Estuary (URE), a hyper-turbid, monsoon-dominated system on the west coast of India, receives substantial urban and industrial effluents, leading to elevated metal concentrations in dissolved (DM), suspended (SPM), and sediment phases. This study investigates the seasonal behaviour, estuarine gradients, and partitioning characteristics of heavy metals (Cr, Mn, Fe, Co, Cu, Zn, Pb, Cd, Hg) across DM, SPM, and surface sediments to assess their mobility, reactivity, and environmental risk. Spatially distributed samples were collected across pre-monsoon, monsoon, and post-monsoon seasons. Partition coefficients (Kd) were calculated to evaluate metal affinity for particulate versus dissolved phases, and pollution indices were applied to assess contamination levels. Metal concentrations in DM were low, whereas SPM and sediments showed significant ($p < 0.05–0.01$) enrichment compared with global river suspended loads and upper continental crust values. Spatio-temporal patterns of Fe and Mn indicated strong terrestrial influence and monsoon-driven variability. Kd values revealed strong particulate affinity for Cr, Fe, and Pb; moderate reactivity for Cu and Zn; and greater dissolved mobility for Cd and Hg. Pollution indices indicated moderate to considerable contamination upstream, with lower accumulation and limited seasonal variation downstream. The findings highlight the dominant role of monsoonal hydrodynamics in governing metal transport, partitioning, and retention within the URE. The estuary functions as both a sink and a secondary source of metals, with mobility varying by element and season.

Keywords: Heavy metal; Partition coefficient; Pollution indices; Anthropogenic contamination

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Floating Debris Detection And Subclassification Using High Resolution Satellite Data

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ABSTRACT

Marine debris (MD) are a global environmental issue with harmful effects on marine ecosystems. To effectively manage and mitigate this problem and create a better living environment, it is crucial to detect and monitor MD. Remote sensing has emerged as a promising method for detecting marine debris by making use of high-resolution Earth Observation satellites with Multispectral instrument. In this study, an attempt has been made to delineate the signatures of marine debris in the satellite observations from other effects. To this end, an image processing technique was developed to identify marine debris from satellite images using various spectral bands of Sentinel-2. The detection of floating materials on subpixel scales relied on two key indexes: the Floating Debris Index (FDI) and the normalized difference vegetation index (NDVI). Spectral signatures were used to identify the dominant materials within pixels on the ocean surface from space. The reflectance intensity was primarily determined by the proportion of floating plastic within the pixels. Once the pixels containing floating debris were identified, an spectral unmixing algorithm was employed to filter out noise pixels. The technique was applied to Sentinel-2 data for the period 2023-2024 for entire Indian coast. The monthly variation of MD distribution is studied for the Mumbai, Chennai and Kerala coasts for the study period. Transport of plastics over the oceans can be modelled as a passive tracer beacause of their buoyancy characteristics. To further investige the transport pathways of MD, the lagrangian technique was used, which use the current and wind data. This approach has the potential to become a valuable tool in the fight against marine debris, aiding in the efforts to clean up our oceans.

Keywords: Coastal waters, Marine Debri, High resolution data, plastic, Sentinel 2.

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How PFAS are threatening our oceans

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ABSTRACT

Because of their unique water and dirt repellant properties, per- and polyfluorinated alkyl substances (PFAS) are being used in many different and often useful applications, such as in fire extinghuisers, cosmetics, ski wax, non-stick cookware, glues, protective layers on carpets and furniture, fast food packaging materials, etc. They are also being used to prioduce the polymer Teflon®. However, PFAS belong to the most persistent synthetic chemicals on earth. The C-F bond in these compounds is the strongest bond we know in chemistry and so strong that effectively no degradation takes place. Because these compounds are also mobile, they have meanhwile been distributed worldwide. Meanwhile strict tolerance levels are in place in Europe and the US. This has led to concern about PFAS levels in fish Europe, and also in marine waters and estuaries. Due to their surfactant-like behavior, with a polar and a non-polar part in the molecule, PFAS tend to concentrate in the surf. PFAS concentrations in the surf up to 1-2 mg/L have been reported in Belgium. People swimming and surfing at beaches all around the world may accumulate PFAS through their skin or by oral intake. Storms blow the PFAS from the surf onto the land, such as we found in the dunes along the Dutch coast. Teflon® particles are being found as microplastics in marine waters and fish. A large epidemiological study among 8,000 inhabitants of Antwerp harbour showed PFAS levels in their serum of up to 500 mg/L.

Only PFOS (and PFOA), two of the thousands of PFAS compounds, have already been banned since around 2012. A proposal to ban all PFAS compounds is currently under discussion by the European Union but serious opposition is felt from the chemical industry. PFAS factories are spread over the world with also a production plant in India.

Keywords: PFAS, surf, fish, levels, toxicology

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High - Risk Antimicrobial- Resistant Bacteria In Estuarine Sediments : Mar Indexing And Arg Profiling From The Cochin Estuary

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ABSTRACT

Antimicrobial resistance (AMR) in aquatic systems poses increasing environmental and public health risks. This study investigates the phenotypic and genotypic traits of multidrug-resistant (MDR) bacteria isolated from sediments collected at a sewage discharge site in the Cochin estuary (9.9658° N, 76.2433° E). Sediment samples were serially diluted, cultured on nutrient agar, and screened for susceptibility to 19 antibiotics representing different classes using the Kirby–Bauer method. Two MDR isolates with high MAR indices—Stenotrophomonas maltophilia (0.78) and Achromobacter xylosoxidans (0.68)—were selected for detailed analysis. Both showed broad resistance in gradient strip assays (0.16–256 µg/mL), and MIC tests revealed inhibition only at very high concentrations (4096 µg/mL- Ampicillin), indicating strong tolerance. Moderate biofilm formation was confirmed through microtiter assays and Congo Red agar. The isolates also survived acidic conditions (pH 2) and displayed active efflux mechanisms, suggesting high stress adaptation. Genotypic screening detected the blaTEM gene in both strains, while tetA, qnrS and ErmB were absent. The presence of highly resistant, biofilm-forming bacteria at this sewage discharge point highlights the influence of domestic and industrial inputs and identifies the Cochin estuary as a potential reservoir of antimicrobial resistance.

Keywords: AMR, MDR bacteria, MAR index, ARGs, Cochin estuary

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Phosphorus Patterns In Tropical Estuaries: Unravelling Bioavailabilty And Eutrophication Susceptibility

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ABSTRACT

Phosphorus (P) dynamics play a critical role in controlling productivity and eutrophication in tropical estuarine ecosystems. This study presents a comparative assessment of sediment P speciation and bioavailability in the Amba and Shastri estuaries along the Indian west coast, representing contrasting hydrological regimes and anthropogenic pressures. Sequential extraction and SEDEX analyses of seasonal samples (2021–22) revealed distinct spatial and temporal variations in P forms, largely governed by organic matter (OM) content, redox conditions, and land-use dynamics. Total P concentrations were comparable in both estuaries (Amba: 29 µmol/g; Shastri: 27 µmol/g). Detrital P dominated (Amba: 19–57%; Shastri: 9–31%), followed by refractory P (Amba: 9–31%; Shastri: 8–34%), indicating strong lithogenic control. Elevated exchangeable, reducible, and oxidizable fractions reflected tidal mixing, redoxmediated remobilization, and OM remineralization. The bioavailable P fraction, influenced by redox potential, OM degradation, and sediment resuspension, was high in both systems, highlighting strong sediment–water coupling and active nutrient recycling, and suggesting potential eutrophication susceptibility under anthropogenic influence. Source analysis of potential P contributors, including fish (33 µmol/g) and bivalve tissues (10 µmol/g), urban sewage (6 µmol/g), fertilizers (14 µmol/g), riverine sediments (3 µmol/g), and basaltic rocks (2 µmol/g), analysed in this study revealed highest P in fish bone and lowest in basalts, and intermediate ranges in the sewage and fertilizer, have indicated that anthropogenic and biogenic inputs outweigh geogenic sources in these monsoon dominated tropical estuaries. Overall, the study underscores the dynamic interplay between natural geochemical processes and human activities in regulating P cycling, speciation, and eutrophication potential in tropical estuarine systems along the rapidly developing western coast of India.

Keywords: Speciation; Tropical estuary; Bioavailability; Redox potential; Organic matter

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Plastic container as entrapment hazard for hermit crab (*Coenobita* spp.): Evidence from the Nicobar Islands, India

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ABSTRACT

Plastic container entrapment is a serious global threat for terrestrial hermit crabs (*Coenobita* spp.), which are a key faunal group of a beach ecosystem. They help maintain the beach health by processing carrions and are vital component of terrestrial and aquatic food chain. However, the influence of container dimensions in hermit crab entrapment remains an unexplored aspect. We investigated the effects of physical characteristics of container (opening diameter and volume) on hermit crab entrapment at 28 remote beaches of the Nicobar Islands. We recorded 4783 entrapments with 4102 hermit crabs trapped in 198 containers (plastic & glass bottles) and 681 trapped in non-bottle containers (Styrofoam boxes, helmets, fishing floats, etc.). Only 0.52% of entrapped hermit crabs were found alive and 80% of the entrapment occurred in bottles with volumes of 5000 ml, 2000 ml, 1500 ml, 1250 ml, 1000 ml, 900 ml, and 800 ml. The bottle opening diameter acts as a size-selective filter, which allowed entry of hermit crabs whose shell widths were smaller than the bottle opening diameter; while larger shells were associated with larger cavity openings. This size-selective entrapment could disproportionately impact hermit crab population that can potentially cause decline of smaller hermit crabs. Such declines may cause cascading effects on beach ecosystem health that necessitates further rigorous investigation.

Keywords: Beach Litter, Anomura, Marine Pollution, Ecological Traps, Single-use Plastics

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The effect of anthrophony on marine mammals using multidisciplinary bibliometric analysis

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ABSTRACT

The ocean is a dynamic environment, teeming with symphonies of various sounds. The marine soundscape has three main components: geophony (natural abiotic sounds), biophony (biological sounds) and anthrophony (human-generated sounds). The increasing presence of the anthrophony is causing problems for marine life, especially the mammals, who rely on sound to communicate with each other. In this study, we have assessed the effect of this noise pollution on marine mammals using Dimensions — a free multidisciplinary research discovery and analytics platform. We analysed publication trends, identified key impact categories such as behavioural change, communication disruption, and physiological stress, and mapped the taxonomic and geographic distribution of existing research. We identified 4 major sources of anthrophony and categorised their impacts into 8 categories. Our findings highlight strong biases toward certain species and regions, gaps in studies, and a general underrepresentation of noise sources beyond vessel activities. The historical development of this research field closely follows geopolitical shifts, towards the advancement of naval technologies, and expanding during globalisation with the rise of shipping and offshore industries. However, regional disparities remain stark. Research is concentrated in the global North, while the global South, particularly those bordering the Indian Ocean, are notably underrepresented due to the paucity of resources. This study tries to underscore the urgent need for broader research efforts, region-specific policy frameworks, capacity-building, long-term monitoring, and international collaboration to ensure underwater noise is appropriately managed as part of marine conservation strategies, with a brief mention of the ongoing research efforts in India.

Keywords: Anthrophony, Underwater noise, Marine mammals, Behavioural impacts, Communication masking, Bibliometric analysis

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Assessment Of Trace Element Distribution, Bioaccumulation, And Health Risks In Silver Pomfret From Major Fishing Grounds Of The Bay Of Bengal

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 # Presenting author: Tanjila Akter

ABSTRACT

Trace elements, both essential and toxic, are widespread in marine ecosystems and can pose health risks through bioaccumulation in seafood. This study assessed trace element concentrations in silver pomfret (*Pampus argenteus*) from three fishing zones in the Bay of Bengal—south patches, middle ground, and swatch of no ground—within Bangladesh's maritime area. Using EDXRF spectrometry, we analysed elements including Ca, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Hg, and Pb. Most elements showed significant spatial variation ($p < 0.05$), except Hg and Pb. Levels of Cr, Ni, As, Hg, and Pb were below permissible limits, whereas Mn, Fe, Co, Cu, Zn, and Se exceeded FAO/WHO guidelines. The Se/Hg molar ratio indicated reduced mercury toxicity. Pollution indices revealed high contamination by Cr, Mn, Se, and Co, though overall metal pollution remained low. IMBI values near 1 suggest substantial bioaccumulation, but THQ, HI, CR, and TCR levels were below risk thresholds, implying minimal health risk from consumption. Multivariate analyses, e.g., Pearson's correlation, PCA, and HCA identified anthropogenic sources as key contributors. These findings highlight the significance of continuous monitoring to safeguard seafood quality and public health in coastal communities dependent on fish-based diets.

Keywords: Trace elements, Potentially toxic elements (PTEs), Silver pomfret, Health risk, Bay of Bengal

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Sources, Fate, Accumulation And Transport Dynamics Of Textile Fibres In Oceanic Environments

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ABSTRACT

Global production of textile fibers—both synthetic and natural—has more than doubled in the past two decades, reaching 107 million tonnes in 2018 and projected to hit 145 million tonnes by 2030 under current trends. Synthetic fibers now represent nearly two-thirds of global fiber output and about 14.5% of all plastic production. Yet, most fibers found in the environment are natural, such as cotton and wool. The growing consumption of textiles has led to significant microfiber accumulation in marine environments, where their impacts and degradation times remain poorly understood. Textile fibers are the dominant anthropogenic particles in global microplastic pollution, accounting for 80–90% of microplastic counts. High concentrations have been recorded in oceans, sediments, polar regions, and terrestrial and freshwater systems, and even in atmospheric samples from remote areas. Their ubiquity has led to detections in food, drinking water, human lungs, and the digestive tracts of many organisms. Although the effects of microfiber ingestion on marine life are still being studied, evidence suggests potential physical harm, reduced feeding, and pollutant transfer. Additionally, the use of dyes, additives, and flame retardants during fiber production raises concerns about fibers as vectors of hazardous chemicals. Future research must clarify fiber degradation rates, ecological effects, and mitigation strategies to curb microfiber release. This presentation will summarize current knowledge on the sources, occurrence, transport, and fate of textile fibers in marine environments, discuss findings on their distribution, degradation, and sinking behavior, and review the main analytical methods used. Identifying critical knowledge gaps will help guide efforts toward sustainable textile production and reduced microfiber pollution.

Keywords: microfibers, textile fibres, microplastics, pollution

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Calcite Precipitation as a Pathway for Nanoplastic Immobilisation: Structural and Spectroscopic Evidence

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ABSTRACT

Nanoplastics (NPs) are now recognised as persistent pollutants in freshwater and marine systems, yet the processes that control their behaviour in natural waters are still not fully understood. In this study, we explore how NPs interact with calcium carbonate minerals during precipitation and examine the influence of humic acid (HA) as a representative natural organic component. Through a combination of FTIR and Raman spectroscopy along with SEM-EDS imaging, we find that NPs become incorporated into the forming calcite phase. The presence of HA and NPs produced noticeable changes in the vibrational features of carbonate groups, indicating modifications in the mineral structure. Raman observations also showed that well-defined calcite crystals were mainly associated with NPs-free systems, whereas the introduction of NPs or HA appeared to disrupt normal crystallisation pathways. To test the stability of this process under different aqueous conditions, we carried out experiments across a range of Ca/Mg ratios. High NP removal efficiencies were consistently observed, suggesting that this entrapment mechanism operates robustly even in ion-rich environments. At last, a precipitation experiment was conducted in different natural matrices, where we observed a significantly high removal of NPs in seawater and estuarine water compared to river water. Overall, our findings provide fresh insight into the interactions between NPs and mineral-forming processes. Further, it suggests that calcite precipitation is a potentially important pathway through which NPs may be immobilised in natural aquatic settings.

Keywords: Nanoplastics, Calcite, Encapsulation, Precipitation, Interaction

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Oil Spill Response Strategy Maps: A Geospatial Early Warning And Preparedness Tool For Marine Pollution Hazards

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ABSTRACT

Indian Coast Guard (ICG), the central coordinating agency for oil spill incidents in Indian waters. Indian National Centre for Ocean Information Services (INCOIS) has been involved in issuing oil spill advisories since 2011. Oil spill advisories issued by INCOIS to the Indian Coast Guard enhance preparedness, response efficiency, and coordination during oil spill incidents. They enable the Coast Guard to respond swiftly, allocate resources effectively, and mitigate the impacts of oil spills on the marine environment and coastal communities. In addition to oil spill advisories, INCOIS started generating Oil Spill Response Strategy (OSRS) maps that contain the details of oil spills and plans to reduce impacts to sensitive natural, cultural, and economic resources. They also set priorities for various spill risks and direct the response until real-time information becomes available. The present paper describes the method of generating OSRS maps for a real oil spill event that occurred off the Mangalore coast during June 2022. The proposed oil spill response strategies were indicated in Geographical Information System platform which is collectively called as an OSRS map. The map contains information such as oil trajectory patterns, geomorphological classes and the location of resource availability, Pollution control vessels, and shore-based facilities near to the spill location. This OSRS map will be communicated to the Regional and District Response Centers established by Indian Coast Guard wherein the centers serve as operational hubs for oil spill response activities in their respective regions. The OSRS map along with oil spill advisories provide critical input to incident commanders, enabling them to assess the situation accurately, monitor the spill's progression, and make informed decisions regarding response strategies, resource allocation, and operational priorities. However, the availability of accurate and real-time information enhances the overall effectiveness of incident management.

Keywords : Response, Strategies, pollution, spills, maps

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A Non-Intrusive Bubble Barrier For Marco/Microplastic Capture And Safe Fish Passage

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ABSTRACT

Plastic and microplastic litter in riverine ecosystems have become a global crisis. It contributes predominantly to aquatic biodiversity loss, and widespread ecosystem disruption. Traditional plastic interception technologies often hinder fish movement and require extensive infrastructure. In addition, they lack efficiency in capturing microplastic fragments. To bridge this gap, this study explores the potential of using a fish-friendly bubble barrier system to capture plastics without hindering aquatic fauna and fauna. The proposed system operates by releasing compressed air through a perforated pipe placed diagonally on the riverbed. As the air rises, it forms a continuous bubble curtain that pushes floating plastics toward a designated corner of the channel. While fish can still navigate through a deliberately created passage gap. Experiments were conducted in both recirculating flume as well as in field, by changing the approach angle (25°, 35°, and 45°) and the fish passage gap. Results showed that the designed system could capture 86% and 90% of the plastic particles in laboratory and field, respectively. By introducing life fish into the system, it could be observed that the fish passage effectively helped in the movement when compared to bubble curtain without fish passage. These results show that the bubble curtain is an effective solution to tackle plastic pollution in rivers and it will aid in reduction the plastic input to ocean. In addition, the system also aids in the movement of fish without hindering its behaviour.

Keywords: Riverine pollution control, Bubble barrier, Fish-friendly technology, Plastic pollution mitigation, Microplastic interception.

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From Plastic To Plastiome: How Microplastic Can Hitchhike The Antimicrobial Resistance In The Aquatic Environment?

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ABSTRACT

Microplastics (MPs) are emerging contaminants in aquatic ecosystems that act both as physical pollutants and as biological vectors. Their surfaces rapidly develop biofilms, forming a specialized ecological niche called the plastisphere, which selectively enriches microbial communities, including pathogens and antibiotic resistance genes (ARGs). This combined microbial and genetic assemblage, termed the plastiome, functions as a mobile reservoir of antimicrobial resistance (AMR) capable of spreading ARGs across taxa and environmental compartments. Yet, the mechanisms driving ARG enrichment, transfer, and ecological consequences within the plastiome remain insufficiently resolved, underscoring the need for integrated One Health–oriented research and monitoring.This study used metagenomic approaches to characterize microbial communities and resistomes on MPs collected from two rivers near Tokyo, Japan, and to compare them with surrounding river water. MPs, dominated by polyethylene and polypropylene, were isolated, and microbial DNA was sequenced to identify taxa, ARGs, biocide and metal resistance genes (BMRGs), and mobile genetic elements (MGEs). Network analyses were applied to infer co-selection processes and horizontal gene transfer potentials.MPs hosted distinct, enriched microbial communities relative to river water, with overrepresentation of clinically relevant genera such as Exiguobacterium and Eubacterium. ARG loads on MPs were approximately 3.5-fold higher than in ambient water, with multidrug resistance genes, BMRGs, and MGEs significantly enriched, including determinants against vancomycin, beta-lactams, arsenic, mercury, and multiple biocides. Co-occurrence networks revealed dense associations among ARGs, BMRGs, and MGEs in MP biofilms, in contrast to sparse interactions in river water, indicating that MPs act as active microhabitats that foster ARG persistence and dissemination. These findings position the plastiome as a critical but underrecognized dimension of environmental AMR, reinforcing the need to incorporate MP-associated resistomes into AMR surveillance and mitigation within the One Health framework.

Keywords: Microplastics, Plastisphere, AMR, One Health, Aquatic evironment

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Upcycled Biomass–Polymer Carbonized Composites for Heavy-Metal Removal: A Sustainable Strategy to Combat Ocean Pollution

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ABSTRACT

Heavy-metal contamination has emerged as a serious threat to marine ecosystems, where toxic metals persist, bioaccumulate, and disrupt ecological balance. Addressing this challenge demands sustainable, low-cost remediation materials that can be deployed at scale. In this study, various natural waste resources—including cow dung, rice husk, coconut coir, sugarcane bagasse, charcoal, and graphite—were carbonized and integrated with natural polymers such as alginate and chitosan to synthesize eco-friendly composites for heavy-metal removal from contaminated waters. Comprehensive characterization using FTIR, TGA, DSC, SEM-EDAX, and BET analyses revealed that the biocomposites possessed high surface area, enhanced porosity, and favourable surface charge properties conducive to metal adsorption. Batch adsorption experiments were conducted to investigate the effects of pH, dosage, temperature, and contact time on removal performance. Metal removal was quantitatively evaluated using ICP-MS and DMA. Among the prepared formulations, the composite incorporating coconut coir exhibited the highest adsorption efficiency. The optimized material achieved removal rates of ~85% for Pb and Fe; ~95% for Cu, Cd, Cr, Zn, and Hg; and ~70% for Co and Ni. Kinetic modeling further provided insight into the adsorption mechanisms and rate-limiting steps. Overall, this study demonstrates that converting biodegradable waste into functional carbonized composites offers a promising, ocean-friendly solution for mitigating heavy-metal pollution in aquatic environments.

KeywordS: Green Synthesis, Remediation, optimization, Heavy metal, pollutants

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Closed Chamber In-Glass extraction: An unconventional method for estimating PFAS from river water incorporating rocket evaporation

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ABSTRACT

In the contemporary era, PFAS-related contamination has emerged to be a significant problem that has attracted a lot of scientific interest. Water bodies all across the world have been found to have PFAS. A total of twenty-eight water samples were taken from the river that passes through the heavily populated urban area. Additionally, the possibility of using in-glass closed-chamber rocket evaporation as a framework for the quick, simple, and plastic-free preconcentration of materials was investigated. Recoveries ranging from 80% to 170% were calculated at three different spiking doses in order to verify the procedure. Additionally, a gradient flow technique based on LC/HRMS was developed for a PFAS mix including 24 analytes, with LOD and LOQ in the range of 0.25-3.84 ng/mL and 0.83-12.81 ng/mL, respectively. The PFAS found in this investigation were divided into various groups. For all samples, PFHpA showed a concentration of 203.3 ng/l, PFHpS at 141.04 ng/l, and PFHxS at 126 ng/L. Additionally, Pearson's correlation was used in the study to learn more about how various PFAS coexist. However, the method's computed green index was 0.65.

Keywords: PFAS, Water, Rocket evaporation, Liquid chromatography

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Microplastic Occurrence In Edible Marine And Freshwater Dried Fish And Human Implications

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ABSTRACT

Dried fish are regarded both as staple food and as a delicacy worldwide. The growing prevalence of microplastics (MPs) in aquatic ecosystems, together with documented cases of fish ingesting MPs, leads to the internalisation and accumulation of these particles in fish biomass, which in turn facilitates their transfer to higher trophic levels. In India, both freshwater and marine dried fish are enjoyed as delicacies, yet no comparative study has examined microplastic levels in marine versus freshwater dried fish. In the present study, we investigated the occurrence of MPs in dried fish samples representing four freshwater and eight marine fish species. Specimens of each species were first soaked in distilled water and then dissected to separate the gills, gastrointestinal tract, and muscle tissues. MPs were extracted from the tissue samples by digesting the fish biomass with potassium hydroxide, followed by density separation using sodium chloride solution and subsequent filtration. We identified four MP types, fibres, fragments, foam and films. Overall, fibres were most common, representing 50 % of the MPs, while fragments accounted for 32 %. Among the species examined, the marine fish Ephippus orbis exhibited the highest MPs load per individual, followed by Trachurus trachurus, and in freshwater species, Puntius chola showed the greatest MPs count, followed by Parambassis ranga. We observed microplastics in a range of colours, transparent, black, green, red, yellow, blue, brown and white, with transparent particles being the most abundant. Among fish organs, the gastrointestinal tract contained the highest MPs counts than the gills and muscle tissue. Our findings indicate that dried fish sold openly in markets, whether freshwater or marine, accumulate MPs within their biomass. Dried fish are typically eaten whole with only minimal processing before cooking, which increases the chances of MPs being transferred to the consumers through contaminated fish.

Keywords: Dried fish, Marine, Freshwater, Microplastics, Seafood

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Nitrate-Coupled Microbial Degradation Of Polycyclic Aromatic Hydrocarbons In Coastal Ecosystems

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ABSTRACT

The accumulation of polycyclic aromatic hydrocarbons (PAHs) in anoxic estuarine sediments poses a major threat to ocean health, limiting natural recovery and impairing benthic biodiversity. Understanding how indigenous microbial communities mediate PAH degradation is essential for developing sustainable, ecosystem-based remediation strategies. This study examines the role of dissimilatory nitrate-reducing pathways in the biodegradation of naphthalene and fluoranthene in two contrasting sediments from the Lima Estuary (Portugal). Long-term anoxic microcosms with nitrate supplementation were established to assess PAH degradation, nitrogen transformation, microbial community dynamics, and predicted functional pathways. Naphthalene and fluoranthene concentrations were found to decrease over time with distinct degradation dynamics that varied between the two sediment types. Nitrate consumption, nitrite accumulation, ammonium production, and N_2O/N_2 generation indicated the active coupling of PAH degradation with denitrification and dissimilatory nitrate reduction to ammonium (DNRA) processes. High-throughput sequencing and functional predictions revealed the enrichment of nitrate-reducing and PAH-transforming taxa, alongside metabolic pathways enabling both anaerobic activation and oxygen-dependent ring cleavage in nominally anoxic environments. These findings highlight the metabolic versatility of estuarine microbial communities and their critical role in sustaining sediment resilience. Understanding the link between nutrient cycling and contaminant attenuation in coastal ecosystems will provide valuable insights for nature-based solutions aligned with global ocean health goals and the UN Decade of Ocean Science.

Keywords: polycyclic aromatic hydrocarbons (PAHs), denitrification, dissimilatory nitrate reduction to ammonia (DNRA), naphthalene, fluoranthene

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Organochlorine Pesticides and PCBs in Seagrass Sediments of Palk Bay, Tamil Nadu: Levels and Risk Interpretation

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ABSTRACT

The ecologically productive seagrass meadows of Palk Bay is home to Dugongs, the only marine herbivore mammal exsits in Indian waters. However, these dugong habitats are prone for pollutions, specifically persistent organic pollutants (POPs). The present study quantified organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) across 27 sampling stations covering different depth gradients at distance 0 m, 500 m, and 1 km in northern, middle, and southern Palk Bay. POPs were analysed using Gas Chromatography following QuEChERS extraction. Distance wise trends showed modest variation, with Aldrin (10–11 µg/kg), Endrin (10–12 µg/kg), and Endosulfan sulfate (10.6–10.8 µg/kg) peaking at mid-transect points. ∑PCB increased gradually from 43 µg/kg nearshore to 46 µg/kg offshore, while ∑DDT remained consistently high (33–36 µg/kg), reflecting uniform legacy inputs across distances. Regionally, southern Palk bay exhibited the highest contamination, particularly for ∑PCB (45–48 µg/kg) and ∑DDT (34–36 µg/kg). Northern sites showed comparatively lower Lindane (4.3–4.5 µg/kg; TEL 0.32, PEL 1.0) and Heptachlor Epoxide (1–2 µg/kg; TEL 0.6, PEL 2.0). Several compounds exceeded PEL thresholds, including DDD (TEL 1.22, PEL 7.81), DDT (TEL 1.19, PEL 4.77), and Dieldrin (TEL 0.02, PEL 0.24). ∑PCB surpassed its TEL (34.1 µg/kg) across most sites. The mean Risk Quotient (1.24–1.46) indicated persistent moderate to high ecological risk. Multivariate analyses reinforced these patterns: hierarchical clustering grouped ∑PCB and ∑DDT as dominant loadings, while PCA (PC1 explaining 99% variance) separated high-impact contaminants from lower load compounds. Overall, widespread TEL–PEL exceedances, strong spatial structuring, and elevated risk signals ingrained POP contamination in Palk Bay. This baseline underscores the need for pollutant source tracking, trophic transfer and bioavailability assessments for long term conservation and monitoring of seagrass habitats in Palk Bay.

Keywords: Coastal ecosystem health, Threshold effect level (TEL), Probable effect level (PEL), Seagrass habitat Pollution, Environment Risk Assessment

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The Invisible Threat: Mapping Microplastic Contamination in Coastal Seafood and High-Risk Species

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ABSTRACT

Microplastic (MP) contamination has emerged as a persistent threat to coastal ecosystems, demanding a detailed understanding of its bioavailability, trophic transfer, and implications for seafood safety. To evaluate potential risks to consumers, this study investigated MP ingestion in 14 commercially important marine species—including crabs, prawns, bivalves, cephalopods, and finfish—collected from coastal waters. The assessment focused on MP abundance, organ-specific retention, polymer composition, and associated health risks. Whole-body MP loads varied significantly across taxonomic groups. Shellfish exhibited moderate contamination (17.30–24.47 particles per organism), whereas finfish showed a wider accumulation range (7.21–34.19 particles). When normalised to biomass, finfish demonstrated comparatively higher MP concentrations, reaching up to 4.88 MPs/g, whereas shellfish displayed moderate levels. Organ-wise analysis confirmed the gastrointestinal tract as the primary site of MP retention, followed by the gills and hepatopancreas, with minimal accumulation observed in edible muscle tissues. Polymer characterisation identified polystyrene (PS), polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), and polyvinyl ether (PVE) as the dominant polymers, suggesting inputs from fishing gear abrasion, packaging waste, and land-based runoff. Notably, species such as *Nemipterus japonicus*, *Scomberomorus commerson*, *Pampus argenteus*, and edible crabs demonstrated relatively elevated MP burdens, indicating higher exposure risk among widely consumed seafood. This multi-species dataset provides novel insights into MP ingestion patterns across marine trophic levels and highlights the urgent need for strengthened coastal waste management, routine seafood monitoring, and targeted regulatory measures to safeguard marine biodiversity and human health.

Keywords: Microplastics, Coastal Pollution, Trophic Transfer, Seafood Safety, Polymer Composition, Marine Ecosystems.

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Transformation Of Microplastics In Aquatic Conditions And Their Role In Heavy Metal (Pb^{2+}) Transport: Effects Of Uv Aging And Biofilms

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ABSTRACT

Plastics have significant global concerns due to persistence and widespread contamination in aquatic environments. As these materials undergo physicochemical degradation of these plastics weakens their structural integrity, leading to fragment into microplastics (MPs) (0.1 to 5000 μm). Once released, MPs experience environmental weathering particularly UV irradiation which alters their surface properties and enhances their ability to transport of co-contaiminants. This study simulates the artificial sunlight UV exposure on secondary MPs of polyethylene terephthalate (PET) and polypropylene (PP) to understand these changes influence their adsorption behaviour with Pb^{2+} comparing to virgin MPs. Environmental factors including pH (3-9), salinity (0.5–3%), and temperature (5–45 °C), and biofilm formation were also evaluated to reflect realistic aquatic conditions. UV aging induced notable surface modifications, including increased roughness, cracking, and enhanced hydrophilicity accompanied by the formation of carbonyl and hydroxyl functional groups. These transformations significantly improved Pb^{2+} adsorption capacity, increasing by 123% for PET
and 93% for PP. Biofilm development further contributed to Pb^{2+} uptake by introducing biological interaction that increased adsorption increasing surface heterogeneity. Adsorption performance was further affected by high pH and moderate temperature, whereas increased salinity reduced adsorption. In batch adsorption models, Kinetic data best fitted the pseudosecond order model (R2>0.95), indicating chemisorption, while isotherms are better by the Langmuir model, suggesting homogenous monolayer adsorption. Overall, this study demonstrates that UV-aged and biofilm-colonized MPs exhibit enhanced reactivity toward heavy metals, underscoring their evolving role as mobile carriers of co-pollutants in aquatic ecosystems.

Keywords: UV Aged, Microplastics, Adsorption, Heavy metals, Aquatic

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Mapping Microplastic Pollution In Mangroves: Multicompartmental Analysis Along The Maharashtra Coast

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ABSTRACT

This research investigates the presence, distribution, and characterization of microplastics (MPs) across environmental matrices such as surface waters, water column, and the gastrointestinal tract (GIT) and gills of fish within the mangrove estuary ecosystem of Mumbai, India. MPs were detected in all tested matrices, demonstrating clear vertical stratification and bioaccumulation patterns. MP concentrations accounted for 53.8 ± 24.33 MPs/L and 3.73 ± 1.40 MPs/m³ in the water column and surface water, respectively. Elevated MP retention in fish gills (6.36 ± 2.22 MPs/g) highlights the direct, non-selective, and prolonged exposure to suspended particles, whereas GIT (4.75 ± 0.89 MPs/g) effectively indicates ingestion-related MP exposure. Shape analysis revealed that fibres (56.47%) dominated in water samples, while fragments (58.22%) were more prevalent in fish GIT and gills, suggesting selective ingestion or retention. Particle size distribution showed that smaller MPs (< 50µm) predominate in biotic samples, while larger particles (300-5000µm) were abundant in surface waters. Colour analysis revealed a predominance of blue and black MPs, while polymer characterization using Micro-FTIR spectroscopy identified polyethylene (PE), polypropylene (PP), ethylene vinyl alcohol (EVA), polyacrylamide (PAM), and polyvinyl chloride (PVC) as the major polymer types. These polymers may largely originate from sources including textiles, packaging, personal care products, tyre wear, and fishing activities. The study highlights the complex pathways of MPs shaped by environmental dynamics and trophic interactions, highlighting the importance of ongoing risk and toxicological assessments. These findings provide crucial insights for policymakers to develop region-specific waste management and pollution control strategies to safeguard vulnerable coastal ecosystems.

Keywords: seawater, fish, gill, gut, microplastics, micro-FTIR spectroscopy

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Contrasting Behaviours Of Smaller And Larger Microplastics: Hydrodynamic Drivers, Beaching Patterns, And Ecological Risks Along The North Western Indian Ocean

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ABSTRACT

Microplastics (MPs), an insidious pollutant, have emerged as a critical contaminant in coastal ecosystems, raising profound ecological concerns. Yet, the differential beaching patterns and ecological risks posed by smaller v/s larger sized MPs along the Northwestern Indian Ocean coastline remain poorly understood. This study addresses this gap by disentangling size-based variations of smaller (20µm-1mm) and larger sized MPs (1-5mm) to unravel the hydrodynamic and environmental drivers shaping their distribution in beach sediments. The findings revealed a pronounced dominance of larger sized MPs in Mumbai, primarily fibres and films of both sizes classes, suggesting a strong influence of coastal hydrodynamics and anthropogenic pressures. In contrast, Goa displayed a higher prevalence of smaller sized MPs, chiefly fragments, likely linked to finer sediment textures and localized depositional processes, whereas Karnataka exhibited a more balanced distribution, suggesting the interplay of heterogeneous sediment properties and varied pollution sources. Across sites, MP beaching patterns may be governed by sediment characteristics, particle size–shape interactions, and key environmental drivers which together modulate retention and spatial variability. Polymer analysis revealed an intriguing trend wherein, smaller sized MP exhibited markedly greater polymer diversity (n = 16) compared to larger sized MPs (n = 8) class, suggesting progressive fragmentation and weathering of complex, multi-material plastic products. Additionally, cigarette butts emerged as a significant yet underrecognized contributor, particularly in the larger size class. Beaching indices signalled moderate to high ecological risks, with smaller sized MPs posing greater threats owing to their enhanced reactivity and toxicity potential. By contrasting the behaviours of smaller and larger sized MPs, this study emphasizes the need to treat them as distinct fractions to reveal their divergent ecological roles and the combined hydrodynamic and anthropogenic forces shaping their coastal fate .

Keywords: larger sized microplastics, smaller sized microplastics, hydrodynamic drivers, beaching pattern, Indian ocean coastline

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Global Technological Transitions and Marine Megafauna Exposure to Emerging Contaminants: New Evidence from North Sea Marine Mammals and perspectives.

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ABSTRACT

Around the world, the accelerating transition toward low-carbon technologies—batteries, offshore wind, photovoltaics, advanced electronics—has drastically increased the extraction, use, and environmental release of trace elements and Critical Raw Materials (CRMs). These elements circulate across continents through atmospheric transport, ocean currents, international supply chains, and waste streams, yet their biological impacts on marine wildlife remain poorly understood at the global scale.

Here, we present new empirical data (2019–2025) from marine mammal species in the North Sea—one of the most industrialised and intensively monitored marine regions worldwide—providing an early-warning signal on how modern technological development may reshape elemental contamination patterns. Using ICP-MS, DMA-80, and stable isotope analysis, we document tissue- and species-specific accumulation of CRMs, rare earth elements (REEs), and other trace metals in seals, porpoises, and dolphins. Increasing temporal trends in elements such as Al, Nb, and Sb between 1999–2001 and 2019–2024 suggest rising environmental inputs linked to global technological production rather than local sources alone.

These findings carry broader significance for regions experiencing rapid industrialisation, offshore renewable expansion, or increased waste flows—including South and East Asia, South America, and the Arctic. They underscore the need for international monitoring strategies addressing CRMs as emerging global contaminants, complementing existing programmes focused on POPs and mercury.

Keywords: Critical Raw Materials, Emerging contaminants, Marine megafauna, Rare earth elements, Offshore renewable energy, One Health

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Threat of endocrine disruptor, Bisphenol A on aquatic vertebrates: Biochemical approach

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ABSTRACT

Endocrine disrupting chemicals (EDCs) are a major global concern due to their widespread presence and strong ability to interfere with hormone-regulated physiological processes in aquatic organisms. Exposure of vertebrates, including fish to EDCs, disrupts the hypothalamic pituitary gonadal (HPG) axis, which leads to alterations in steroidogenesis, gametogenesis, sexual maturation, and spawning success. These disruptions result in poor recruitment, decline in stock and threat to natural fish population. Among EDCs, bisphenol A (BPA) is a predominant xenoestrogen. In the current experiment, acute toxicity of BPA to climbing perch, *Anabas testudineus* (25 ± 5 g; 10 ± 2 cm) was determined using Probit analysis, establishing a 96-h LC_{50} of 16.77 ppm. Based on this, fish were exposed for 60 days to sublethal BPA concentrations of 0.419, 0.838, and 1.677 ppm in triplicate, along with a BPA-free control. All fish were maintained under standard husbandry conditions and fed a 40% protein, 6% lipid diet to satiation. BPA exposure altered the biochemical markers for endocrine disruption. Thereby shows strong dose-dependent increased responses, with serum glucose (103%), cortisol (202%), and HSP70 (427%), while brain acetylcholine esterase activity decreased by 62%. Hematological alterations at 1.677 ppm results in increases in RBC (20%), WBC (102%), HGB (18%), HCT (11%), and MCHC (26%), with a corresponding 28% decrease in 1.677ppmMCV when compared with control. Hormonal study shows that, significant increases in 17β-estradiol (239%) & vitellogenin (84%), and reductions in 11-ketotestosterone (23%) & testosterone (81%) ($p < 0.05$) in BPA exposed groups (1.677 ppm). Histological observation showed the early oocytes maturation and lipid accumulation in hepatocytes at higher dose (1.677 ppm). Molecular analysis revealed a 3.42-fold increase in hepatic HSP mRNA expression and a significant downregulation of TNF-α across all BPA treatments. CAS3a (3.38-fold) and CYP450 (2-fold) exhibited peak expression at 0.419 mg/L. Results of the study conclude that even the lower concentration of BPA (0.419 ppm) altered the physiology and reproductive potential of *A. testudineus.*

Keywords: Endocrine disrupting chemicals (EDCs), Bisphenol A (BPA), Steroidogenesis, Histopathology, 17β-estradiol.

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Partitioning Dynamics of PCB 28 and PCB 153 in Global Surface Oceans

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ABSTRACT

Polychlorinated Biphenyls (PCBs) are toxic persistent organic pollutants that bioaccumulate in marine food webs. Despite being banned for decades, these substances continue to threaten ocean health due to their environmental stability and ability for long-range transport. The distribution of PCBs between dissolved and particulate phases in oceans is critical for determining their exchange with atmosphere, removal through particle sinking, and potential exposure pathways for marine organisms. Here, we used a global multimedia model to quantify seasonal and spatial variations in surface-ocean partitioning and air-sea exchange for two representative congeners PCB 153 and PCB 28. Model simulations were run from 1930 to 2024. The results indicated that PCB 28 remains predominantly dissolved, with global average particulate fraction (PF) of approx. 1.3%, whereas PCB 153 shows a higher global average PF of about 3.9%. Both PCBs have their highest PF values in cold and productive waters, particularly in the Southern Ocean, where PF was around 11%. Seasonal analysis indicates that PCB 153 shows a noticeable variation of 3.6-4.2% across months, whereas PCB 28 was insensitive to seasonal forcing. Overall, the results indicate that hydrophobic PCBs like PCB 153 are more strongly linked to particle processes, while lighter PCBs like PCB 28 remain mostly dissolved and continue cycling between the ocean and atmosphere.

Keywords: Polychlorinated Biphenyls (PCBs), Particulate Fraction (PF), Multimedia Model

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Remediation Of Ciprofloxacin And Norfloxacin Antibiotics In Wastewater Using Spent Mushroom–Derived Laccase: Fate, Toxicity, And Degradation

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ABSTRACT

Fluoroquinolone antibiotics, widely detected in wastewater and surface waters, also pose serious environmental risks to the ocean ecosystem. Enzymatic degradation offers a sustainable alternative for removing such contaminants. This study investigates the degradation of two common fluoroquinolones—ciprofloxacin and norfloxacin—using laccase extracted from spent mushroom waste (SMW) of Pleurotus florida. Laccase, with its trinuclear copper center, effectively targets organic micropollutants. Key parameters, including pH (3–6), temperature (30 °C and 50 °C), and ABTS concentration (0.05–1 mM), were optimized to maximize degradation efficiency. Under optimal conditions (pH 4.5, 30 °C, 0.05 mM ABTS), ciprofloxacin and norfloxacin removal reached 86.12–75.94% and 83.27–65.94% within 3 h. Degradation at 50 °C further confirmed the enzyme's thermostability. LC–MS analysis revealed transformation via decarboxylation, depiperylyzation, dealkylation, and defluorination. Toxicity assays using *E. coli* and *Staphylococcus aureus* indicated that the biodegraded products were non-toxic. Storage stability tests over 28 days showed maximum enzyme stability at pH 4.5 and 30 °C. Overall, SMW-derived laccase offers an efficient and eco-friendly solution for removing fluoroquinolones while supporting agro-waste valorization and circular economy goals.

Keywords: Antibiotics, Fluoroquinolone, Spent mushroom waste, Laccase, micropoolutants, Circular economy

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Microplastic pollution as an emerging environmental driver of gut-brain axis dysfunction through integrated metabolic and inflammatory pathway disruption

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ABSTRACT

Microplastics (MPs) pollution poses a growing environmental threat with significant implications for gastrointestinal and neurological health. Polyethylene (PE) and polypropylene (PP) MPs were structurally characterised and orally administered to adult rodents for 45 consecutive days to delineate their impact on gut-brain axis (GBA) homeostasis. Chronic MP exposure induced a marked increase in intestinal permeability, accompanied by significant depletion of microbial-derived short-chain fatty acids, reflecting impaired fermentative metabolism and disruption of gut microbial functionality. These metabolic alterations coincided with compromised intestinal barrier integrity, as evidenced by the suppression of the tight junction protein ZO-1, particularly in the PE-exposed groups. Systemic redox imbalance was evident through reduced antioxidant defences and enhanced lipid peroxidation in both colonic and brain tissues. This oxidative milieu was paralleled by robust activation of inflammatory signalling, characterised by elevated IL-1β and TNF-α levels, NF-κB upregulation, and downregulation of PPAR-γ. Neurochemical dysregulation was further supported by increased acetylcholinesterase activity. Notably, MP exposure led to suppression of brain-derived neurotrophic factor, indicating impaired synaptic plasticity, and was associated with increased amyloid precursor protein expression and early tau pathology. Behavioural deficits and histopathological alterations in intestinal and neural tissues corroborated these findings. Furthermore, immunohistochemical detection of fluorescence-tagged microplastics in zebrafish confirmed tissue accumulation of these microplastics. Collectively, these findings delineate a mechanistic framework in which MP-induced metabolic insufficiency and barrier disruption potentiate oxidative and inflammatory cascades, ultimately impairing neuroplastic signalling along the GBA dysregulation, with PE-MP exerting a greater neurotoxic impact than PP-MP.

Keywords: Microplastics, short-chain fatty acids, brain-derived neurotrophic factor, neuroinflammation, gut-brain axis.

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Biosurfactant Producing Microbial Consortia As Sustainable Agents For Marine Oil Spill Biodegradation

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ABSTRACT

Microbial biosurfactants represent a sustainable biotechnological tool for marine oil pollution. Microbes isolated from agricultural leaf litters were screened for biosurfactant production, yielding four strains (K1–K4) and a consortium (K5) that were evaluated for degrading hydrocarbons like engine oil and n-hexadecane found in marine spill residues. All cultures displayed strong surface-active properties, with emulsification values ranging from 62% to 94% and notable affinity for hydrocarbons. The consortium K5 showed the highest adhesion to EO (91%) and NH (89%), demonstrating the enhanced effectiveness of combined microbial strains. GCMS analysis of biodegradation of engine oil using microbial consortium showed substantial decreases in major engine-oil constituents, such as hexadecanoic acid methyl ester and triacontanoic acid methyl ester (44.9% to 38.15%) and triacontanoic acid methyl ester (36.22% to 31.23%), along with the appearance of new metabolites, 1,3,5-tris(cyclohexyl)hex-1-ene and methyl stearate. These shifts in composition provide direct evidence of microbial transformation and degradation of persistent hydrocarbons. Overall, the findings highlight the strong potential of biosurfactant producing microbial consortia as sustainable tools for reducing oil pollution and aiding the recovery of marine environments exposed to complex chemical contaminants.

Keywords: Biosurfactants, Hydrocarbon degradation, Marine oil pollution, Microbial consortia, GCMS analysis

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AI-Based Monitoring and Productivity Mapping of Chaetomorpha for Ocean Health Assessment

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ABSTRACT

Coastal ecosystems are increasingly impacted by nutrient enrichment, climate variability, and anthropogenic pressures, demanding robust and scalable monitoring for ocean health assessment. Chaetomorpha, a filamentous green macroalga, is a key bioindicator involved in nutrient cycling and water quality regulation. Traditional methods for quantifying Chaetomorpha abundance and productivity are labor-intensive with limited spatial coverage, hindering effective management.

This research develops an AI-based framework for near real-time detection and productivity mapping of Chaetomorpha in coastal environments. It integrates deep learning segmentation models with high-resolution imagery from underwater and aerial platforms. Environmental variables such as temperature, salinity, and nutrient concentrations are incorporated to enhance prediction accuracy.

The system produces spatially explicit maps of algal coverage and biomass proxies, revealing spatiotemporal growth dynamics and ecological drivers of Chaetomorpha proliferation. Validation against field data shows significant improvement over manual surveys, reducing effort and enabling frequent monitoring.

This automated system provides actionable data supporting conservation, sustainable aquaculture, and climate resilience strategies in coastal zones. By embedding Chaetomorpha as a bioindicator in an intelligent observation pipeline, this study advances ocean health assessment methodologies required for modern environmental monitoring. The approach contributes to broader efforts in leveraging AI for ecosystem monitoring, facilitating adaptive management amid accelerating ecological change.

This innovative AI framework transforms marine ecosystem monitoring by enabling large-scale, timely, and accurate assessments that inform environmental management and policy under ongoing ecological pressures.

Keywords: Chaetomorpha, Bioindicator species, AI-based monitoring, Coastal ecosystem health, Deep learning segmentation.

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Ai-Based Monitoring And Productivity Mapping Of *Chaetomorpha* For Ocean Health Assessment

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ABSTRACT

Coastal ecosystems are increasingly stressed by nutrient enrichment, climate variability, and growing anthropogenic pressures, underscoring the need for scalable and high-precision monitoring tools for effective ocean health assessment. Chaetomorpha, a filamentous green macroalga, functions as a valuable bioindicator due to its role in nutrient cycling, primary productivity, and water quality regulation. However, conventional monitoring approaches remain labor-intensive, time-consuming, and limited in spatial and temporal resolution, restricting their applicability for dynamic coastal systems. This study presents an AI-enabled framework for near real-time detection, quantification, and productivity assessment of Chaetomorpha using deep learning segmentation models integrated with high-resolution underwater and aerial imagery. Environmental variables including temperature, salinity, light availability, and nutrient concentrations are incorporated to strengthen predictive performance and ecological interpretation. The system generates spatially continuous maps of Chaetomorpha distribution and biomass indicators, capturing fine-scale spatiotemporal patterns and identifying environmental drivers that influence algal proliferation. Validation against field measurements shows substantial improvement over manual surveys, reducing operational effort while enabling frequent and large-scale monitoring. By delivering accurate, timely, and actionable ecological data, the proposed framework enhances decision-support capabilities for coastal conservation, sustainable aquaculture planning, and climate resilience initiatives. Overall, this AI-driven approach advances modern marine ecosystem monitoring by providing an efficient and adaptive method for assessing ocean health in rapidly changing coastal environments.

Keywords: Chaetomorpha, Bioindicator species, AI-based monitoring, Coastal ecosystem health, Deep learning segmentation.

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Restoration of Ocean Health: Studies on hydrocarbon bioremediation through a novel hydrocarbonoclastic marine bacterium Bacillus tequilensis G6

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ABSTRACT

The present study explores the genomic potential of marine bacterium capable of degrading Poly Aromatic Hydrocarbons (PAHs), isolated from the marine sediments of Bay of Bengal (14°59.908'N 80°34.008'E). The enriched isolate, strain G6 exhibited a clear zone on pyrene (50 mg/L) containing minimal medium, indicating hydrocarbon degradation activity. Morphological and biochemical characterization revealed that the Strain G6 is an aerobic, rod shaped, Gram-positive, catalase-positive and endospore forming bacterium. Phylogenetic analysis based on 16S rRNA gene indicated a 91% sequence similarity with Bacillus tequelensis. The strain demonsrated efficient pyrene degradation, achieving 89±1.5% in the presence of pyrene as a sole carbon source (100 mg/L). GCMS and FTIR analysis confirmed the changes in functional groups and the conversion of PAHs into mono aromatic intermediate compounds. Optimal conditions for growth and pyrene degradation were determined to be pH 6.5, temperature 28±1° C and 2.5% NaCl. Genomic analysis revealed the presence of genes encoding key hydrocarbon-degrading enzymes including aromatic ring hydroxylase, cytochrome P450 monooxygenase and catechol 2,3 dioxygenase, highlighting the metabolic versatility. Secondary metabolite analysis identified biosynthetic clusters related to biosurfactant and siderophore production, supporting hydrocarbon solubilisation and enzymatic activity. These findings demonstrated the potential of Bacillus tequelensis G6 in developing eco-friendly remediation strategies for restoration of oil contaminated marine environments.

Keywords: PAHs, hydrocarbon degradation, marine bacteria, remediation, genomics

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Network-Based Investigation Of Petroleum Hydrocarbons-Induced Ecotoxicological Effects And Their Risk Assessment

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ABSTRACT

Petroleum hydrocarbons (PHs) are compounds composed mostly of carbon and hydrogen, originating from crude oil and its derivatives. PHs are primarily released into the environment through the diffusion of oils, resulting from anthropogenic activities like transportation and offshore drilling, and accidental incidents such as oil spills. Once released, these PHs can persist in different ecosystems and cause long-term detrimental ecological impacts. While the hazards associated with such PH contaminations are often assessed by the concentrations of total petroleum hydrocarbons in the environment, studies focusing on the risks associated with individual PHs are limited. In this study, different network-based frameworks were utilized to explore and understand the adverse ecological effects associated with PH exposure. First, a list of 320 PHs was systematically curated from published reports. Next, biological endpoint data from toxicological databases was systematically integrated, and a stressor-centric adverse outcome pathway (AOP) network, linking 75 PHs with 177 ecotoxicologically-relevant high confidence AOPs within AOP-Wiki, was constructed. Further, stressor-species networks, based on reported toxicity concentrations and bioconcentration factors data within ECOTOX, were constructed for 80 PHs and 28 PHs, respectively. It was found that crustaceans are documented to be affected by many of these PHs. Finally, the aquatic toxicity data within ECOTOX was used to construct species sensitivity distributions for PHs, and their corresponding hazard concentrations (HC05), that are harmful to 5% of species in the aquatic ecosystem, were derived. Further, the predicted no-effect concentrations (PNECs) and risk quotients for the US EPA priority polycyclic aromatic hydrocarbons (PAHs) were computed by using their environmental concentration data for Indian coastal and river waters. Overall, this study highlights the importance of using network-based approaches and risk assessment methods to understand the PH-induced toxicities effectively.

Keywords: Petroleum hydrocarbons, Adverse outcome pathway, Stressor-species network, Ecological risk assessment, Species sensitivity distribution

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Marine-Derived Fungal Synthesis of Silver Nanoparticles for Multifunctional Applications

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ABSTRACT

The present study employs a sustainable green biotechnology approach for the rapid, ecofriendly, and efficient synthesis of silver nanoparticles (AgNPs) using marine fungal mycelial filtrate. The bio-reduction process was visually confirmed by a distinct color change from pale yellow to dark brown, indicating the formation of mycogenic AgNPs. UV–Vis spectroscopy further validated nanoparticle synthesis, showing a characteristic surface plasmon resonance peak at 431 nm. Comprehensive characterization was performed using FTIR analysis, which identified functional groups responsible for reducing and capping the nanoparticles. High-Resolution Transmission Electron Microscopy (HRTEM) revealed predominantly spherical AgNPs with an average size of 38 nm. XRD analysis confirmed the crystalline nature of the nanoparticles, exhibiting diffraction peaks corresponding to the planes [111], [200], [220], [311], and [222]. The biosynthesized AgNPs demonstrated strong and broad-spectrum antibacterial activity against both Gram-positive and Gram-negative human pathogenic bacteria. They also exhibited significant antifungal activity against plant pathogenic fungi. Antioxidant evaluation using the DPPH assay showed high radical scavenging potential, indicating their effectiveness in oxidative stress mitigation. Moreover, the AgNPs displayed potent anticancer activity against the MCF-7 breast cancer cell line, with an IC_{50} value of 53.33 µg/mL, highlighting their therapeutic potential. Additionally, the photocatalytic performance of the nanoparticles was assessed using methylene blue dye, achieving an impressive 96% degradation within 3 hours. Overall, this study demonstrates the efficient synthesis and multifunctional biotechnological applications of marine mycogenic silver nanoparticles in antimicrobial, antioxidant, anticancer, and environmental remediation fields.

Keywords: Green synthesis, AgNPs, DPPH, Anticancer

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Ai-Enabled Ecotoxicity Assessment In Aquatic Systems: A Next-Gen Water Trend

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ABSTRACT

Marine ecotoxicity has become a critical global concern as emerging pollutants—including industrial chemicals, personal care products, pharmaceuticals, heavy metals, plastic debris, and numerous organic contaminants—continue to intensify pressure on aquatic ecosystems. The rapid increase in the production of harmful environmental chemicals, driven largely by anthropogenic activities, has led to the widespread introduction of toxic substances into marine and freshwater environments. Major contributors to aquatic pollution include wastewater, metals and metalloids, industrial effluents, contaminated sediments, nutrients, polycyclic aromatic hydrocarbons, flame retardants, persistent organic pollutants, pharmaceuticals, pesticides, herbicides, endocrine disruptors, and emerging contaminants such as microplastics and engineered nanoparticles. Detecting these contaminants remains an initial step toward effective mitigation and environmental management. However, traditional analytical techniques rely heavily on sophisticated laboratory infrastructure, making real-time, in situ monitoring challenging. Emerging AI-assisted technologies are increasingly recognized for their ability to process complex datasets, identify contaminant patterns, and support the development of advanced monitoring frameworks. The current study aims to evaluate existing models of ecotoxicity effects and pollutant interactions, particularly their synergistic impacts on human and aquatic health, using bibliometric analysis. It further highlights biomonitoring strategies for tracking pollutant accumulation and understanding associated toxicological effects through data-driven modeling. By addressing current gaps in water treatment approaches and pollutant management, this work underscores the need for integrated, technologically advanced solutions to safeguard aquatic ecosystems and public health.

Keywords: Ecotoxicity, Marine Ecosystem, AI-Based Model, Emerging Pollutants, Bibliometrix.

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High-Hazard Polymer Accumulation Shapes Microplastic Risk Along the Indian Coast

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ABSTRACT

Microplastic pollution along the Indian coastline is increasingly recognized as a significant environmental stressor, yet spatial comparisons remain constrained by heterogeneous samplingmethodologies and inconsistent reporting across studies. In this work, we compileandnormalize published microplastic datasets from key Indian coastal sectors—includingthesouthwest coast (Goa, Kochi), northwest coast (Mumbai), and the Bay of Bengal margin(West Bengal, Tamil Nadu, Andhra Pradesh)—as well as major estuarine inputs suchastheVembanad Lake and Hooghly systems. Data were standardized by particle size class, polymeridentity, morphological type, and sampling matrix to enable cross-study comparability. A toxicity-weighted evaluation was performed using the Polymer Hazard Index (PHI), whichintegrates polymer-specific hazard classifications based on documented carcinogenicity, persistence, monomer toxicity, and additive leaching potential. Although polyethylene(PE)and polypropylene (PP) are numerically dominant across most sampling locations, PHIanalysis highlights substantially elevated risk contributions from polymers such as PVC, PS, PET, and nylon, despite their comparatively lower abundances. Notably, the Bay of Bengal coast exhibited the highest cumulative hazard scores, reflecting strong riverine fluxes, highparticulate loads, monsoonal stratification, and dense coastal population pressures. The synthesis demonstrates that hazard-weighted indices provide a more ecologicallyrelevant measure of microplastic risk than abundance metrics alone. Integrating these spatial patternswith PHI results shows that Indian coastal accumulation hotspots—particularly alongtheBayof Bengal—host a disproportionate share of high-hazard polymers, revealingriskintensification that is obscured in abundance-based assessments and underscoring the needforhazard-resolved coastal monitoring.

Keywords: Microplastics, Coastal risk evaluation, Polymer Hazard Index (PHI), Indiancoastal

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Microplastics As Reservoirs Of Antibiotic-Resistant Microbiota In Aquatic Systems

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ABSTRACT

Microplastics are increasingly recognised as a critical threat to ocean health due to their persistence, ubiquity, and ability to act as substrates for diverse microbial communities. In marine and coastal environments, these particles can harbour bacteria, protozoa, and archaea, potentially transforming them into vectors for pathogenic and antibiotic-resistant microorganisms. Such microbe-plastic interactions may disrupt natural microbial balances, impact nutrient cycling, and compromise the health of aquatic species, thereby influencing overall ocean ecosystem resilience. This study investigates the microbial assemblages associated with microplastics ingested by mosquito larvae filter feeding in various coastal and estuarine habitats. Microplastics were isolated from mosquito larvae belonging to *Anopheles*, *Aedes* and *Culex* spp. by oxidative digestion and filtration, followed by microscopic examination and manual collection. Associated bacteria were cultured on selective media, identified through biochemical assays, and compared with the gut microbiota of laboratory-reared larvae and larvae grown in contaminated environmental water. Antibiotic susceptibility testing was performed to detect resistant strains potentially arising from microbial aggregation and horizontal gene transfer on microplastic surfaces. The findings highlight the capacity of microplastics to support distinct and antibiotic-resistant microbial communities, raising concerns about their role as emerging vectors of disease within aquatic food webs.

Keywords: microplastics, plastisphere, antibiotic resistance genes (ARGs), mosquito larvae, gut microbiota

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Isolation And Preliminary Characterization Of Marine Bacteria Capable Of Polyethylene Glycol Degradation

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ABSTRACT

Polyethylene glycol (PEG) is a widely used synthetic polymer present in pharmaceuticals, cosmetics, detergents, and various industrial processes. Its extensive use leads to continuous release into natural environments, where PEG persists due to its chemical stability and slow degradation. Microbial degradation offers an eco-friendly approach to reduce PEG contamination, yet information on PEG-degrading bacteria in natural habitats remains limited. This study aimed to screen and isolate PEG-degrading bacteria from plastic samples collected at Edavanakkad Beach, using PEG as the sole carbon and energy source. A total of 109 bacterial isolates were obtained through serial dilution and culture-based methods. Initial screening on Minimal Salt Medium (MSM) containing 0.01% (w/v) PEG resulted in 40 isolates showing clear zones of polymer utilization, indicating PEG-degrading ability. PEG consumption was also inferred from temporal variations in OD_{600}, measured at regular intervals using a microplate-based assay. Based on OD values, isolates were classified as strong, moderate, weak, or non-degraders. Approximately 15% showed strong PEG degradation, 55% moderate, and 30% weak degradation. These PEG-positive isolates likely possess hydrolytic enzymes capable of initiating ether-bond cleavage during PEG breakdown. The study demonstrates that both zone-formation screening and OD-based PEG screening are simple and effective preliminary tools for identifying PEG-degrading bacteria. Overall, the findings reveal that plastic-associated microbial communities harbor diverse bacteria with significant potential for PEG bioremediation and wastewater treatment, supporting future work on enzyme characterization and optimization of PEG degradation pathways.

Keywords: Polyethylene glycol (PEG) degradation, Marine bacteria, Bioremediation, Plasticassociated microbiota, Hydrolytic enzymes

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Organochlorine Pesticide in Riverine, Estuarine, and Coastal Environments of Goa, India

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ABSTRACT

Persistent organic pollutants (POPs), particularly organochlorine pesticides (OCPs), continue to remain a major environmental concern due to their long-range atmospheric transport, environmental persistence, bioaccumulation potential, and associated ecological and human health risks. Despite regulatory bans, legacy OCPs are still detected in aquatic systems influenced by agricultural, industrial, and urban inputs. Goa's Mandovi and Zuari riverine, estuarine and coastal system is ecologically and socio-economically significant, yet limited research exists on OCP contamination across these interconnected environments.This study assesses the occurrence, concentration, and spatial distribution of OCPs in surface water and sediment samples collected along Goa's riverine, estuarine, and coastal regions.

Sampling was carried out across 20 stations during December 2024 and January 2025, covering varied salinity gradients. Water samples were collected using a Niskin sampler and sediments using a Van Veen grab. Extraction of OCPs from sediment was performed using USEPA-3546 microwave-assisted extraction, and water samples were processed via solid-phase extraction. All samples were purified through alumina/silica columns, and instrumental quantification was performed using Gas Chromatography with Electron Capture Detector (GC-ECD) for 20 OCP congeners.

The results revealed that ΣHCHs, ΣDDTs, ΣENDOS, ΣCHLs, and ΣOther OCPs were detected in varying concentrations across all matrices. ΣHCHs in water ranged from 19.9–56.0 ng/L, dominated by γ-HCH, while sediments showed 1.5–8.1 ng/g with β-HCH highest at ME-1. ΣDDTs in sediments ranged 0–1.8 ng/g, dominated by p,p'-DDE, indicating historical usage and degradation. Endosulfan sulfate was predominant among ∑ENDOS, suggesting secondary sources. Coastal sites generally exhibited lower concentrations compared to estuarine and riverine zones, highlighting terrestrial runoff influence. The study provides one of the first comprehensive datasets on OCP occurrence across Goa's riverine, estuarine and coastal environment and establishes a scientific baseline for future monitoring, ecological risk assessment, and policy-based pollution mitigation strategies.

Keywords: Organochlorine pesticides, riverine-estuarine-coastal systems, GC-ECD and HCHs.

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Tracing Microplastics from Shore to Shell: Ingestion and Ecological Risk in the intertidal Hermit Crab Species Clibanarius ransoni Forest, 1953

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ABSTRACT

Growing microplastic (MP) contamination in Gujarat's coastal habitats presents a significant ecological challenge for benthic crustaceans in intertidal zones. The hermit crab species Clibanarius ransoni is particularly vulnerable due to continuous interaction with sediment, seawater, and shell water. This study investigated MP contamination across environmental matrices—sediment, seawater, and shell water—and assessed MP accumulation in the gastrointestinal tract (GIT) of the species. Environmental sampling revealed measurable MP loads across all abiotic compartments, demonstrating widespread microplastic distribution throughout Gujarat's coastal region. The average MP load in seawater, GIT, and shell water was 0.49 ± 0.17 MPs/L, 7.96 ± 3.43 MPs/individual, and 3.46 ± 0.75 MPs/L, respectively. Black and blue fibrous MPs dominated in seawater, sediment, GIT, and shell water of the hermit crab species. Microscopic analysis showed MPs within the 0.5-1 mm size range were most prevalent. FT-IR spectroscopy confirmed the presence of commonly used polymers, primarily polyethene (PE) and polypropylene (PP), in particles isolated from both biotic and abiotic samples. Ecological risk assessment revealed considerable MP-induced environmental risk across Gujarat's coastal ecosystem, threatening benthic food webs and dependent organisms. This integrated study of environmental contamination, tissue accumulation, and trophic ecology underscores the urgent need for targeted mitigation strategies to address microplastic pollution in Gujarat's coastal habitats.

Keywords: Intertidal region, Plastic pollution; Trophic ecology; Decapoda, Gujarat

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Microplastics Degradation By Bacterial Enzymes: Strategic Approach To Control Plastic Pollution

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ABSTRACT

Microplastics (MPs) are small plastic pieces with size < 5mm that have entered and polluted the environment. While many investigations including several critical reviews on MPs in the environment have been conducted, most of them are focused on their occurrences in the marine environment. These microplastics have severely affected humans, animals, agroecosystems, food chain, and environment. To overcome this problem, microbial remediation has demonstrated greater promises to degrade or remove MPs from the environment in a sustainable manner among the various remediation techniques such as biostimulation, enzymatic degradation. Microbes are genetically engineered with specific genes encoding for the enzymes for plastic degradation. Thus, they eliminate MPs by using the corresponding carbon content in the pollutants as energy sources for development. Investigating novel remediation techniques are essential, even though technological procedures to characterize MPs are still developing. Collectively, these advancements indicate a strong shift towards biologically driven, eco-friendly solutions with the potential to transform global plastic waste management.

Keywords: Microplastic, Bioremediaton, Bacterial enzymes, Degradation, Biostimulation

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Atmospheric Microplastic Over North Indian Ocean: Review On Sources, Transport And Regional Impact

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ABSTRACT

Microplastics (MPs) are synthetic polymer particles less than 5 mm, recognized as an "contaminant of emerging concern" because of their persistence and ubiquitous nature. Consequently, MPs are now detected in every ecological matrices including aquatic, terrestrial and atmosphere. However, Atmospheric MPs (AMPs) have become a notable fraction of airborne particulate matter over the Northern Indian Ocean (NIO), a rapidly evolving marine– atmosphere system that require much consideration. AMPs undergo long range transport from emission regions to remote continental as well as oceanic ecosystems. NIO encompasses Arabian Sea and Bay of Bengal, one of the most populated and industrially active ocean basin regions. These regions are highly susceptible to AMPs due to major shipping activities, monsoon-driven winds and subsequent river discharge. The aeolian transport of MPs can be due to south westerly winds which may carry continental MPs over Arabian Sea and north easterly winds mobilize particles from Indian subcontinent and Indo-China into Bay of Bengal and central NIO. Also, in recent years, AMPs has been detected in remote islands, open ocean – air masses and coastal ecosystems surrounding NIO. Thus, these miniscule particles constitute an important component of the global plastic cycle undergoing suspension, aeolian transport and atmospheric deposition (dry and wet). In this study, aerosol samples will be collected through high volume sampler which will undergo filtration and density separation techniques. Visual identification will be done by using stereo zoom microscopy followed by µ-FTIR for polymeric identification. This study will address the major knowledge gaps which includes detection of AMPs, seasonal variations, source apportionment, transportation models and health risk assessment providing a robust framework for studies over NIO. This research will align with India's National air programme by addressing AMPs as an emerging pollutant over Indian Ocean.

Keywords: atmospheric microplastic, North Indian Ocean, atmospheric deposition, marineatmosphere interaction

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Addressing microplastic (MP) contamination in the deep-sea sediments of the south-western Bay of Bengal

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ABSTRACT

Microplastic pollution in marine ecosystems has become a pressing environmental concern with increasing attention directed towards its presence in deep-sea environments. The Bay of Bengal, a vital marine ecosystem, faces significant anthropogenic pressures yet the extent of microplastic contamination in its deep-sea sediments remains poorly understood. In the present study, sediment samples were collected from two bathymetric depths of 1000 meters and 1750 meters in the Bay of Bengal and examined for the presence of microplastic contamination. The sampling station A (1000-meter depth) sediment sample exhibited the highest number of microplastics 50 ± 3.46 fragments/gram compared to station B (1750-meter depth), 19 ± 6.29 fragments/gram. According to the typewise study, thread-like microplastics were overwhelmingly dominant, particularly at 1750 meter depth accounting for 66% of all identified particles, followed by 28% bristle type, 6% fragment type respectively. On the other hand, sediment collected from the 1000 meter depth (sample A) showed more diversity with 57% thread-type, 26% bristle type and 17% fragment-type particles. Lastly, the characterization of microplastics revealed a diverse range of polymers such as Polyethylene (PE), Acrylonitrile Butadiene Styrene (ABS), and Polyacrylonitrile (PAN). PE and ABS were predominantly found at 1000 m sediments, whereas 1750 m sediments exhibited a higher density of PAN fragments. ABS was consistently detected at both depths, suggesting a persistent and widespread presence. This study provides one of the first detailed Raman-based assessments of deep-sea microplastics in the Bay of Bengal and underscores the need for continued monitoring of deep benthic environments under growing anthropogenic stress.

Keywords: Microplastic, Bay of Bengal, Deep sea sediment, RAMAN Spectroscopy, Anthropogenic

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Microplastic Pollution along the Eastern Coast of India: Comprehensive Assessment in Marine Waters, Beach Sand, and Commercial Fish Species

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ABSTRACT

Microplastic pollution has emerged as a critical environmental issue globally, yet large sections of the Indian coastline remain understudied. This work presents the first comprehensive assessment of microplastics along the eastern coast of India, covering seven major and densely populated beaches across West Bengal, Odisha, and Andhra Pradesh (nearly 1200 kms). Water, beach sand, and four commercially important marine fish species (Rastrelliger kanagurta, Leiognathus ruconius, Sardinella gibbosa, and Megalops cyprinoides) were analysed to understand the extent of microplastic contamination and its ecological implications. Seawater samples exhibited a high microplastic abundance (80 ± 33 items/m³), dominated by polypropylene, while sand samples contained 4 ± 2 items/kg dry weight, with polystyrene being the most prevalent polymer. Visual characterization revealed a predominance of white and transparent particles, with fragments and foams as the dominant shapes. Polymer Hazard Index (PHI) scores placed most locations in hazard categories IV and V, indicating severe risk. Approximately 29.6% of the fish samples contained microplastics (200 µm–2 mm), with PET and PP as the dominant polymers. Sardinella gibbosa and Rastrelliger kanagurta showed the highest levels of ingestion, raising concerns regarding ecological health and food safety. The random distribution of microplastics across species and locations suggests diverse and complex pollution sources, including tourism, fishing, riverine discharge, and improper waste management. This study highlights the alarming microplastic burden along the eastern coast of India and underscores the urgent need for improved waste management, extensive monitoring, and further investigation into trophic transfer, nanoplastic formation, and associated contaminant interactions in coastal ecosystems.

Keywords: Microplastic; Eastern coast of India; Beach sand and seawater; Fish bioaccumulation; Pollution indices

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Development of biochar based nanozyme for optical detection of chlorpyrifos in water matrices

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ABSTRACT

In recent years, the commercial production of edible mushrooms has garnered considerable attention due to the increasing demand for nutrient-dense food. Biochar and nitrogen-doped biochar nanoflakes were synthesized by a combination of slow pyrolysis, chemical oxidation, and acetone extraction process. A mixture of SMS and urea is commonly used as a precursor for the synthesis of the nitrogen-doped nanozyme, where only SMS was used as a carbon and nitrogen source. The biochar nanozyme is further characterized by FETEM, XPS, and TGA. The XPS study confirms the presence of several elements, including carbon, nitrogen, oxygen, and other trace elements. The FETEM study discloses the morphology of both nanozymes. The biochar nanozyme-based colorimetric and ratio metric fluorescence biosensor platform demonstrates exceptional sensitivity and specificity towards the application in visual detection of chlorpyrifos. Furthermore, the biochar nanozyme-based colorimetric platform is utilized for the real-time detection in tap water to ensure the practical applicability of the proposed biosensing system for point-of-care detection.

Keywords: Nanozyme; Spent mushroom substrate; Nanobiochar; Water monitoring; Chlorpyrifos

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The Climbing Tide of Microplastics: From Sediment Contamination to Polymeric Hazards in the Mahi River Estuary

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ABSTRACT

Microplastic contamination (MP) has emerged as a major environmental threat, particularly in estuarine ecosystems. This study assessed the prevalence, characteristics, and polymeric risk associated with the MPs in Mahi River Estuary, Gujarat, India. Thirty sediment sampling sites were surveyed from Khambhat to Kamboi. A total of 1371 MP particles were found, with an average abundance of 0.76 ± 0.25 MPs/g dry weight. MP concentrations varied significantly across sites, with the highest levels at Chokari and the lowest at Umraya. Fibers were the dominant MP shape, followed by fragments, films, and form. Particle sized 1-2 mm and and <1 mm was most prevalent, and multiple colours were recorded. ATR- FTIR analysis revealed that polyethylene tetraphene (PET), polyethylene (PE), and polypropylene (PP) as the most abundant polymers. Risk assessment indicated moderate to considerable contamination across 28 sites based on the contamination factor, while Kanvadi and Chokari showed notably higher pollution levels. The Hazardous Index categorised 10 locations as Class V, including high potential polymer toxicity, and the Pollution Risk Index placed 12 sites in the very high-risk category. These elevated risks likely stem from intensive fishing, tourism, industrial discharge, and inadequate waste management across the estuary. The finding demonstrates substantial MP contamination in the Mahi estuarine sediments and highlight the pressing need for targeted pollution control, improved waste handling, and further ecological impact studies to safeguard this critical aquatic ecosystem.

Keywords: Estuarine threat, Fiber, FTIR, Gulf of Khambhat, Plastic pollution

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Post-Synthetically Modified Imidazole frameworks as potential porous materials for environmental applications

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ABSTRACT

Metal–Organic Frameworks (MOFs), emerged as highly versatile porous materials with application in numerous research fields such as environment, energy, chemical, biological etc. MOFs owing to their combination of metal nodes and organic linkers, generate well-ordered structures with exceptional surface areas. Their tunable pore environments and rich chemical flexibility make MOFs attractive for tackling environmental challenges. Due to their multidisciplinary applications, "Metal–Organic Frameworks (MOFs)" research has been selected for the Nobel Prize in Chemistry in 2025. Zeolitic Imidazole Frameworks (ZIFs) are subclass of MOFs which are composed of zinc ions as metal center and imidazoles as organic linkers, these linkers can be covalently modified for various applications. A key advancement that further enhances their utility is post-synthetic modification (PSM), a strategy that introduces new functional groups into pre-formed frameworks without altering their crystallinity. In this work, two PSM pathways are employed to improve the ability of MOFs to detect and remove pollutants. For detection, fluorophore groups are grafted onto amino-functional ZIFs, enabling introduction of attached moiety's properties to the hybrid structure. For metal detection and capture, metal chelating groups are introduced through PSM to create strong binding sites for soft heavy-metal ions or critical rare earth metals (CRMs), resulting in higher selectivity and adsorption efficiency. In this regard, we have synthesized and characterized quinoline and benzothiazole based derivatives for the detection and potential removal of inorganic/organic pollutants from wastewater. We have also investigated the selectivity and sensitivity of the designed materials using absorbance and fluorescence spectroscopy. These modifications demonstrate how targeted chemical adjustments can transform MOFs into powerful materials for high efficiency and cost-effectiveness. This work also provides a clear demonstration of how PSM can be used to tune ZIFs to address specific environmental challenges.

Keywords: MOFs, Post-synthetic modification, metal sensor, metal capture, pollutant removal

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Mercury In Perna Viridis Along The Goa Coast: A Comparative Assessment Of Betul And Vasco Sites

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ABSTRACT

Mercury (Hg) is a global pollutant with strong persistence, bioaccumulation, and biomagnification. Green mussels (Perna viridis), owing to their filter-feeding nature and limited mobility, are widely recognized as effective indicators of metal pollution. This study evaluates total mercury (THg) accumulation in P. viridis collected from two ecologically contrasting sites along the Goa coast Betul (low anthropogenic influence) and Vasco (highly urbanized and industrialized). A total of 36 mussels (18 per site) and corresponding sediment samples were analysed. Morphometric parameters (length, breadth, height, shell weight, tissue weight) were recorded, and THg in freeze-dried tissues and sediments was quantified using a Direct Mercury Analyzer (DMA-80). Results revealed clear spatial variations in Hg accumulation in mussels. Mussels from Vasco exhibited comparatively high THg levels (average value of 86.09 µg/kg; n=18) range (56.17µg/kg -124.44 µg/kg) compared to Betul (average value of 53.11 µg/kg; n=18; range (27.76 µg/kg -91.74µg/kg), might be consistent with enhanced exposure from port activity, shipyard operations and sewage discharge. Interestingly, smaller mussels from Vasco showed disproportionately higher Hg concentrations, indicating that elevated environmental Hg can override typical size-dependent accumulation patterns. Sediment Hg values were comparatively low at both sites (Betul: 0.0001 - 35.15µg/kg; n=5) Vasco:8.46µg/kg; n=1), suggesting that dissolved and particulate-phase Hg, rather than sediment-bound Hg, may be the dominant exposure pathway for mussels in these regions. Morphometric correlations showed weak or inconsistent relationships with THg, highlighting the stronger influence of environmental ontamination over biological factors. Overall, the study demonstrates that P. viridis effectively reflects spatial variability in Hg pollution and can serve as a sensitive bioindicator for coastal monitoring programs in India. Although Hg levels were within international seafood safety limits (500µg/kg), continuous monitoring is essential given the rising anthropogenic pressures along Goa's coastline and the potential long-term risks to marine biota and human consumers.

Keywords: Mercury, Green mussels, Bioaccumulation, and bioindicator

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Fatty Acid-Modified Mg/Al Layered Double Hydroxide For Efficient Adsorptive Removal Of Diclofenac From Water

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ABSTRACT

Nowadays, pharmaceuticals and personal care products (PPCPs) have gained growing attention as a group of contaminants of emerging concern due to their ubiquitous occurrence in aquatic ecosystems. Diclofenac (DCF) is a commonly used nonsteroidal anti-inflammatory drug and is frequently detected in different aquatic environments worldwide. It shows a strong tendency for bioaccumulation in aquatic organisms, as reflected by its octanol-water partition coefficient (log Kow) of 4.51, particularly in lipid-rich tissues of aquatic fauna, raising concerns about ecological toxicity and long-term adverse effects. In response to this growing challenge, this study investigates a sustainable remediation strategy using palmitic acid-modified Mg/Al layered double hydroxide (PA-Mg/Al-LDH) for the adsorptive removal of DCF from aqueous environments. In this approach, the inherent affinity of DCF for lipid-rich tissues is leveraged to improve its removal by LDHs, achieved by modifying the LDH surface with palmitic acid, a common saturated fatty acid, to increase surface hydrophobicity. Various characterization techniques, including FT-IR, SEM, and contact angle analysis, confirmed that the LDH was successfully modified with palmitic acid. Preliminary adsorption studies demonstrated that the modified LDH exhibited superior DCF adsorption efficiency (98%) compared to the pristine LDH (45%). Further investigations on DCF adsorption by PA-Mg/Al-LDH examined the effects of various experimental parameters such as adsorbent dosage (0.01-0.5 g), contact time (15-120 minutes), pH (4-12), and initial DCF concentration in water (1-100 mg/L). The results underscore the potential of PA-Mg/Al-LDH as an effective adsorbent for DCF removal from aqueous solutions, and can also be utilized for the removal of other lipophilic organic pollutants.

Keywords: Diclofenac, Adsorption, Layered double hydroxides, Hydrophobic modification, Aquatic systems.

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Effects of microplastics and their role as vectors for pathogens and heavy metals in Litopenaeus vannamei

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ABSTRACT

Microplastics (MPs) are hazardous environmental pollutants that affect the marine environment as well as the aquaculture industry. Litopenaeus vannamei is a major environmental indicator as well as an important seafood species. In the present study, the synergistic effects of MPs and pathogens/heavy metals were investigated. Post-exposure, shrimps were dissected to understand the tissue internalisation and gut accumulation of MPs as well as their role as vectors for pathogens and heavy metals. Experiments revealed that, 24 hours post-exposure, the polypropylene (PP)-treated shrimps showed the highest MP accumulation, followed by pathogen biofilm-treated shrimps (PP + Vibrio harveyi and PP + Aeromonas sp.). Oxidative enzymes SOD and CAT were expressed at maximum levels in the shrimps of the treatment groups (PP only, PP + Pathogen, and PVC + Copper) in comparison with controls. Furthermore, mortality was observed in the shrimps exposed to the PP-only treatment and the PP with Aeromonas biofilm treatment within 24 hours. Gut accumulation and tissue internalisation of these treated MPs show their capabilities to act as possible vectors for both pathogens and heavy metals. However, a detailed study has to be carried out to understand the functional aspect of the synergistic effects of MPs with other pollutants that affect the shrimp's health.

Keywords: Microplastics, Litopenaeus vannamei, Pathogens, Heavy metals, Oxidative stress

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Investigating The Accumulation Trends Of Heavy Metals And Dioxin-Like Persistent Organic Pollutants Emitted From Urban Solid Waste Dumpsites In Marine And Aquatic Systems

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ABSTRACT

In many developing countries, growing waste volumes are often dumped in unlined, poorly managed sites that are prone to frequent fires. Firefighting typically involves excessive water spraying, which produces large volumes of combustion-derived runoff (CDR), a toxic liquid similar to landfill leachate. This runoff can transfer the pollutants into surrounding ecosystems. The Brahmapuram MSW dumpsite (9° 59′ 28″ N, 76° 21′ 59″ E), located in the low-lying flood-prone catchment area of the river Kadambrayar and in proximity to Chitrapuzha in Kochi, Kerala, India, was selected as the study area. These rivers are tributaries of the Periyar River, which empties into the Vembanad Lake and ultimately reaches the Arabian Sea. This hydrological linkage leads to the transport of contaminants into marine environments. The study was conducted during a major fire accident that occurred at the dumpyard in March 2023, which is expected to have resulted in significant land emissions of various organic and inorganic pollutants. The present study comprehensively evaluated the physicochemical quality of CDR and the distribution of pollutants, including heavy metals and dioxins, across downstream environmental compartments, including surface soil, sediment, surface water, and groundwater. In addition, ambient air, burned residue, soil, sediment, and locally available fish were analysed for dioxin-like persistent organic pollutants (dl-POPs), including PCDDs, PCDFs, and dl-PCBs. GC-MS/MS was used to quantify the TEQ levels to assess the combustion-derived dioxin emission and their potential trophic transfer. Results show high concentrations of dl-POPs in burned residue and soil, with a decreasing gradient in downstream sediments. Fish samples show early signs of bioaccumulation, pointing to possible food chain exposure. The environmental risk in the region was assessed using various statistical indices, including the Leachate Pollution Index (LPI), the Geoaccumulation Index (Igeo), the Enrichment Factor (EF), and the Pollution Load Index (PLI). The Toxicity Characteristic Leaching Procedure (TCLP) and spatial models were used to predict metal enrichment and dispersion patterns at the site. Leachability tests suggested that up to 25% of metals in fire residues could leach over time, posing serious long-term risks to soil, groundwater, and nearby aquatic ecosystems, enhanced by the persistence and toxicity of dl-POPs.

Keywords: MSW fire incidents, leachate pollution, Heavy metal pollution, dl-POPs emission, bioaccumulation.

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Comparative Assessment of the distribution, composition and abundance of Polycyclic Aromatic Hydrocarbons in Pelagic and Beached Tarballs

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ABSTRACT

Microplastics, heavy metals, oil spills, and organic pollutants (POPs) ABSTRACT This study undertakes a comparative assessment of the distribution, composition, and abundance of polycyclic aromatic hydrocarbons (PAHs) in pelagic tarballs collected from the Arabian Sea in 2018 and beached tarballs from the coastlines of Goa (2018) and Gujarat (2019). The quantitative analysis revealed that total PAH concentrations in pelagic tarballs ranged from 12.5 to 315 µg/g, whereas beached tarballs exhibited lower concentrations between 5.6 and 83.7 µg/g. Evaluation of toxic equivalency (TEQ) index indicated higher carcinogenic potential in pelagic tarballs (0.5 to 5.1 µg/g) compared to beached tarballs (0.04 to 1.2 µg/g). Both sample types showed phenanthrene and fluorene as the most abundant PAHs, along with significant levels of acenaphthene and chrysene. The similar PAH profiles observed in both pelagic and beached tarballs suggest shared petroleum sources, while differences in concentration and toxicity reflect the influence of environmental conditions and the residence period which eventually alter the weatering processes of the tarballs. This study provides a deeper regional insight into the distribution of pelagic and beached tarballs and their ecological consequences. The markedly high TEQ in pelagic tarballs is particularly alarming, as their ingestion by marine organisms could trigger serious biomagnification risks throughout the food web. Furthermore, the persistent ecological risks associated with phenanthrene, underscoring the need for continuous monitoring and targeted mitigation to protect marine ecosystems.

Keywords: Tarballs, PAHs, Phenanthrene, Toxic equivalency, Pelagic tarballs.

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Risk Assessment And Implications Of Heavy Metals In Edible Mollusc Species From The Northwest Maharashtra Coast

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ABSTRACT

Heavy metal contamination along the coast of Maharashtra has become a significant environmental and public health concern, particularly due to expanding urbanization, industrial discharge, and the growing dependence on seafood amongst the coastal communities. In the present study, the concentrations of ten heavy metals (Fe, Zn, Mn, Cu, Co, Cr, Ni, As, Pb, Cd) in the soft tissues of two widely consumed edible molluscs, Meretrix casta and Paphia malabarica, were assessed. The mollusc samples were procured from major and highly popular seafood landing centres that serve as important entry points into the regional food supply. Soft tissues were digested using a microwave digestion system and the heavy metal concentrations were determined through ICP-OES and ICP-MS. Human health risk assessment was done using Target Hazard Quotient (THQ), Hazard Index (HI), and Cancer Risk (CR), following USEPA guidelines. In the current study, six metals, viz. Fe, Mn, Co, Ni, As, and Cd were found to exceed permissible limits in several samples, indicating a substantial contamination in the edible soft tissues. Seasonal variation was evident, with consistently higher metal accumulation in the premonsoon period. Although the THQ values for individual metals remained below 1, the combined effects were more notable, with P. malabarica showing an HI exceeding 1, indicating potential cumulative non-carcinogenic risk. Carcinogenic risk values for Cd, Cr, and Ni surpassed acceptable limits in both mollusc species, while As contributed a moderate carcinogenic concern. Overall, the study highlighted significant long-term health implications for communities that depend on the study species as an affordable and daily protein source. The findings emphasized the need for regular biomonitoring, strengthened coastal wastemanagement practices, and safe seafood-consumption advisories. The results also provide valuable baseline data for future coastal pollution assessments and for formulating seafood safety guidelines.

Keywords: Heavy metals, Marine pollution, Seafood safety, Health risk assessment, Carcinogenic.

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Assessment of Water quality, Plankton and Benthic organisms diversity at Largest Port, Kandla, of the Kachchh – Gujarat, India

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ABSTRACT

Kandla town located in the banks of Kandla Creek and one of the major ports of India is located in this part of the country dealing with India's hub for exporting grains commodities and huge quanity of cargo handling. The port activity contrbutes to the entire economic activity of the city. Several studies have been done in order to understand the effects of various pollutants on marine life of this region. The present study is aimed to assess the marine water quality characteristics and also to study the diversity of Planktonic and Benthic organisms of this region for a period of three months covering one year study, including January 2024, May 2024 and July 2024 at three identified locations, including two offshore location and one creek system of Kandla. The study revealed a total of 197 Planktonic species with phytoplankton and zooplankton numbers being 87 and 110 respectively. Highest number of the Plankton were recorded during Winter (145) followed by summer (140) and monsoon (101). In case of benthic organisms are concerned, a total of 11 types of benthic organisms have been recorded, amongst which a total of 7, 9 and 6 major groups were observed in winter, summer and monsoon seasons respectively. The water quality characteristics showed a range of pH (7.41 to 7.98), Turbidity (86 - 330 NTU), Salinity (35.8 - 40.9 mg/L), Dissolved oxygen (5.34 - 7.30 mg/l), Biological Oxygen Demand (1.20– 2.84 mg/L). In case of heavy metal concentrations are concerned, the water quality had maximum occurrence of Nickel, Cadmium, Manganese and Cobalt among various heavy metals studied.

Keywords: Kandla port, Gulf of Kachchh, Plankton, Benthic organisms, Water quality.

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Groundwater to Ocean: Revealing the Role of Submarine Groundwater Discharge in Microplastic Flux

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ABSTRACT

The ocean receives microplastics through multiple pathways such as rivers, wind, and surface runoff, yet several transport mechanisms remain poorly recognized. Subterranean estuaries, the narrow zones where terrestrial groundwater and seawater mix beneath the coastal seabed, represent one such knowledge gap. These systems are driven by submarine groundwater discharge (SGD), an often-invisible process capable of transporting dissolved and particulate material offshore. Its role in microplastic transport, however, has received very limited scientific attention. In this study, we investigated the contribution of SGD to microplastic flux in a subterranean estuary along the Malpe coast on India's southwest margin. Microplastic concentrations were measured in groundwater and seepage zones, and fluxes to the Arabian Sea were estimated. Water samples contained an average of 7.56 ± 6.45 particles L -1 , with groundwater seepage variability emerging as the dominant factor controlling microplastic flux ($r = 0.88$, $p = 0.0008$, $n = 10$). Fibres were the most abundant morphotype, primarily within the 1–5 mm size range, and polyethylene was the prevailing polymer. Flux estimates indicated that SGD transported approximately 18.93 ± 10.25 particles m-2 h -1 into coastal waters. The strong dominance of polyethylene fibres suggests fishing-related activity as the primary source, consistent with the long-standing artisanal fishing practices along the Malpe coast. This work provides the first quantitative evidence of microplastic transport via SGD in an Indian subterranean estuary. The findings highlight SGD as a previously underappreciated pathway that may significantly contribute to coastal microplastic loads. Recognizing and incorporating such hidden vectors will be essential for improving coastal microplastic budgets and developing management strategies that capture the full complexity of plastic movement in coastal environments.

Keywords: Microplastic flux, Pollution pathways, Subterranean estuary, Submarine groundwater discharge, Marine ecosystems

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Environmental Screening Of Pesticide Residues In Mangrove And Sediment Sample

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ABSTRACT

Mangrove ecosystems play a crucial role in coastal protection and nutrient cycling, yet they are increasingly exposed to pollutants released from agricultural and industrial activities. This study investigates the presence and distribution of pesticide residues in mangrove plant and surrounding sediments. Avicennia marina plant and sediment samples were collected from a site in Vashi creek, Mumbai. Liquid chromatography mass spectrometry (LC-MS) coupled with an orbitrap mass analyzer provides a powerful and reliable platform for qualitative screening of pesticides and a range of other chemical contaminents. The findings reveal distinct variations in pesticide contamination within a single sample of A. marina stem and leaf compared to the surrounding sediments. The sediment sample demonstrated to have 42% of substantial retention of several pesticide groups. In total, 26 pesticides across various group was detected including 10 insecticides, 8 fungicides, 6 herbicides, and 2 rodenticides. The samples were contaminated with diverse group of the insecticide such as carbamates was most predomiants. Among them carbamate group of insecticide were dominates than the other groups. The triazole group exhibited the highest occurrence among the various group of fungicides. Additionally, phenyl ureas herbicides were the predominant class detected in mangrove plant and sediment sample. These findings highlights capacity of mangrove ecosystems to act as sinks for persistent pollutants and emphasize the need for stronger monitoring and management strategies to protect coastal biodiversity. Overall, the study provide baseline data for moitoring and risk assessmet studies and guiding future plan for selecting the pesticides groups for conservation plans.

Keywords: LC-MS1 , Pesticides2 , SPE3 , Mangroves4 , Carbamate5 , Triazole6

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Cyclone Dana's Impact on the Microplastic Pollution Load in the Sundarbans

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ABSTRACT

The world's largest mangrove ecosystem, the Sundarbans, is a Ramsar site of India. The widespread distribution of microplastics (MPs) poses an ecological threat to Sundarbans. This study investigates extreme cyclone 'Dana' pre-storm and post-storm impact on the abundance of MP, types, shapes, colors, ecological risk assessment including Pollution Load Index (PLI) and Coefficient of Microplastic Impact (CMPI), and discharge of MP through the river network (Hooghly, Matla, Bidhyadhari, and Datta), and beach (Bakkhali) to the Bay of Bengal (BoB). The study results revealed that during the pre-cyclone period, the average concentrations of MPs in the water samples was recorded high than post-cyclone in Bakkhali (1500 ± 725 patticles/L, and 975 ± 403 particles/L), and the Hooghly river (1414 ± 1001 particles/L, 800 ± 158 particles/L). The PLI values indicated extreme contamination at Bakkhali (4.41) and heavy contamination in the Hooghly river (2.34) in pre-storm and all five locations have moderate PLI in post-storm. The CMPI depicts that the film have maximum impact in Bakkhali (0.58), and Bidhyadhari (0.7) during pre-strom and CMPI for film and filament has maximum impact on the Bidhyadhari river (0.75), and Bakkhali (0.69) during post-storm. These results show a significant fall in MP concentrations after storm in sediment water matrix possibly due to post cyclone high river discharge and fresh sediment depostion. This study highlights the need for dynamic monitoring strategies, legislative control, and community participation to mitigate MP contamination and protect the Sundarbans ecological resilence.

Keywords: Cyclone, Microplastics, Risk assessment, River network, LULC

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Risk assessment of microplastics and their associated heavy metals pollution near a Ramsar site in Assam

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ABSTRACT

Understanding the distribution of various types of plastics and microplastics in an ecosystem is a significant challenge for researchers worldwide, as these particles often appear similar. Microplastics are defined as plastic particles ranging in size from 5 mm to 1 μm. They can serve as a pathway for various pollutants, including heavy metals, dyes, and organic contaminants. They are harmful not only to humans but also to the aquatic ecosystem, causing organ damage and hindering growth and nutrient uptake in plants. In this study, we examined the Boragaon dumping site in Guwahati, Assam, along with a nearby agricultural field for soil sampling. This location was chosen due to the presence of Deepor Beel, a Ramsar site under the International Convention, which is adjacent to the dumping site. The topsoil was collected from five different locations at each site, which underwent density separation to extract microplastics from the soil. In addition to other physicochemical properties of the soil, such as pH, electrical conductivity, available NPK, soil aggregate stability, and heavy metal concentration, these properties were also measured to determine their correlation with microplastics. The results indicate that all the soil samples contain an abundance of microplastics. Ninety percent of the microplastics found in soil samples consist primarily of polypropylene, followed by low-density polyethylene and polyethylene terephthalate, in that order. This significant finding regarding microplastics at the dumping site and agricultural fields indicates a high likelihood of plastic pollution affecting the Ramsar wetland and the surrounding aquatic ecosystem, which serves as a crucial habitat for migrating birds. Therefore, targeted mitigation measures and sustained environmental monitoring are crucial to maintaining the ecological integrity of the Deepor Beel Ramsar site.

Keywords: microplastic; ecosystem; organism; wetland; dumping site

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Designing Efficient Microbial Consortia and Optimizing Process Parameters for Enhanced Biosurfactant-Mediated Crude Oil Bioremediation

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ABSTRACT

Crude oil (CO) spills remain a major threat to aquatic ecosystems, underscoring the need for efficient and environmentally sustainable remediation approaches. Conventional physicochemical and thermal methods, although partially effective, are often constrained by high costs, secondary pollution, and limited performance under variable environmental conditions. In contrast, microbial bioremediation offers a promising, eco-compatible alternative for degrading hydrocarbons in oily wastewater. However, the metabolic limitations of individual strains hinder complete degradation of the complex aliphatic and aromatic fractions of CO. To address this challenge, the present study designed and evaluated fourteen microbial consortia formulated from *Bacillus subtilis* strains (SMP2, VSL-2, IS5, EXSP-1, PPSL-2), *Pseudomonas aeruginosa* (PA), and *Agrobacterium fabrum* (SLAJ). Using 1% (v/v) CO as the sole carbon source, Consortium 11 (SLAJ, PA, IS-5, SMP2) demonstrated superior performance, achieving 79.35 ± 0.35% degradation within 7 days, accompanied by the highest biomass yield. Time-course analyses revealed enhanced growth kinetics, elevated alkane hydroxylase activity, and substantial biosurfactant (BS) production. RSM–CCD optimization further showed that maximum degradation (96.7%) occurred at 2.8 g/L CO, 14.2% (v/v) inoculum, and 0.71 CMC BS. GC–MS confirmed efficient breakdown of both aliphatic (91.52%) and aromatic (67.72%) fractions. The extracted BS exhibited a lipopeptide structure, strong hydrophobic properties, and stability across diverse physical conditions. Notably, the consortium also produced diverse value-added compounds, enhancing the economic sustainability and circularity of the overall bioremediation process. Overall, the study highlights engineered microbial consortia as a robust and scalable strategy for BS-assisted CO bioremediation, offering a sustainable solution for environmental restoration.

Keywords: Biosurfactant, Bioremediation, Consortia, Lipopeptide, Oil spill

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Advanced Oil Spill Detection Using Transfer Learning and Approximate Approaches from satellite images

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ABSTRACT

Advanced detection of marine oil spills is essential for safeguarding ecosystems and facilitating economic activities. Standard techniques that depend on manual or simple image processing often have trouble with the complexity of Synthetic Aperture Radar (SAR) satellite images. This project builds on the recent work of Ghada Atteia et al. (2025) and looks at more advanced ways to find oil spills using two different types of machine learning: transfer learning and approximate learning. A fully automated software pipeline is created for finding oil spills using Sentinel-1 SAR data from the Copernicus Data Space. Transfer learning uses pre-trained convolutional neural networks, like MobileNetV2, that have been fine-tuned on SAR images to find things accurately even when there isn't much labeled data. Approximate learning uses probabilistic and heuristic models that can deal with uncertainty and cut down on the need for a lot of annotations. This makes it possible to find anomalies in SAR data. The project methodically contrasts these methodologies employing evaluation metrics such as accuracy, mean intersection over union (mIoU), precision, recall, and F1-score. The results show that they work well together because they balance detection accuracy, computational efficiency, and scalability for real-world monitoring. The pipeline's modular design makes it easy to reproduce and add to operational environmental systems. This work improves scalable, efficient oil spill detection from complex satellite imagery by combining the high accuracy of transfer learning with the robustness of approximate models. It provides new ideas and tools for keeping an eye on marine pollution by using open-access satellite data to help with sustainable environmental management and quick responses to oil spills.

Keywords: Oil spill detection, Synthetic Aperture Radar, Transfer learning, Approximate learning, Deep learning

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Seasonal variability and hydrodynamic transport modelling of surface-water microplastics along the Puducherry coast, southeastern India.

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ABSTRACT

This research investigated the seasonal variability and hydrodynamic transport of surface-water microplastics (MPs) along the Puducherry coast in southeastern India, combining field data with MIKE-21 two-dimensional particle-tracking simulations. Surface-water sampling performed in January (post-northeast monsoon), June (summer), and September (pre-northeast monsoon) 2022 detected microplastics in all samples, with mean abundances varying from 6.4 × 10^3 ± 2.2 × 10^3 items km^{-2} to 2.8 × 10^4 ± 0.6 × 10^3 items km^{-2}. Seasonal variations were markedly significant ($F = 24.8$; $p < 0.001$), although spatial differences among stations were minimal, suggesting that monsoon-induced hydrodynamics predominantly influence MP distribution. The polymer composition transitioned from fragment-dominated, denser materials in January to buoyant films and fibers in June and September.The particle paths of MIKE-21 reflected these observations: January simulations indicated limited advection and significant nearshore retention, aligning with localized accumulation; June demonstrated the highest lateral dispersion and offshore export (> 40% of particles) due to intensified winds and currents; September revealed mixed behavior characterized by intermittent export and entrapment in nearshore eddies. The modeled transport regimes elucidate the observed retention-export continuum and underscore the interaction between seasonal current reversals and polymer-specific buoyancy. The integrated observational–modelling methodology indicates that tranquil post-monsoon

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intervals promote local accumulation, while vigorous summer conditions facilitate dispersal and cross-shelf export. The seasonally fluctuating dynamics, aligned with regional and worldwide coastal research, highlight the necessity for time-sensitive management solutions that integrate polymer properties with hydrodynamic transport modeling to alleviate microplastic pollution along India's southeast coast.

Keywords: Hydrodynamic transport, MIKE-21, Particle-tracking, Nearshore eddies, Surface-water microplastics

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Occurrence and Spatial Variability of PFAS along the Yamuna River.

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ABSTRACT

Per- and polyfluoroalkyl substances (PFAS) have emerged as persistent environmental contaminants of global concern, yet their distribution in major South Asian river systems remains poorly understood. This study presents preliminary results on the occurrence and spatial variability of PFAS along a major stretch of the Yamuna River, spanning Haryana, Delhi, and Uttar Pradesh. Across all sampled sites, total PFAS (∑PFAS) concentrations ranged from below detection limits (BDL) to 578 ng/L, with an average concentration of 222.18 ng/L. The highest ∑PFAS level was recorded in Haryana (578 ng/L), predominantly comprising PFPeA, PFBS, and PFHpS, likely linked to textile industry effluent discharges. In the Delhi segment, elevated concentrations were observed at IP, KK, and Waz, indicating the inefficiency of wastewater treatment plants in removing recalcitrant PFAS. Downstream stretches in Uttar Pradesh also exhibited high PFAS levels, possibly due to inputs from leather processing, detergent manufacturing, and oil refinery units.
Notably, PFOS and PFOA concentrations exceeded the USEPA maximum contaminant levels by 10^2–10^4-fold, posing significant risks to communities reliant on Yamuna surface waters. The observed spatial variability underscores the influence of diverse point and non-point sources, including industrial clusters, drains transporting WWTP effluents, and urban runoff. These findings provide critical baseline evidence of widespread PFAS contamination in the Yamuna River and highlight the urgent need for comprehensive spatio-temporal assessments, ecological risk evaluations, and public health impact studies to support effective management and mitigation strategies.

Keywords: Per- and polyfluoroalkyl substances (PFAS), Emerging contaminants, Aqueous Systems, River Yamuna, Environmental health

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Biochar-Based Removal of Microplastics from Aquatic Systems: A Critical Review

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ABSTRACT

Microplastics (MPs), defined as plastic particles smaller than 5 mm, have become ubiquitous pollutants in global aquatic systems, posing serious threats to marine organisms, fisheries, and human health. Their persistence, high surface area, and ability to adsorb other pollutants make MPs a significant challenge for conventional water treatment methods, which are often ineffective at removing small-sized MPs. This highlights the urgent need for innovative and sustainable remediation strategies. Biochar, a carbon-rich material produced via biomass pyrolysis, has emerged as a promising solution due to its high porosity, large surface area, adjustable surface chemistry, and low-cost production from biomass waste. Biochar and its composites have demonstrated efficacy in adsorption, filtration, and aggregation-based removal of MPs in aquatic environments. Modifications with metals, polymers, or surface functional groups further enhance removal efficiency under diverse conditions. This review critically examines the application of biochar in MP removal, considering factors such as pH, temperature, and the presence of competing contaminants. It also explores potential applications with other water treatment technologies, including coagulation–flocculation and anaerobic granular sludge systems, and discusses regeneration methods to restore biochar functionality. Attention is given to potential drawbacks, such as the leaching of harmful substances and metals. Despite these challenges, biochar-based strategies offer a sustainable, cost-effective, and adaptable approach to mitigating microplastic pollution in aquatic ecosystems. Further research is needed to optimize biochar properties, understand adsorption mechanisms under realistic environmental conditions, and scale up applications for industrial and coastal water treatment. This review emphasizes biochar's potential as a practical tool for enhancing ocean health, protecting marine biodiversity, and supporting sustainable water management.

Keywords: Biochar, Microplastics, Aquatic Systems, Water Remediation, Sustainable Technology

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Biodegradable polyvinyl alcohol–chitosan cryogels functionalized with tannic acid-modified biochar for sustainable microplastic remediation

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ABSTRACT

Microplastics (MPs) pollution has been increasingly cited as a long-term threat to the aquatic environment. Commonly used removal technologies either produce a by-product or are not environmentally approachable, thus necessitating the design of sustainable sorbent materials. In this study, polyvinyl alcohol–chitosan (PVA–CS) cryogels were fabricated through freeze-drying and subsequently integrated with tannic acid-modified biochar derived from peanut shell waste to enhance surface functionality, porosity, and mechanical stability. The resulting cryogels formed a highly porous, flexible, and hydrophilic three-dimensional structure. Two variants were synthesized to investigate surface-dependent adsorption: a hydrophilic PVA–CS cryogel and a hydrophobically modified stearic acid-coated (10 %) cryogel, enabling comparison of their sorption efficiencies towards the MP particles.

Initial batch adsorption studies were performed at varying concentrations of polystyrene (PS) and low-density polyethylene (LDPE) (50:50 wt. basis) MPs (0.25-500 mg L^{-1}) with a fixed cryogel dosage (1 g L^{-1}), demonstrating that uncoated cryogel and stearic acid-coated cryogel had the highest removal efficiencies of 86.4 ± 2.32 % and 93.1 ± 1.71 %, respectively, which was due to increased hydrophobic-hydrophobic interactions. The Fourier-transform infrared (FTIR) spectroscopy identified the presence of -OH, -COOH and phenolic groups on the uncoated cryogels (wide peaks at 3330-3370 cm^{-1} and 1710 cm^{-1}). In contrast, C-H stretching bands at 2850 cm^{-1} and 2920 cm^{-1} were used to confirm the presence of stearic acid coating on the cryogels. These pre-modification outcomes indicate that the surface modification and biochar addition increase adsorption performance significantly, which will be studied more thoroughly with other important analyses like contact angle, zeta potential, morphological and crystalography analysis, etc. The suggested chitosan-PVA cryogel technology is a biodegradable, waste-valorized, and circular bioeconomy-oriented solution to the reduction of microplastic contamination of aquatic life.

Keywords: Adsorption, Aquaculture, Circular bioeconomy, Cryogels, Microplastics

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Tracing The Source Of Microplastics In Commercially Important Marine Species Along Western Indian Coast Through Polymer Characterisation.

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ABSTRACT

The present study, conducted as part of the Marine Litter Survey and its Impact on Fisheries program, investigates the occurrence, characterization, and polymer composition of microplastics (MPs) in commercially important marine fish species along the west coast of India. Twenty four finfish, shellfish and cephalopod species representing pelagic, demersal and benthic trophic levels were analysed to assess MP in gill, gut and tissue. Isolation of MPs was performed through chemical digestion followed by stereomicroscopic observation and FTIR spectroscopy for polymer identification. FTIR spectra revealed distinct absorption peaks confirming the dominance of Polyethylene Terephthalate (PET), Oxidized Polyolefins (OP), and PolyEthylene (PE) as major polymers, with characteristic bands at 3342, 2918, 1735, 1244–1100, and 720 cm^{-1}. Samples such as *Lates calcarifer* (sea bass), *Cynoglossus arel* (sole fish), and *Lactarius lactarius* (false trevally) showed PET and OP dominace, while *Mugil cephalus* (flathead grey mullet) and *Feneropenaeus indicus* (Indian white prawn) exhibited traces of polyethylene and polypropylene. Probable sources included fishing gear, synthetic textiles, PET bottles, and packaging debris. Among all, demersal and estuarine species showed higher MP abundance, suggesting benthic deposition and trophic transfer as key pathways. The study confirms the ubiquity of MPs in fish organs including gills, gut, tissues posing potential ecological and food safety risks. These findings provide a baseline for continuous monitoring of polymeric pollution in marine biota and emphasize the need for stringent management of fishing and plastic waste along the Indian coastline.

Keywords: FTIR spectroscopy, Polymer pollution, Fishing gear debris, Trophic transfer.

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Assessment Of Metal Toxicity Through Bioavailability And Bioaccumulation In Two Trophical Estuaries, Maharashtra, West Coast Of India

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ABSTRACT

The present work investigates the chemical partitioning of Fe, Mn, Zn, Cu, Co and Ni in two short sediment cores (20 cm) collected from tropical estuaries namely, Savitri and Vashishti, Maharashtra, India. Also, the concentration of metals in the widely consumed edible bivalve *S. cucullata* was determined to decipher the implications of metal toxicity. The bioavailable concentrations of Mn, Zn, Cu, Co and Ni in sediment were present in significant (> 15 %) proportion in both estuaries. Hence, it suggested anthropogenic sources of metals possibly from industrial effluents released from the Lote Parshuram Industrial Estate present in the catchment area of the Vashishti Estuary, while the Savitri Estuary receives input of metal waste mainly from the Common Effluent Treatment Plant (CETP) at Mahad. Among the bioavailable fractions, the metals were predominantly associated with carbonate, Fe-Mn oxide/hydroxide and organic matter/sulphide fractions suggesting their adsorption onto carbonates, scavenging of metals by Fe-Mn oxides/hydroxides and complexation with the organic matter. Additionally, Mn in carbonate and Fe-Mn oxide/hydroxide fractions showed an overall increase towards the surface of both sediment cores. Thus, indicated its potential mobilisation into the overlying water column with alterations in pH and redox potential. The Risk Assessment Code (RAC) indicated a medium risk of Mn (Vs3) and Ni to estuarine fauna, whereas the Screening Quick Reference Table (SQUIRT) revealed potential toxicity of Mn and Co (Vs3). *S. cucullata* showed a strong affinity towards Fe, Zn and Cu which was attributed to their crucial role in oxygen transport, metalloenzyme function, shell formation and antioxidant defence as well as the presence of proteins viz., metallothioneins, ferritin and transferrin that mediate metal binding, sequestration and storage within tissues. Also, the concentration of Fe, Mn, Zn and Cu in the bivalves surpassed the standard permissible limits and thus, suggested their toxicity.

Keywords: Tropical Estuaries, Metal Bioavailability, Bioaccumulation, Edible bivalves, Toxicity

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Microplastic Accumulation and its Energetic Costs in Seafood from Goan Coastal Habitats: Linking Tissue Load with Condition Indices and Biochemical Reserves.

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ABSTRACT

Microplastics (MPs) are prevalent coastal pollutants and present a mounting threat to marine food webs and humans. Regional studies on the west coast of India have reported MPs in water, sediments and seafood thereby emerging Goa as a hotspot. Bivalves and fish are high-value filter feeders and effective sentinels for microplastic exposure, yet few studies from Indian coasts simultaneously evaluate accumulation and the sublethal energetic consequences for these organisms.

This study quantifies microplastic accumulation in bivalves and fish from contrasting Goan coastal habitats and examines whether microplastic burden correlates with organismal health metrics: gravimetric condition index (for bivalves), Fulton's Condition Factor and Hepatosomatic Index (for fish) and biochemical energy reserves (glycogen, total lipid, total protein). Sampling follows a spatially stratified collection at various locations in Goa. MPs will be isolated using established digestion and density-separation protocols and characterized by morphology and polymer type. Condition indices will be calculated from morphometric data, while biochemical assays will follow standard colorimetric spectrophotometric methods.

Literature review suggests that MPs are detectable in Goan seafood matrices, consistent with reports from elsewhere in the region and that their presence has been associated with altered metabolism and downregulated biochemical reserves (glycogen, lipid, protein) indicating possible energetic costs even when overt mortality or gross condition changes are not manifested.

Connecting microplastic burden with condition indices and biochemical reserves, this study seeks to assess energy trade-offs as related to microplastic exposure in Goan seafood species and serve as a foundation for ecological risk assessment and seafood safety concerns in the region. The results will help determine the local monitoring priorities and management strategies for the coastal pollution.

Keywords: Microplastic, Seafood, Condition index, Monitoring, Pollutant

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Quantifying Submarine Groundwater Discharge and Associated Nutrient Fluxes in the Karst Coastal Aquifer in Southern Tamil Nadu

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ABSTRACT

Submarine Groundwater Discharge (SGD) has become widely recognized as a critical environmental concern, significantly affecting coastal biogeochemistry while remaining one of the least unrecognized processes of the hydrological cycle. SGD not only represents a hidden pathway through which significant volumes of valuable freshwater enter the sea, but it also serves as a major conduit for transporting nutrients and contaminants from land to the coastal environment.The Ayankulam area of the Thisayanvilai region in Tirunelveli District provides a distinctive geomorphological setting, highlighted by the well-known “Miracle Well,” which retains large quantities of water even during periods of limited rainfall or even dry months. This anomalous hydrological behaviour is attributed to an underlying karstic aquifer system characterized by high porosity, dissolution features, and well-connected subsurface channels.

The primary objective of this study is to quantify SGD and its associated nutrient fluxes. Radon-222 (^{222}Rn), a naturally occurring geochemical tracer, was employed within a radon mass-balance framework to estimate SGD fluxes. The findings indicate peak discharge rates and also show a clear seasonal contrast.Nutrient fluxes associated with SGD showed substantial seasonal variations in the delivery of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) through submarine groundwater discharge, which alters the coastal ecosystem dynamics. The study’s major outcomes confirm the magnitude of freshwater and nutrient fluxes contributed by SGD along the Uvari coast. Additionally, the results underline that seasonal differences between the post- and pre-monsoon periods significantly influence the formation and intensity of SGD zones within the study region.

Keywords: SGD, Radon, Nutrient, MiracleWell,Ayankulam, Tirunelveli

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Oxygen Crisis In Urbanized Estuaries: Shifting Nutrient And Organic Matter Pathways

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ABSTRACT

Deoxygenation is intensifying across urban estuarine ecosystems due to nutrient enrichment, organic matter (OM) loading, hydrological alterations, and climate change. Urbanized estuaries, with restricted water exchange and high anthropogenic inputs, are hotspots of oxygen depletion, posing significant challenges for estuarine sustainability and coastal management. The shallow, slow-breathing waters of the Ulhas-Thane Estuary-Creek System (UTECS) along northwest India exhibit year-round oxygen variability, driven by stratification, hypoxic sewage advection, and chronic nutrient enrichment. These processes reveal strong ICEP–HE linkages, highlighting eutrophication risks in the Arabian Sea. Low oxygen disrupts nitrification–denitrification, promotes ammonium accumulation, and favors anaerobic decomposition, while high suspended solids modify phosphorus settling and dissolved organic phosphorus transformations during lowflow periods. Phosphorus exchange further increases nitrogen surplus, suppresses desorption, and elevates ammonium in DIN, restricting its utilization during high-flow conditions. Among phosphorus forms, Organic-P downwells substantially into sediments, whereas labile and bioavailable forms accumulate in hypoxic shallow waters under weak residual hydrodynamics. OM exhibits wide stable isotope ranges ($\delta^{13}C$: −32‰ to −22‰; $\delta^{15}N$: ~5–23‰), reflecting source variability, seasonal hydrology, and anthropogenic inputs. High suspended solids enhance sediment trapping and reduce flushing, promoting localized accumulation, prolonged particle residence, and particulate OM remineralization. Biomarker and isotopic analyses indicate terrestrial OM dominance in riverine regions, shifting to marine and anthropogenic sources in accumulated sediments with substantial detritus input. High organic carbon stock in deeper sediments, reflecting ongoing hydrodynamic and human influences. These findings emphasize urbanization's role in amplifying biogeochemical feedbacks that sustain oxygen loss and selfreinforcing eutrophication cycles, underscoring the need for informed management of urban estuarine systems.

Keywords: Biogeochemistry, Pollution, Carbon, Eutrophication, Urbanization, Hypoxia

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Polycyclic Aromatic Hydrocarbons In Coral Reef Waters : An Assessment From The Lakshadweep Archipelago.

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ABSTRACT

Coral reef ecosystems, also known as the rainforests of the ocean, are among the most biologically diverse and productive habitats on Earth, making significant contributions to the conservation of marine biodiversity and maintaining balance in coastal environments. Nowadays, these reef ecosystems are increasingly threatened by anthropogenic pollutants, including polycyclic aromatic hydrocarbons (PAHs). The Lakshadweep Archipelago, located in the Arabian Sea, represents one such fragile reef ecosystem vulnerable to contamination. The current investigation points out the distribution, sources, and ecological risk of sixteen priority PAHs in the water column of four coral lagoons, namely Kiltan, Kalpeni, Kadmat, and Minicoy, during April 2025. PAH concentrations in the dissolved and particulate phase ranged from 20.88 to 240.14 ng L^{-1} and 145.74 to 355.95 ng L^{-1}, respectively, indicating relatively low contamination compared with other coral reef systems worldwide. Source apportionment studies revealed mixed petrogenic and pyrogenic sources, reflecting the influence of both petroleum-related discharges and combustion emissions associated with maritime activities. A human health risk assessment revealed no immediate non-carcinogenic risk for adults and children. Incremental Lifetime Cancer Risk (ILCR) values were within the potential low-risk limits, suggesting minimal carcinogenic risk associated with PAH exposure in the study area.

Keywords: Polycyclic aromatic hydrocarbons, Coral reef ecosystems, Lakshadweep Archipelago, Source apportionment, Human health risk assessment

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Hydrological And Nutrient Controls On Greenhouse Gas Fluxes In The Kavvai Estuary, A Pristine Wetland In The Southwest India

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ABSTRACT

Methane (CH_4) and nitrous oxide (N_2O) are critical greenhouse gases whose dynamics in tropical wetlands are strongly influenced by seasonal variations and environmental gradients. This study examines seasonal variability of CH_4 and N_2O concentrations and fluxes in the Kavvai estuary across the monsoon, post-monsoon, and pre-monsoon periods. Mean concentrations and fluxes of both gases peaked during the monsoon (CH_4: 27.47 nM; N_2O: 38.88 nM; CH_4 flux: 18.50 µmol m^{-2} d^{-1}; N_2O flux: 22.38 µmol m^{-2} d^{-1}), followed by substantial declines in the postmonsoon and pre-monsoon seasons. Pre-monsoon conditions, marked by elevated salinity and temperature, were associated with the lowest gas concentrations and even negative fluxes. Both CH_4 and N_2O exhibited extremely strong positive correlation (r = 0.991), indicating coupled biogeochemical processes. Both gases exhibited significant negative correlations with temperature and salinity, consistent with the suppression of microbial production under saline pre-monsoon conditions. Among nutrients, nitrate showed the strongest positive relationship with CH_4 (r = 0.735) and N_2O (r = 0.737), complemented by moderate positive correlations with nitrite and ammonia. Overall, the results highlight the sensitivity of greenhouse gas dynamics in the Kavvai wetland to seasonal hydrological fluctuations and nutrient inputs, emphasizing the estuary's vulnerability to climate-driven alterations in monsoon patterns.

Keywords: Coastal Wetlands; Greenhouse gases; Methane (CH_4); Nitrous oxide (N_2O); Biogeochemistry.

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Gafrarium divaricatum (Gmelin, 1971) as a model organism for in situ biomonitoring of heavy metal pollution in the coastal environment

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ABSTRACT

Heavy metal pollution has a serious impact on marine ecosystems and biodiversity due to its toxicity, long-term persistence, and ability to accumulate in the tissues of aquatic organisms. This study examined the effects of heavy metals in the forked venus clam, Gafrarium divaricatum, collected from three coastal sites in Maharashtra: Alava–Ratnagiri (S1), Bandra Bandstand (S2), and Aksa (S3). Eleven heavy metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, As, Pb, and Hg) were measured in the gill, digestive gland, mantle, and foot. Genotoxicity in gill tissues was assessed using the comet assay, and oxidative stress was evaluated through SOD, CAT, and GST activities in gill, digestive gland, mantle, and foot. The results showed a clear spatial trend in bioaccumulation, with the highest metal loads at Bandra, followed by Aksa and Ratnagiri. The gill and digestive gland accumulated the most metals, while the mantle and foot showed lower concentrations. Clams from the more polluted sites exhibited significantly higher DNA damage and oxidative stress, with the highest responses in the digestive gland and gills. These findings identify Bandra Bandstand as the most contaminated site, and highlight the digestive gland and gill as reliable indicators of oxidative stress and DNA damage. Overall, the results demonstrate that heavy metals can induce cellular and physiological responses in G. divaricatum. The integrated biomarker approach supports the use of this species as an effective bioindicator for coastal pollution monitoring.

Keywords: Heavy metal, Bioaccumulation, Oxidative stress, Genotoxicity, Bioindicator.

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Does the Phytoplankton Bloom Intensify the Oxygen Minimum Zone (OMZ) in the Bay of Bengal?

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ABSTRACT

The Oxygen Minimum Zone (OMZ) in the Bay of Bengal (BoB) is a significant biogeochemical feature characterised by low dissolved oxygen (DO) levels, which impact local marine ecosystems and the nitrogen cycle. This study examines the mechanism by which periodic phytoplankton blooms intensify the deepening of the oxygen minimum zone in the Bay of Bengal, particularly in coastal and mesoscale-affected regions. The primary mechanism is enhanced biological oxygen consumption at depth and phytoplankton blooms, often triggered by episodic nutrient influx from river discharge (e.g., the Ganges-Brahmaputra) or mesoscale physical phenomena such as cyclonic eddies, which result in heightened primary production within the surface euphotic zone. This productivity leads to the subsequent creation and export of significant quantities of particulate organic matter (POM) to the subsurface layers. As this organic matter sinks into the pycnocline and the oxygen minimum zone, microbial breakdown (remineralization) swiftly depletes the already scarce dissolved oxygen. This process is highly effective in the BoB due to the strong, freshwater-driven stratification, which works as a barrier, blocking the vertical flow of oxygen from the surface to the OMZ layer. The combination of increased oxygen demand from organic matter decay and restricted ventilation from stratification) leads to a transient but significant intensification of the OMZ, with DO concentrations occasionally dropping to near-anoxic levels, particularly in the northwestern coastal regions during peak discharge periods. This study addresses the pressing issues of coastal water, which was investigated under the Prediction of Coastal Water Quality Program by the Ministry of Earth Sciences, Government of India. This study observed numerous algal blooms and hypoxic conditions in the shelf waters of the Bay of Bengal. Understanding the variability and severity of these bloom-induced hypoxic events is crucial for predicting the probability of the Bay of Bengal's oxygen minimum zone evolving into a functionally anoxic state and the subsequent impacts on nitrogen loss processes (denitrification/anammox) and local fisheries.

Keywords: Water quality, algal blooms, OMZ, Bay of Bengal

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Bioaccumulation Pattern Of Toxic Metals In True Mangrove Flora: Prospects Phytoremediation In Mangrove Conservation

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ABSTRACT

The study presents the investigation of trace metal accumulation in the leaves of the major true mangrove plant species from Kochi southwest coast of India. Metal concentrations were analysed in leaves of *Rhizophora mucronata, Kandelia candel, Bruguiera gymnorrhiza, Bruguiera cylindrica, Avicennia officinalis, Avicennia marina and Aegiceras corniculatum.* Trace metals, Co, Fe, Mn, Cu, Zn, Al which are essential for plants but toxic in excess levels; heavy metal, Cd, Pb, Cr, Ni and V which are not essential to plants but toxic at high levels were the focus of the study. A level of metal accumulation was found be highest in Acanthaceae mangroves which include *Avicennia officinalis* (2.09±0.09 for Mn) and *Avicennia marina* (2.1±0.10 for Al). The trace metal found in highest concentration in the leaves was manganese. Pb showed the highest bioaccumulation factor of 0.60± 0.002 whereas Cr, Ni and V were below the detection limit. The concentration of Cd in the leaf samples varied from 0.0056 ± 0.001 μg g^{-1} (*A. marina*) to 0.2296 ± 0.002 μg g^{-1}(*K.candel*). The metal accumulation pattern and the hierarchy metal accumulation the was found to vary with the taxonomical differences between the mangrove flora. Principal component analysis confirmed the taxonomical variation in metal enrichment in the mangrove leaves. The Na/K levels in the leaves of the plants identified were also determined to understand the correlation of salt excluding nature and bioaccumulation. The salt exclusion capacity of the mangroves is found to have significant influence on the bioaccumulation of metals in mangroves. The mangroves of genus *Brugiera* exhibited lowest heavy metal concentration and bioaccumulation. The study reveals the selective metal accumulation in specific plant species and highlights the potential of these plants infringing the marine coastal lines as a bioindicator of heavy metal pollution as well as its use in phytoremediation which can lead to the conservation of this dwindling highly productive ecosystems.

Keywords: Heavy metal, Mangroves, Bioaccumulation, Salt exclusion, phytoremediat

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Assesment Of Nutrient Fluxes Via Land-Sea Interactions To The Southeast Estuary, Tamil Nadu, India

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ABSTRACT

Land-Sea interaction is a critical, yet often overlooked, pathway for nutrients from land to sea. This process can deliver dissolved inorganic nitrogen (DIN), soluble reactive phosphorus (SRP), and dissolved silica (DSi) to coastal waters at concentrations significantly exceeding those in surface runoff. These nutrients are essential for primary production but can cause eutrophication when introduced in excess. This research quantifies the nutrient fluxes from land-sea interaction into the southeast estuary in southeast India, a system influenced by both fresh terrestrial groundwater and recirculated seawater. Multiple tracers (224Ra, 226Ra, 222Rn) were employed for assessing land-sea interaction fluxes, and loads of nutrients have been determined by integrating nutrient concentrations into a mass-balance framework. land-sea interaction ranged from 0.04–0.12 m3 m-2 d-1 in the estuarine environment and 0.03–0.15 m3 m-2 d-1 at groundwater discharge sites. Resulting nutrient fluxes were substantial, with DIN inputs of 6.3–29 mmol m-2 d-1 and SRP inputs of 0.05–1.2 mmol m-2 d-1 in the estuary and 3.3–24 mmol m-2 d-1 (DIN) and 0.08–1.1 mmol m-2 d-1 (SRP) from groundwater sources. DSi inputs remained elevated across all land-sea interaction sites, reflecting strong groundwater–sediment interactions. These nutrients from land-sea interaction promote primary output, but if loading surpasses ecosystem absorption capability, they can also worsen eutrophication, change species composition, and raise the danger of hypoxia. In addition, land-sea interaction sustains baseline productivity and supports fisheries by providing vital nutrients during times of low flow. This work emphasises the important but little-known role that land-sea interaction plays in coastal nitrogen budgets and its consequences for the management of estuary health in the southeast.

Keywords: Groundwater, Nutrient fluxes, Eutrophication, Radium tracers, Biogeochemistry, Southeast estuary

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Quantifying Contaminants In The Sediments Of Cochin Estuary Post-Brahmapuram Waste Fire Disaster

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ABSTRACT

Following the major Brahmapuram waste-plant fire and effluent discharge disaster in March 2023, toxic smoke and leachates were released into nearby water bodies. This study assesses its impact on the environmental quality of the Cochin estuary, from Thevara to Brahmapuram. Sediment samples were analysed for trace metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn), fatty acids, and multiple classes of pesticides. Post-disaster results showed increased concentrations of several heavy metals in stations near to the Brahmapuram, with cadmium ranging from 0.6– 26.7 ppm, chromium 11.8–219.0 ppm, nickel 4.1–89.9 ppm, copper 2.4–71.4 ppm, and zinc up to 511.5 ppm. Geochemical indices such as Enrichment Factor (EF), Contamination Factor (CF), Geoaccumulation Index (Igeo), and Pollution Load Index (PLI) indicated moderate to severe contamination, with PLI values exceeding the safe threshold in stations closer to Brahmapuram. Pesticide residues like organochlorines (o,p-DDE), organophosphates (Phosphamidon), pyrethroids (Bifenthrin), and carbamates (Carbaryl) were widely detected which may be due to their persistence in the environment or unauthorized use. These findings reveal that the 2023 Brahmapuram disaster intensified pollutant release to sediments in the estuarine environment, which may cause long-term threats to water quality and biodiversity. This research highlights the critical necessity for environmental monitoring, waste management, and restoration efforts to mitigate future ecological damage in the Cochin estuary.

Keywords: Cochin Estuary, Brahmapuram Fire Disaster, Sediment Contamination, Trace Metals and Pesticides, Environmental Risk Assessment

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Assessing the Vulnerability of Tropical Brittlestars to Heavy Metal Pollution: Insights from Oxygen Uptake, Regeneration, and Survival

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ABSTRACT

Heavy metal pollution is increasingly affecting coastal ecosystems, altering the physiological functions and regenerative capacities of benthic invertebrates. The present study aims to investigate the effects of copper (Cu) and lead (Pb) individually and in combination- on the oxygen uptake, regeneration, and survival of burrowing brittle stars such as Ophiactis savignyi. Samples were collected from Sri Vijaya Puram, Andaman and Nicobar Islands and also environmental parameters were recorded to establish baseline conditions with the help of Aqua Troll600 probe. These species have been selected as model organisms due to their distinct oxygen acquisition strategies and burrowing behaviors, which make them suitable for assessing species-specific vulnerability to metal pollution. Live specimens are being maintained under controlled laboratory conditions and exposed to varying concentrations of the selected metals. Oxygen consumption is monitored weekly by Winkler method, while calcification, dry weight, and arm and disc regeneration are being evaluated as indicators of physiological and structural responses. The study aims to identify species that are more susceptible to heavy metal stress and to understand the interactive effects of metals on metabolism and regenerative capacity. The findings are expected to provide valuable insights into the physiological limits of burrowing brittle stars and contribute to understanding the ecological risks associated with metal contamination in the coastal waters of the Andaman and Nicobar Islands.

Keywords: Metabolism, Regeneration, Heavy metals, Brittle stars, and Coastal pollution

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Dynamics of Coastal Ocean Acidification: A Review of Global and Regional Factors

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ABSTRACT

Ocean chemistry plays a fundamental role in maintaining the stability of marine ecosystems. Ocean acidification is the long-term decline in ocean pH primarily driven by rising atmospheric CO_2 . Inorganic carbon reaches the ocean environment through air–sea gas exchange, the carbonate equilibrium, and both biological and physical carbon pumps. Since the Industrial Revolution, the average global ocean pH has declined by ~ 0.10–0.11 units, showing a measurable shift in ocean chemistry. Although total alkalinity provides buffering capacity against pH fluctuations, increased acidification reduces this capacity. In both coastal and open-ocean systems, total alkalinity and dissolved inorganic carbon exhibit broadly similar spatial patterns. Coastal waters are more dynamic than the open ocean, acting as a transition zone influenced by terrestrial inputs, river discharge, and variable circulation. Consequently, coastal acidification results not only from atmospheric CO_2 dissolution but also from region-specific drivers such as eutrophication, watershed-derived organic matter, intensified upwelling of CO_2-rich deep waters, and diverse anthropogenic pressures. Ocean acidification has ecological consequences like and weakened calcification of calcium carbonate structures in shell bearing organisms. It also alters nutrient cycling, biological productivity, and overall ecosystem functioning. International initiatives such as the Monaco Ocean Acidification Conferences, the UN Ocean Conferences, and the UNFCCC COP platforms stress on the global commitment to mitigate acidification primarily through CO_2 emission reductions. Coastal regions exhibit particularly complex trends, with upwelling zones representing global hotspots of low pH . Studies show that reduced pH values have been reported from the California Current (pH ~7.43), the Tanga–Pemba seascape of East Africa (pH ~7.43), and the Benguela Upwelling System (pH ~7.7). Similar low-pH conditions occur in the Bay of Bengal and Arabian Sea. This review synthesises key global and regional drivers shaping acidification patterns in coastal waters.

Keywords: pH, Alkalinity, DIC, Calcification, Reduction.

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A Baseline Study On The Polybrominated Diphenyl Ethers In The Cochin Estuary, India

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ABSTRACT

Polybrominated diphenyl ethers (PBDEs) are a class of synthetic organobromine chemicals widely utilised as flame retardants to reduce fire hazards in a wide range of consumer and industrial goods. Textiles, upholstery, car interiors, building insulation materials, polymers, and, most notably, electronic equipment such as televisions, computers, and circuit boards. Their widespread use over the past few decades has led to their ubiquitous presence in nature. PBDEs are chemically stable, hydrophobic, and resistant to degradation, allowing them to persist in soil, water, and sediment for extended periods. Due to their lipophilic nature, they tend to bioaccumulate and biomagnify in aquatic and terrestrial food webs, posing ecological and human health risks. In India, comprehensive studies on PBDEs, especially in aquatic environments, remain limited. A significant knowledge gap exists regarding the seasonal variability, contamination profiles, and potential ecological implications of tropical estuarine systems. The present study, therefore, focuses on determining the occurrence, distribution, and seasonal dynamics of selected PBDE congeners in surface sediments of the Cochin estuary—one of the largest estuarine systems along the southwest coast of India. Surface sediment samples were collected from fifteen stations covering different salinity zones during three seasons: pre-monsoon (April 2023), monsoon (September 2023), and post-monsoon (December 2023). Seven priority PBDE congeners were analysed to understand spatial and temporal variations. The total PBDE concentrations along the study area exhibited high concentrations during the post-monsoon season (1.661 to 2.584 ng/g), followed by the pre-monsoon season (1.237 to 2.122 ng/g) and the monsoon season (0.142 to 0.289 ng/g). The hazard quotient (HQ) and risk quotient (RQ) data indicate that the PBDE accumulation in the water sediments of the Cochin estuary is at a low-risk level. The correlation data showed a significant positive relationship between the individual PBDE congeners, indicating a common source of origin. This may include leaching from disposal sites, volatilisation from consumer products, emissions into the atmosphere during manufacture, and land-based anthropogenic inputs such as wastewater discharges from residential and industrial complexes.

Keywords: Polybrominated diphenyl ethers, Contamination status, Ecological risk, Cochin es

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Assessment Of Potentially Toxic Metals Along Different Ecosystem Components Of The Cochin Estuarine-Coastal System During Southwest Monsoon.

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ABSTRACT

This study examines the distribution and ecological controls of potentially toxic metals (PTMs) across ecosystem components in the Cochin estuarine-coastal continuum during the Southwest Monsoon (August 2024). Surface and bottom waters, and sediment were collected from 4 estuarine and 10 coastal stations during first and fourth weeks, while biota (*Villoritta cyprinoides*) samples were collected during the fourth week from estuarine locations. In the water column, the coastal system showed surface-dominated temporal variability, particularly with cadmium (Cd), which increased during the fourth week (up to 23.43 µg/L). Metals such as Zn (71.11-142.57 µg/L) and Mn (2.26-3.44 µg/L) also displayed surface enrichment. Conversely, the estuary exhibited bottom water driven sediment-water interactions, with Fe averaging 152.11 µg/L ± 129.42 . A localized estuarine Cd surface concentration (10.60 µg/L at E2) reflected land-based inputs. Bottom water correlations between the metals like (Cu-Ni r = 0.78, Co-Fe r = 0.73) indicate redox-mediated mobilization, whereas Cd showed weak or negative correlations (Cd-Fe r = -0.30), indicating that Cd behaviour is independent of sediment diagenesis. Sediments contained the highest overall PTMs loads, with estuarine concentrtaions of Zn ,Fe, Mn, Ni, and Cr consistent with strong associations among Fe-Pb-Zn-Cr (r = 0.68-0.91). Biota exhibited substantial accumulation, including Fe (2.28–2.63×10^6 mg/kg), Cd (2.58–4.71×10^6 mg/kg), and Zn (8.66×10^4–1.03×10^5 mg/kg). Strong correlation among metals in biota samples such as Co-Mn (r = 0.9997), Mn-Zn (r = 0.9731) highlight co-accumulation. Overall, coastal waters behaved as a surface-controlled, dispersive system, whereas the estuary functioned as a bottom-controlled, PTMs-accumulating zone, shaped by flocculation, redox reactions, sediment resuspension, and biological uptake.

Keywords: Surface enrichment, flocculation, redox reactions, Diageneis, Dispersive system

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Spatio-Temporal Assessment Of Marine Litter Along The Maharashtra Coast Using Ospar Shoreline Survey Protocols

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ABSTRACT

Marine litter has become a critical environmental issue along the Maharashtra coast due to rapid urbanisation, intensive fishing, and inadequate waste management. This study quantified and characterised marine litter across ten representative beaches from April 2024 to March 2025 using standard OSPAR and UNEP/IOC shoreline protocols. Plastics dominated the total debris (85.9 ± 3.6%), followed by glass (3.8 ± 0.9%), foam (3.4 ± 0.8%), paper (3.5 ± 0.9%), rubber (3.2 ± 0.8%), textiles (3.7 ± 0.9%), metal (2.6 ± 0.7%), wood (2.8 ± 0.6%), and ceramics/others (0.8 ± 0.3%). Principal Component Analysis (PCA) identified two dominant litter source categories and grouped beaches into three types: urban-tourism dominated (Versova, Juhu, Alibaug) with high consumer plastic input; fishing-influenced (Mandavi, Dahanu, Devbag) dominated by abandoned, lost or otherwise discarded fishing gear (ALDFG); and low-impact (Tarkarli, Aare Ware, Gorai, Girgaon) with mixed inputs and minimal litter. Seasonal variation showed maximum litter deposition during the southwest monsoon due to hydrodynamic transport. Fishing gear such as nets and ropes comprised a major share of plastic debris, indicating significant ALDFG inputs. Clean Coast Index (CCI) classified Versova and Dahanu as “Extremely Dirty,” while the Plastic Abundance Index (PAI) averaged 4.41 items/m², confirming plastic dominance. The presence of nurdles (1.5%) indicated primary microplastic pollution. The findings emphasise the need for integrated coastal management through improved waste interception, systematic gear retrieval, and continuous monitoring to mitigate marine litter and enhance shoreline sustainability.

Keywords: CCI,PAI ,ALDFG, Shoreline survey, Plastic pollution

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Spatial Distribution and Functional Dynamics of Marine and Pathogenic Bacterial Communities Along the Visakhapatnam Coast, Bay of Bengal, India: 16S rRNA gene amplicon sequencing approach

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ABSTRACT

The Visakhapatnam coastal ecosystem experiences multi-source contamination from port operations, industrial effluents, and anthropogenic inputs, creating selective pressures that reshape bacterial community structure across spatially heterogeneous contamination gradients. This study characterized functional bacterial communities across 11 coastal stations from the fishing harbour to Bheemunipatnam using high-throughput 16S rRNA gene amplicon sequencing, focusing on ecosystem health, pathogenicity, and bioremediation potential using validated databases and functional prediction analyses. Findings revealed 6,850 bacterial species classified into six functional categories. Natural marine bacteria dominated the ecosystem (448,405 reads, representing 92.8% of the species diversity), with the *Qipengyuania citrea* being the most abundant. These bacteria maintain ocean balance and support healthy ecosystems by processing organic matter and cycling nutrients. Opportunistic pathogenic bacteria emerged as the second most abundant group (367,794 reads, 1.9% of the species diversity), dominated by the *Psychrobacter immobilis*. Despite representing a small species diversity, these bacteria exhibited concerning abundance levels at specific coastal locations, posing potential health risks to beach visitors and communities engaging in recreational activities. Environmental Cleanup bacteria constituted the third major group (163,634 reads, representing 4.0% species diversity), led by *Planococcus kocurii*, demonstrating significant natural recovery potential. Additionally, Nutrient-cycling Bacteria (11,740 reads, 22 species), Pollution Indicator Bacteria (10,294 reads, 64 species), and Unclassified Bacteria (9,895 reads, 1 species) were identified, with varying ecological significance. While disease-causing bacteria represent less than 2% of total species, their high abundance at certain stations poses significant public health concerns. This study emphasizes coastal marine health, and targeted surveillance at high-abundance pathogenic zones provides baseline data for developing coastal health monitoring protocols, ensuring safe recreational water use.

Keywords:16S rRNA gene amplicon sequencing, functional ecology, antibiotic resistance, bioremediation, Pathogenic bacteria, public health

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Session Convener: Dr. Veda Vinay Manerikar

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Occurrence, Abundance, And Polymer-Specific Risk Of Microplastics In Textile Industrial Clusters And Their Implications For Marine Pollution

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ABSTRACT

Microplastics (MP) discharged from textile industries represent a significant yet under-documented source of pollution in developing industrial regions, with direct implications for riverine, estuarine, and marine environments. This study presents the first multi-cluster assessment of microplastic levels in influent and effluent from textile industries across major manufacturing hubs in India, highlighting their role in supplying ocean-bound MP. MPs were quantified and characterised using wet peroxide oxidation, stereomicroscopy, and micro-Fourier transform infrared imaging. Influent samples showed very high MP abundance (24,500 ± 12,500 particles per litre), which decreased to 10,900 ± 4,000 particles per litre after treatment, indicating substantial but incomplete removal and continuous discharge into receiving waters that ultimately flow toward coastal systems.Effluent samples showed a shift toward smaller particle sizes (25–50 micrometres), reflecting fragmentation and limited retention of fine particles capable of long-distance transport and marine accumulation. The polymer profile was dominated by polyethylene terephthalate, polyamide, polypropylene, and polyethylene, while the presence of high-hazard polymers such as polymethyl methacrylate and acrylonitrile–butadiene–styrene, although less abundant, considerably elevated ecological risk. Polymer Hazard Index values ranged from 19.35 to 1133.38, placing several industries in high-risk and danger categories. Correlation and redundancy analyses revealed strong relationships between MP characteristics and effluent chemistry, indicating combined chemical and mechanical pathways of microfiber generation. The findings establish textile industries as persistent point sources of MPs which enter freshwater networks and contribute to downstream marine pollution. The study underscores the need for polymer-targeted mitigation, improved tertiary treatment, and strengthened regulatory oversight to reduce the flow of ocean-bound microplastics and safeguard marine ecosystems.

Keywords: Microplastics**,**Textile Effluent**,** Polymer Hazards**, Polymer** Characterization, Marine Pollution

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A Microfluidics-Driven Strategy For Detection And Sorting Of Microplastics In Ocean-Relevant Conditions

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ABSTRACT

The escalating proliferation of microplastics in the world's oceans poses a critical threat to marine ecosystems and human health. Their ubiquitous presence has resulted in trophic transfer and bioaccumulation across diverse marine organisms ultimately entering the human food chain. Studies indicate that microplastics can disrupt physiological functions, induce metabolic disorders and reduce survival rates in marine life while in humans they have been associated with developmental impairments and metabolic dysfunctions. These emerging concerns underline the urgent need for advanced technologies capable of detecting and removing microplastics from environmental waters. Microfluidics has recently emerged as a promising Lab-on-a-Chip approach for rapid, cost-effective microplastics sorting and analysis. In this study, a novel microfluidic device designed for the detection and size-based sorting of common seawater microplastics namely polyethylene (PE), polypropylene (PP) and Nylon-6 (N6) is proposed and computationally evaluated. The performance of the device was investigated using COMSOL Multiphysics simulations based on hydrodynamic focusing for single-stream alignment, particle size-dependent inertial lift forces and density-driven lateral migration under varying operating conditions including volumetric flow rates and particle concentrations. Simulation results demonstrate effective particle separation into designated outlets indicating a strong correlation between device geometry, flow conditions and separation efficiency. The findings establish the presented device as a viable platform for microplastic sensing and sorting in seawater. With further optimization and integration of downstream analytics, this design holds significant potential for field-deployable environmental monitoring and microplastic detection-applications.

Keywords: Microplastics pollution, Microfluidics, Hydrodynamic focusing, Seawater, Lab-on-a-Chip

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Integrated Adsorption and Photocatalytic Degradation of Microplastics Using Biochar– ZnO Nanocomposite

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ABSTRACT

Persistent microplastics that escape conventional wastewater treatment systems pose a growing environmental threat, highlighting the need for effective degradation-focused remediation strategies. In this study, a magnetic biochar-based photocatalytic nanocomposite was developed following a systematic assessment of biochars produced from different feedstocks (rice husk and wheat straw) and pre-treatments (acid and alkaline) to identify the most suitable biochar. Comprehensive characterization indicated that alkaline pre-treated wheat straw biochar (WSB) possessed enhanced aromaticity, porosity, crystallinity, and structural stability, rendering it highly effective for hydrophobic interactions with various types of microplastics, including polystyrene (PS MPs). Subsequently, WSB was magnetized and coupled with ZnO nanoparticles (ZnNPs) biogenically synthesized using Thiosphaera pantotropha to achieve enhanced adsorption and photocatalytic degradation of PS MPs. Optical analyses of WSB-ZnO nanocomposite revealed an extended absorption range towards the visible spectrum, a lower band gap (2.35 eV) compared to ZnNPs (2.91 eV), and reduced photoluminescence intensity, indicating suppressed electron–hole recombination. Photocatalytic experiments showed increasing degradation of PS MPs with irradiation time, achieving 36.6% weight loss after 48 h at an optimal catalyst dosage of 0.75 g/L, significantly outperforming ZnNPs (21.6%). FTIR, XRD, and SEM analyses of degraded PS MPs confirmed surface oxidation, pitting, and crack formation, whereas TGA revealed reduced thermal stability, all indicative of polymer chain scission and oxidative degradation. TOC reduction with increasing irradiation time confirmed progressive mineralization of degradation intermediates. Overall, the WSB–ZnO nanocomposite demonstrates an efficient, sustainable and cost-effective photocatalyst for microplastic removal and degradation, offering significant promise for water treatment applications.

Keywords: Biochar; Biogenic synthesis; Microplastic degradation; Nanocomposite; Photocatalysis

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From A Sponge Of The Bay Of Bengal Sea: Bacillus Vietnamensis As A Potential Organism For Marine Microplastic Degradation

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ABSTRACT

Rapidly increasing plastic waste, particularly, polyethylene terephthalate (PET) is of serious concern due to its widespread use, durability and resistance to natural degradation. These plastics convert into microplastics and pervade the whole marine ecosystem causing serious ecological stress. Marine sponges are primitive sessile organisms, and considered as excellent filter feeders that can filter particles present in seawater to metabolize them as their food source. Marine sponges provide classic examples of microbial-macrofaunal partnerships that have been a productive source of discovery of novel enzymes and bioactive compounds. The extent of microplastic pollution can be gauged by the fact that marine sponges off the Gopalpur coast (~20-25 km in the sea at 30 m depth), harbor bacteria capable of degrading micro-PET plastic. In this context, our research was targeted at the screening of bacterial strains from the marine culture repository in CSIR-IMMT for the degradation of PET plastic. Out of the 25 isolates from the sponges of the Gopalpur coast, one strain GPB-38, showing highest microplastic degradation was selected for further investigation. The degradation of PET was measured by weight reduction study, while biochemical profiling and 16S rRNA gene sequencing were performed to establish the identity and metabolic characteristics of the isolated strain. GPB-38 showed the highest efficiency of PET degradation, yielding a 33.12 ± 1.7 % reduction in PET mass. 16S rDNA sequencing showed GPB38 as 92.37% similar to Bacillus vietnamensis. FTIR analysis of degraded PET presented peaks at 1600-1850 cm^{-1} (carbonyl) and 1700-1800 cm^{-1} (methyl), indicating oxidative modification of the polymer surface. SEM images presented surface pits and microcracks, which demonstrated physical deterioration of the PET film. The biodegradation was also investigated by means of CHNS analysis and quantification of TOC in the culture media.This study underlines Bacillus vietnamensis as a promising marine bacterial strain capable of degrading PET opening a new perspective on the ecological and biotechnological roles played by marine bacteria in mitigating plastic pollution.

Keywords: PET degradation1 , Bacillus vietnamensis2 , FTIR3 , SEM4 , bioremediation5

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Polyethylene Microplastics Induced Hepatic Oxidative Stress and Early Non-alcoholic Fatty Liver Disease in Wistar Rats

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ABSTRACT

Polyethylene microplastics (PE-MPs) are persistent environmental pollutants that are widely found in various ecosystems. However, their specific impact on liver function remains inadequately investigated. Adult male wistar rats were orally exposed to PE-MPs (1-10 µm) at doses of 0.1, 1 and 5 mg/kg/day over 28 days. Attenuated total reflectance-fourier transform infrared spectroscopy (ATR-FTIR) and fluorescence microscopy identified accumulations of PE-MPs. Liver tissues were examined histological using Haematoxylin and Eosin staining. Oxidative stress was measured by measuring malondialdehyde (MDA), superoxide dismutase (SOD), and reduced glutathione (GSH) levels. Transcriptomic analysis was performed to detect differentially expressed genes (DEGs). Functional enrichment analyses were conducted using the Gene Ontology (GO) and Kyoto Encyclopedia of Genes and Genomes (KEGG) pathways. Key genes were validated by quantitative reverse transcription polymerase chain reaction (qRT-PCR). Accumulation of PE-MPs was detected in liver tissue. Histological evaluation revealed dose-dependent liver injury, including inflammatory infiltration and periportal fibrosis. Elevated MDA levels indicated increased oxidative stress *via* lipid peroxidation (LPO). qRT-PCR investigation confirmed the upregulation of mitochondrial dysfunction-related genes (*NDUFC*, *UQCRH*, *MT-CO2*), pro-inflammatory genes (*TNF*-α, *CXCL1*, *IL-1*β) and fibrosis markers (*IL-6*, *Col1A1*, α-*SMA*). Transcriptomic analysis identified 189 DEGs linked with oxidative stress, inflammation and lipid metabolism pathways. Altogether, PE-MPs exposure induces oxidative stress, mitochondrial dysfunction, inflammation and fibrosis, contributing to non-alcoholic fatty liver disease (NAFLD) like hepatic alterations. This highlights the potential risk of PE-MPs as emerging environmental threats to liver health.

Keywords: FTIR, Lipid peroxidation, NAFLD, Polyethylene microplastics, Transcriptome-seq

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Micro-Pollutants In Mangrove Ecosystems: Biogeochemical Alterations And Implications For Coastal Functioning.

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ABSTRACT

Mangrove ecosystems occupy dynamic coastal interfaces where terrestrial inputs meet marine processes, making them natural sinks for a wide spectrum of micro-pollutants. Increasing research shows that microplastics, textile fibres, petroleum-derived particles, and trace metals accumulate at high concentrations within mangrove sediments due to low-energy hydrodynamics, fine sediment textures, and the structural complexity of root systems. Once deposited, these contaminants influence fundamental biogeochemical processes by modifying sediment redox conditions, disrupting microbial community structure, and altering pathways of organic matter decomposition and nutrient cycling. Micro-pollutants also exert consistent physiological and behavioural stress on mangrove-associated fauna. Oxidative stress responses, reduced feeding efficiency, impaired reproduction, and early-life stage sensitivity have been reported across crabs, molluscs, polychaetes, and juvenile fishes. These organism-level effects can weaken detrital processing, slow nutrient turnover, and reduce the functional contributions of key species that maintain sediment stability and productivity. At broader ecological scales, the combined biogeochemical and faunal disruptions have the potential to influence carbon burial rates, greenhouse gas fluxes, and the capacity of mangroves to buffer coastal waters from land-derived contaminants. Current evidence highlights that micro-pollutants are not isolated stressors but interact with salinity fluctuations, hypoxia, temperature extremes, and habitat modification, amplifying overall ecosystem vulnerability. This synthesis underscores the emerging consensus that micro-pollution poses a multifaceted threat to the functioning of mangrove systems and, by extension, to the coastal and nearshore marine environments they support. Strengthening monitoring frameworks and integrating pollutant dynamics into mangrove conservation strategies will be critical for sustaining ocean health in rapidly changing coastal landscapes.

Keywords: Mangroves; Micro-pollutants; Microplastics; Sediment; Redox Carbon Burial

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Assessment Of Potential Microplastic Contamination In The Tar River, Goa: A Case Study Of A Freshwater Source To The Mandovi Estuary

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ABSTRACT

Microplastic pollution is a growing environmental concern, with significant implications for freshwater and coastal ecosystems. This study presents a case study of the Tar River in Mapusa, Goa, which drains into the Mandovi River at Penha de Franca. The river originates upstream near the villages of Asnoda and Moide. It is fed by a network of small rivulets that s, influencing the transport and retention of pollutants. Water samples were collected monthly for one year from two sites (including P135.319' E073o 49.172'). Sampling involved on-site sieving with stainless steel sieves, followed by laboratory treatment of the retained sediment using 30% hydrogen peroxide for organic digestion and 5.3M Sodium chloride (NaCl) for density separation. tion revealed fine, colored fibers (red, blue, black) that are resistant to oxidation, suggesting a probable synthetic origin. In the absence of spectroscopic analysis, these are reported as potential microplastic fibers. Field observations indicated the ndiscriminate dumping of solid waste, including plastics, thermocol, idols, and photo frames, along riverbanks, as well as nearby residential settlements that potentially discharge untreated effluents. Seasonal growth of Eichhornia crassipes (water hyacinth) was observed, with fibrous roots appearing to entrap fibers and plastics, suggesting a potential role in microplastic retention and redistribution. Monsoon flooding and surface runoff likely enhance the movement of pollutants into the river. These observations are supported by local news reports that highlight the accumulation of garbage, untreated effluent discharge, and deteriorating water quality over the years (Navhind Times, 12 April 2024; Times of India, 15 March 2019; Navhind Times, 3 October 2023). This case study highlights the Tar River as a potential conduit for the transport of microplastics and other pollutants into the Mandovi estuary and coastal waters. The findings underscore the need for improved waste management, community continued monitoring of freshwater microplastic pollution in the State of Goa.

Keywords: Microplastics, Freshwater pollution, Tar River, Goa, Waste management

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Monsoon-Driven Dynamics of Biogenic Sulfur in the Eastern Arabian Sea.

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ABSTRACT

Dimethylsulfide (DMS), a climatically active trace gas emitted from the ocean, plays a pivotal role in marine cloud formation and the atmospheric sulfur budget. Yet, its seasonal dynamics and controlling mechanisms remain poorly resolved in the monsoon-dominated Arabian Sea. Here, we present the first multi-seasonal and interannual in situ assessment of DMS and its precursors, dimethylsulfoniopropionate (DMSP), dimethylsulfoxide (DMSO), and DMS Flux across the Eastern Arabian Sea (EAS) (2014–2021). Strong hydrographic variability shaped by the Indian monsoon through upwelling, convective mixing, and stratification drove pronounced biogeochemical responses. DMS concentrations (0.17 – 66.4 nM) and sea–air fluxes (0.2–130.5 µmol m^{-2} d^{-1}) peaked during the Southwest Monsoon (SWM), coinciding with nutrient enrichment and blooms of high DMSP-producing phytoplankton, while stratified intermonsoonal periods supported reduced DMS under oligotrophic conditions. Dissolved DMSP (0.4 – 113 nM) and DMSO (0.3 – 92.5 nM) showed similar seasonality, with recurring hotspots in the central basin (11–15°N), influenced by regional circulation and mesoscale eddies. These results highlight the Indian monsoon as a dominant regulator of biogenic sulfur cycling and emissions, underscoring the importance of integrating monsoon-linked feedbacks into climate models to better predict atmosphere–ocean interactions over the Indian Ocean.

Key Words: Arabian Sea, DMSP, DMS, DMSO, flux, and monsoon

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Role Of Nutrient Limitation On Ocean Acidification Impact On Plankton Response In The Western Bay Of Bengal

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ABSTRACT

Perennial rise in atmospheric carbon dioxide (CO2) due to anthropogenic activities increases oceanic carbon uptake, resulting in a decline in seawater pH. The rapid ocean acidification (OA) was reported in the Bay of Bengal (BoB) due to deposition of atmospheric pollutants, in addition to dissolution of atmospheric CO2. OA rates in the BoB are estimated to be 2–3 times higher than in other regions within the same latitudinal belt, suggesting a stronger effect on phytoplankton communities than elsewhere in the globe. The BoB is intensely oligotrophic due to strong stratification driven by nutrient-poor river discharge, resulting in severe nutrient limitation. It is hypothesized that nutrient limitation may overshadow OA impact on plankton in the BoB. To examine this, six microcosm experiments were conducted in the western BoB (13–20°N). The ambient pH was reduced by 0.2 units through CO_2 bubbling to simulate OA projected for 2100, followed by three-day incubations and analysis of multiple parameters. Among the nutrients, phosphate was the most limiting following nitrate. Picoplankton (~96%) dominated at all stations with high Prochlorophytes. Procholorophytes, diatoms and prymeniophytes responded positively to OA, whereas chlorophytes, cyanobacteria and dinoflagellates decreased. The response of phytoplankton linearly correlated with phosphate and nitrate indicating that the response is significantly controlled by availability of nutrients. The decline in the bacterial and microzooplankton abundance was observed due to low nutrient concentrations and prey availability respectively. Enhanced stratification due to melting of Himalayan glacier is projected in future resulting in weak nutrient inputs to surface and intensifying oligotrophy in the BoB. Under such scenario, nutrient limitation may overshadow the OA impact despite rapid decline in the pH due to increase in CO2 dissolution and aerosol deposition in the future.

Keywords: Ocean acidification, pH, nutrients, plankton, Bay of Bengal

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Surviving the sizzle: Unveiling the physiological responses of coral reef shrimps to elevated temperature

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ABSTRACT

This study investigates the impacts of temperature elevation in two coral reef shrimps *Ancylocaris brevicarpalis* and *Thor hainanesis* by exposing them to increasing thermal regimes of 27°C, 30°C and 33°C over 30 days. The experiment have been conducted at the Germpalasm resource centre of the ICAR - Natioanl Bureau of Fish Genetic Resources, Agatti island, Lakshadweep. Growth, Dissolved oxygen (DO) and mortality rates were systematically recorded to understand their physiological thresholds. Additionally, antioxidant assays including FRAP, CAT, H_2O_2, and MDA were conducted to assess oxidative stress and cellular defense mechanisms. Results demonstrated species-specific responses to thermal stress, where both shrimps exhibited reduced growth at elevated temperatures (30°C and 33°C) compared to control. Likewise, the antioxidant markers such as FRAP and CAT triggered adaptive responses in 30 and 33°C, indicating upregulated defense systems compared to control shrimps. However, levels of H_2O_2 and MDA were elevated, reflecting the enhanced oxidative stress and potential cellular damage. We believe that these findings highlight the vulnerability of coral reef shrimps to ongoing climate-driven warming, underscoring the need to consider physiological resilience in conservation strategies for reef ecosystems.

Keywords: Thermal stress, Coral reef shrimp, Antioxidant response, *Ancylocaris brevicarpalis*, *Thor hainanesis*

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A Systematic Review of the Ocean Acidification Research in India: Research Trends, Gaps And Recommendations

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ABSTRACT

Ocean acidification has emerged as a significant threat to marine organisms. In India, this research area is still not fully explored, but expanding at an exponential rate. Hence, it is essential to consolidate the fragmented knowledge into a systematic review. This will assist future researchers to develop their work. We utilized the databases such as Scopus, Web of Science and Ocean Acidification – International Coordination Centre bibliography to conduct a systematic review of ocean acidification research in India. Using the Biblioshiny package in R, we identified spatial and temporal research trends, and growth of ocean acidification literature research, as well as existing knowledge gaps. We used selected relevant keywords to obtain relevant publications. We selected 353 publications by applying relevance filtering and adherence to PRISMA guidelines. Almost one-third of the publications were non-primary articles. Among research articles, only 71 publications were found to investigate the response of marine organisms to ocean acidification. Majority of them involved single stressors, for a short term on very limited taxa. Lack of molecular-level investigation, multifactorial experimental design, and long-term observations were major gaps. This review aims to support researchers, policymakers, and other stakeholders involved in the planning, monitoring, and developing adaptation strategies. Finally, it provides recommendations for future research and policy development.

Keywords: Climate Change, Ocean acidification, marine ecosystem, Indian research, Bibliometric analysis

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Estimating Ocean Acidification Due To Atmospheric Pollutants In The Bay Of Bengal

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ABSTRACT

The dissolution of atmospheric CO_2 causes ocean acidification that results in decrease of pH at a rate of 0.0015-0.0022/year. In addition to CO_2, atmospheric depositions of pollutants further acidify the surface ocean as they contain sulfates and nitrate. Time-series observations conducted between 2007 and 2019 in the coastal Bay of Bengal (BoB) revealed that the acidification rates are 2 to 4 times higher compared to elsewhere in the global ocean in similar latitudinal belt. About 30% of the decline in pH in the coastal BoB is contributed by the atmospheric deposition of pollutants. Based on the aerosol elemental composition data collected between 2006 and 2020 and its relationship with remote sensing aerosol optical depth (AOD), the deposition of sulfate and nitrate over the BoB was estimated. Using empirical relation between concentration of nitrate+sulfate and drop in pH, possible decline in pH due to deposition of atmospheric pollutant was estimated for the entire BoB for a period of 2000-2024. A significant decline in pH due to atmospheric pollutant was observed in the western and northern BoB associating with higher AOD levels. Higher decline in pH was observed during winter followed by spring and fall. The highest rate of increase in AOD was reported in the western BoB in the past two decade resulting in highest drop in pH. This resulted in turning of BoB from sink to source for the atmospheric CO_2. The current models (both regional and global) do not include atmospheric contribution of pH changes resulting in ill-simulation of CO_2 fluxes at the air-sea interface. This study will give opportunity to incorporate the impact of atmospheric pollutants on ocean acidification in the Bay of Bengal for better simulation of pH and future changes of ocean acidification due to climate change.

Keywords: Acidification, pH, Remote sensing, Aerosol Optical Depth, Bay of Bengal

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Dual Perils Beneath the Surface: Eco-physiological Consequences of Ocean Warming and Acidification in Mystus gulio

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ABSTRACT

The incessant release of anthropogenic CO_2 has caused ocean warming (OW) and raised the partial pressure of CO_2, which ultimately results in a foreseeable decline in oceanic pH. The present study endeavoured to elucidate the concurrent ramifications of OW and ocean acidification (OA) on the eco-physiological responses of Mystus gulio over a forty-five-day mesocosm experiment. Physiological parameters encompassing ingestion, absorption, respiration, and excretion rates were evaluated to gauge the scope for growth (SfG). A pronounced reduction in ingestion and absorption rates signified a curtailed energy intake in the studied fish. Respiration rate declined under most treatments, suggesting a compensatory metabolic adjustment. Excretion rate increased across treatments, attributed to enhanced protein catabolism and acid–base regulatory adjustments, which reflected an adaptive yet energetically costly mechanism to mitigate ionic and metabolic imbalances induced by combined stressors. Despite all these adjustments, SfG was markedly suppressed in the combined treatment, underscoring impaired energy acquisition and allocation under dual stressors. At the biochemical levels, antioxidant defenses such as superoxide dismutase (SOD), catalase (CAT), and glutathione-S-transferase (GST) were elevated in the combined treatment, although SOD and GST activities remained low relative to their individual stressor treatment. Despite these defensive mechanisms, lipid peroxidation (LPO) intensified under concurrent exposure, which underscores that defenses were insufficient to counteract persistent environmental stressors. Collectively, the findings unravel that combined stressors imposed significant ramifications on the physiological and oxidative homeostasis of M. gulio, potentially jeopardizing its growth, survival, and ecological sustenance in a business-as-usual emission scenario.

Keywords: Warming, Acidification, Teleost, Physiological energetics, Biomarkers

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Determinants of Daytime Positioning of the Deep Scattering Layer and Their Role in Shaping DSL Dynamics in a Warming Ocean

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ABSTRACT

The Deep Scattering Layer (DSL), formed as an antipredator refuge shapes the ecology of mesopelagic system. Despite the ecological importance of DSLs and the Indian Ocean's distinctive hydrography, a comprehensive understanding of the determinants of their daytime residence depth is still lacking. We identify hydrographic and biological controls on the daytime vertical position of DSL by integrating shipborne ADCP acoustic backscatter, Multiple Plankton Net (MPN) tows, CTD profiles, and satellite-derived products. Shoaling and thinning of the DSL at OMZ stations indicate oxygen sensitivity among constituent taxa. Indirect estimates of ambient light indicate that the daytime DSL shoals with reduced light penetration, which point to the possibility of a threshold light level. Our study reveals dissolved oxygen as the major predictor of daytime DSL depth, exceeding the effects of water column temperature. The coincidence of higher predator concentration and the compactness of the DSL suggest predatory pressure as a secondary constraint for DSL formation. DSL depth emerges from a complex, non-linear system with OMZ as the leading factor, but modulated by other hydrographic and biological parameters. In addition to identifying the leading factor, behavioural response of DSL mesozooplankton to this factor is discussed using acoustic, taxonomic and isotopic methods. A reduced affinity of migrators towards the less oxygenated waters was observed during the research. Similarly, OMZ associated dietary plasticity of migrators like Euphausiids and Myctophid larvae is confirmed by the variability in the nitrogen isotopes of these organisms. Finally, the impacts of rising tropical ocean temperatures on DSL dynamics are discussed, providing new insights into the behavioural traits of DSL-associated mesozooplankton within the climatically vulnerable Arabian Sea OMZ.

Keywords: Oxygen Minimum Zone, Mesozooplankton, Diurnal Vertical Migration, Deep Scattering Layer, Ocean warming

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Effect Of Co_2 Driven Ocean Acidification On Biomineralization In Donax Cuneatus

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ABSTRACT

Ocean acidification (OA) refers to the process of lowering seawater pH over time as the ocean absorbs atmospheric carbon dioxide (CO_2). As carbon dioxide (CO_2) emissions increase ocean acidification (OA) alters seawater chemistry affecting marine life. This process reduces the availability of carbonate ions which are essential for marine calcifying organisms to build up calcium carbonate structures such as shells and skeleton. Oceanic pH has remained relatively stable due to the natural buffering of seawater but CO_2 released due to human activities has disturbed these systems. Biomineralization is a biologically controlled process where organisms produce mineralised structures mainly relying on the availability of CO_3^{2-} and the organisms capacity to regulate internal pH and ion concentrations. Many bivalves use specialised epithelia to concentrate Ca^{2+} and CO_3^{2-} at the calcification site. However this process consumes more energy under acidified conditions diverting energy from other vital processes. Given their ecological and economic importance preserving bivalve populations under future ocean acidification scenarios is crucial. This study aims to investigate the effects of CO_2 - driven ocean acidification on the shell strength of *Donax cuneatus* through controlled microcosm environments reflecting projected ocean acidification conditions (pH 8, 7.8 and 7.6, alongside an ambient control of 8.2). The result revealed shell shifts in mineral composition at pH 7.6 with broadening and flat peaks (XRD pattern) signifying a loss of aragonite crystallinity and possible transformation or dissolution of calcium carbonate phases. Through this microcosm approach the present study will contribute to a deeper understanding of how ocean acidification affects the organisms biological response across multiple levels of analysis.

Keywords : Ocean acidification , Microcosm, Biomineralization, co_2 and Bivalves .

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Nitrate- Mediated Diatom Survival Under Dark Anoxic Stress

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ABSTRACT

Under the current climate change scenarios, rising ocean temperatures are intensifying ocean deoxygenation and its expansion, posing a significant threat to marine life and biogeochemical processes. Diatoms are ubiquitously present in coastal and nutrient-rich waters and possess the unique ability to store nitrate intracellularly ($ICNO_3$). We hypothesize that the stored $ICNO_3$ could potentially serve as an alternative electron acceptor under dark and anoxic condition. In this study, diatom cultures of *Nitzschia* sp grown under 12h light:12h dark (L:D) cycle and at oxic conditions were–subsequently shifted to (1) light-oxic (Oxic-(L:D)), (2) light-anoxic (Anoxic- (L:D)), (3) dark-oxic (Oxic-D) and (4) dark-anoxic (Anoxic -D). In addition, Intracellular (IC) and extracellular (EC) nitrate were measured to understand the NO_3 accumulation and utilization. Our results revealed that highest nitrate uptake was observed in anoxic-D conditions at a rate of 53 pmol cell^{-1} day^{-1}, where 98% of the initial NO_3^- was consumed, compared to oxic-D (42 pmol cell^{-1} day^{-1}; 82%) and light-incubated conditions: 6.9 pmol cell^{-1} day^{-1} (16%) for oxic-(L:D) and 5.9 pmol cell^{-1} day^{-1} (8%) for anoxic- (L:D). The stored $ICNO_3$ was consumed only under anoxic-D conditions (71%; 0.3 pmol cell^{-1} day^{-1}), whereas $ICNO_3$ increased markedly under oxic:D (1348%; 1.35 pmol cell^{-1} day^{-1}), anoxic:(L:D) (338%; 1.15 pmol cell^{-1} day^{-1}) and oxic:(L:D) (248%; 0.43 pmol cell^{-1} day^{-1}), suggested the enhanced $ICNO_3$ utilization in the dark–anoxic condition. Furthermore, extracellular ammonium ($ECNH_4^+$) increased predominantly under anoxic:D conditions (1435%; 3.1 pmol cell^{-1} day^{-1}), indicated the potential dissimilatory nitrate reduction to ammonium. The comparable NO_3^- uptake in antibiotic-treated (AT-*Nitzschia*, 39%) and antibiotic-untreated (UT-*Nitzschia*, 56%) cultures, along with similar $ICNO_3^-$ consumption (AT-*Nitzschia*, 84%; UT-*Nitzschia*, 69%), confirms diatom-mediated nitrate utilization independent of bacterial influence. The marked increase in $ECNH_4^+$ in AT-*Nitzschia* under dark and anoxic conditions further suggested that diatoms could use nitrate as an electron acceptor through dissimilatory nitrate reduction to ammonium (DNRA) to survive in dark, anoxic environments.

Keywords: Diatoms, survival, Dark and anoxia, Intracellular Nitrate, DNRA

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Theme: Ocean Health

Session Title: Restoration of sand dunes, mangroves, seagrass and coral reef

Session Convener: Dr M Srinivasan

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3.	Promoting Marine Flora And Fauna With Bioactive Concrete

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From Assessment To Community Action: Quantifying Seagrass Loss And Catalysing Restoration In The Lakshadweep Archipelago

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ABSTRACT

Seagrasses, a unique group of marine flowering plants, play a vital role in coastal ecosystems by supporting endangered species such as sea cows, sea turtles, and seahorses, and are often referred to as coastal canaries. These meadows possess an exceptional carbon storage potential, rivalling that of boreal and tropical forests. Despite their ecological prominence and long evolutionary history, seagrasses are facing unprecedented decline due to compounded stressors from climate change and anthropogenic activities, and continue to receive inadequate conservation attention. To address this, a field-based assessment was conducted in Agatti Island to document the current diversity and spatial distribution of seagrass beds. Four seagrass species under two families covering a spatial extent of 21 hectares were recorded. Cymodocea rotundata was found to be the dominant species, accounting for 41% and exhibiting a mean shoot density of 22 shoots m^{-2}, followed by Halodule uninervis 28% (115 shoots m^{-2}), Thalassia hemprichii 27% (24 shoots m^{-2}), and Halophila ovalis 3% (19 shoots m^{-2}). The results reveal a drastic decline in seagrass coverage, signalling an alarming threat to these critical island ecosystems. In response, we initiated intensive community awareness programs, which have catalysed community-based restoration actions aimed at meadow recovery. Given the isolated nature of the Lakshadweep archipelago, the ground-truth dataset provides a critical baseline. It opens new avenues for research into the future spatial changes of seagrass distribution, diversity, biomass, and productivity, and for assessing the efficacy of community-driven restoration efforts.

Keywords: Diversity, Seagrass decline, Community-based restoration, Lakshadweep

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Eco-Engineered Concrete For Dual-Purpose Floating Infrastructure

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ABSTRACT

Coastal development is harming marine life. We're addressing this by turning necessary "hard" infrastructure into active habitats. Our research developed innovative concrete materials for floating structures. These aren't standard cement; minor tweaks to the mix composition and the addition of surface texture dramatically improve biological outcomes. What we found: • Significantly higher growth and settlement of marine life. • Increased diversity, especially for key species like oysters and corals. Crucially, this ecological boost is balanced with performance. The modified concrete maintains the durability and stability essential for harsh marine environments. The takeaway: By embedding ecological design directly into floating structures, we can use our infrastructure to actively support marine ecosystems, finding a practical balance between human coastal needs and vital environmental preservation.

Keywords: Ecological Engineering, Marine Infrastructure, Concrete Innovation, Coastal Biodiversity

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Promoting Marine Flora And Fauna With Bioactive Concrete

Vangapandu Harshitha, Varre Sathya Sri Harsha, Boddu Aparna, Gamini Geethuchandh, Bojanki Gnaneswara Balaji, Bandaru Chaitanya Lahar, V. Susheel Agrakanya, Kriti Karna, Laasya

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ABSTRACT

The increasing urbanization and infrastructure development along coastlines has led to significant environmental degradation, particularly in marine ecosystems dominated by Coastal and Marine Infrastructures (CMI). Our technology addresses the challenges of promoting biodiversity in these hardening coastal environments by developing innovative concrete matrices that aim at enhancing the growth of flora and fauna. These innovative concrete matrices can significantly enhance the recruitment and growth of both flora and fauna compared to standard cement, with increased species diversity and abundance of engineering species such as corals and oysters. Textured surfaces will ideally yield greater biological cover and biomass, supporting the hypothesis that increase surface complexity fosters marine life. The minor modifications to concrete composition and design can substantially improve the ecological performance of CMI, enabling them to better serve as habitats for marine organisms while also offering structural benefits such as enhanced durability and stability in harsh marine conditions. In conclusion, integrating ecological engineering principles into the design of coastal infrastructures can mitigate the negative impacts of urbanization on marine ecosystems, promoting healthier marine environments, and improving ecosystem services. This innovative approach provides a viable solution for addressing the urgent need for sustainable coastal development, balancing human needs with ecological preservation.

Keywords: Ecological Engineering, Marine Infrastructure, Concrete Innovation, Coastal Biodiversity

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Session Title: Turning the tide: Tackling ocean acidification with marine carbon removal

Session Convener: Dr. Suhas Shetye

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2.	Estuarine - Coastal Carbon Dynamics Along The West Coast Of India
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4.	Impact Of Ocean Acidification On Coastal Copepods: Implications For Futuristic Coastal Dynamics.

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An Innovative Sustainable Approach Towards Decarbonization: Carbon Dioxide Sequestration in Arabian Sea sediments as Clathrate Hydrates

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ABSTRACT

Global CO_2 emissions from human activities, predominantly the combustion of fossil fuels for energy and transportation, are a major contributor to climate change. The increased concentration of CO_2 in the atmosphere dissolves in seawater, forming carbonic acid and releasing hydrogen ions, which lower the ocean's pH and pose a threat to marine life. Implementing sustainable carbon capture and sequestration (CCS) technologies is crucial for achieving net-zero carbon emissions targets. In this direction, CO_2 sequestration in the form of solid gas hydrates under subsea sediments is a promising approach that would reduce oceanic acidification and provide permanent CO_2 storage (one tonne of CO_2 can be stored in ~3.5 m^3 of gas hydrate).

Gas hydrates are ice-like crystalline compounds formed by the encapsulation of gas molecules (such as CO_2) in hydrogen-bonded water cages at high pressure and low temperatures found in deep-sea sediments. In this study, we investigated the kinetics of hydrate formation and dissociation in several sediment cores collected from the Arabian Sea, at depths ranging from 20 to 2000 meters. The experiments were conducted in a lab-scale high-pressure reactor that mimicked subsea conditions.

Preliminary results indicate that sediment lithology significantly influences the kinetics of hydrate formation, with porous sandy sediments storing considerably higher amounts of CO_2 (~50% higher water-to-hydrate conversion) compared to clayey sediments. Furthermore, to enhance the kinetics of hydrate formation, we employed various biocompatible kinetic hydrate promoters, such as amino acids (including tryptophan and leucine). This study offers valuable insights into CO_2 storage in oceanic sediments located in the Indian Ocean.

Keywords: CO_2 Sequestration, Gas Hydrates, Arabian Sea Sediments, Kinetics, Climate change

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Impact Of Ocean Acidification On Coastal Copepods: Implications For Futuristic Coastal Dynamics.

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ABSTRACT

Anthropogenic ocean acidification, resulting from the increased absorption of atmospheric CO2 by seawater, poses significant threats to marine ecosystems, particularly in coastal environments where pH reductions are expected to be more severe than in the open ocean. Copepods represent a critical link between primary producers and higher trophic levels, yet their responses to the rapid decline in seawater pH expected by the century's end remain poorly constrained— especially in dynamic coastal regions. The current study quantifies the impact of near-future pH scenarios on the survival and population dynamics of Pseudodiaptomus serricaudatus, a perennial coastal and estuarine copepod of the West Coast of India. Adult copepods were incubated at four target pH levels (8.10, 7.81, 7.51, and 7.04) and maintained by an automated CO2-mediated pH Controller to study mortality and population dynamics. Mortality was assessed every three days up to day 10; population life stage composition was recorded on day 15. Mortality remained 23% at pH 8.10 (representing present-day open-ocean conditions) but rose to 30% at pH 7.81 (present-day coastal average), 47% at pH 7.51 (projected late-21st-century coastal value), and 77% at pH 7.04 (extreme 23rd-century scenario). Population data revealed a decline in different life stages and a copepodites-to-nauplius (Co/N) ratio at lower pH values, indicating impaired development. The critical pH threshold for P. serricaudatus appeared to lie between 7.5-7.8, corresponding closely to present-day coastal conditions and near-future projections. These findings suggest that coastal copepod populations may already be experiencing sublethal stress, with potential demographic collapse occurring within decades rather than by the end of the century.

Keywords: Ocean Acidification, Copepods, Life-stages, Mortality, Coastal Dynamics

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Early-Warning indicators of *Pteropod vulnerability* towards Ocean Acidification

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ABSTRACT

The rapid rise in atmospheric CO_2 and its subsequent uptake by the oceans has led to ocean acidification and other associated changes in the marine ecosystem. The recent reports of the shoaling of the aragonite saturation horizon in the northern Indian Ocean are especially concerning and are raising alarms. Pteropods, also known as Sea-butterflies, are believed to be early warning indicators of the impacts of ocean acidification due to their aragonite shell. Upon our investigation in the eastern Arabian Sea, we found that the abundance of pteropods is high during the fall inter-monsoon, which suggests that the system continues to sustain productivity even after the cessation of peak monsoon activity. The pteropods are key components of food sources for many marine species, such as fish, and any changes in their abundance can have cascading effects on the marine food web. We conducted a CO_2 manipulation experiment in the eastern Arabian Sea during December 2024. Pteropods belonging to *Creseis acicula* from the eastern Arabian Sea were subjected to pHT = 7.47, and pCO_2 = 1734 µatm under controlled conditions. Our findings suggest that acidification led to dissolution; however, no significant change in shell biomass was observed. Acidification also led to protrusion through the shells, and these protrusions varied up to 88µm in length. These observed protrusions need to be assessed further to determine if they provide any competitive advantage in combating or minimizing the impact of ocean acidification.

Keywords: Arabian Sea; pH, Pteropod, Acidification, protrusion

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Estuarine - Coastal Carbon Dynamics along the West Coast of India

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ABSTRACT

The estuarine and coastal water interactions were studied through the Coastal Carbon Dynamics (CCD) Project. The Mandovi estuary (mouth region), along with the adjacent coastal waters, was studied from 2023 to 2025 on a monthly basis. This study displayed pronounced seasonal and spatial variability in its biogeochemical features from the estuarine mouth to the coastal region. Our study indicated distinct changes in carbonate chemistry associated with varying freshwater inputs during the South West Monsoon (SWM). During SWM, the estuarine mouth region acts as a hotspot for pCO_2 (1200µatm), primarily driven by tidal mixing and monsoonal discharge. The elevated Total organic carbon during this period also highlights the role of terrestrial organic carbon transport and remineralisation in the observed enhanced pCO_2. In general, the Mandovi estuary functions as a CO_2 source during periods of high discharge, while it acts as a temporary sink during the pre-monsoon. Our findings highlight the importance of tropical estuaries in shaping cabon dynamics and acidification of coastal ecosystems.

Keywords: Estuary, Carbon dynamics, organic matter, tidal mixing

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2. **Ocean engineering, coastal processes, and ocean energy**

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2.	Evolution of Internal Gravity Waves in the presence of Background Flow
3.	Ship-Board observations of Internal Tides generated by Andaman Ridge
4.	Variation of internal solitary waves (ISW) amplitude in the andaman sea as key findings from swot observations.
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Observations Of Internal Waves In The Inner Shelf Off Goa,

Central West Coast Of India

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ABSTRACT

We analysed velocity observations from a one-month moored Acoustic Doppler Current Profiler (ADCP) deployed on the inner shelf off Goa (15°N, 73.7°E; depth 15 m) in 2017 to study internal wave characteristics in the semidiurnal and diurnal bands. The ADCP provided measurements from 2 to 13 m water depth with a 1 m vertical resolution. Harmonic analysis indicates that barotropic tidal currents reach ~10 cm/s. In the baroclinic component, semidiurnal currents attain up to ~2 cm/s, while diurnal currents reach ~5 cm/s, with the latter exhibiting a pronounced spring–neap cycle. Diurnal baroclinic currents are two to three times stronger than semidiurnal currents. These currents show a clear upward energy propagation, and spring-neap cycle suggesting the presence of internal tides in the diurnal band. Spectral analysis of concurrent wind data reveals a strong diurnal land–sea breeze signal, and the diurnal currents show high coherence with winds, indicating the potential influence of local atmospheric forcing. The diurnal baroclinic currents also show surface intensification, unlike the semidiurnal signals,
further supporting a wind-driven contribution. Overall, our results suggest that diurnal internal wave variability on the shallow shelf off the west coast of India is determined by a combination of internal tides and the diurnal land–sea breeze. However, a detailed study using modelling and observation is needed to confirm this.

Key words: ADCP, inner shelf, internal waves

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Evolution Of Internal Gravity Waves In The Presence Of Background Flow

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ABSTRACT

Internal gravity waves in stratified oceanic environments have a significant influence on vertical energy transfer and circulation. This study numerically investigates the propagation and interaction of internal gravity wave modes in uniformly and non-uniformly stratified fluids, with a focus on forcing multiple modes in a confined two-dimensional computational domain. The research examines how individual and combined wave modes propagate, interact, and evolve under background flow conditions representative of oceanic settings. The findings highlight modal amplitude growth and variations in frequency spectra with distance from the forced region, indicating complex energy transfer and wave mode coupling. Energy comparisons reveal differences in kinetic energy distribution between boundary and volume forcing, with volume forcing producing larger wave amplitudes consistent with experimental observations. Although wave breaking and turbulent mixing are not observed, the simulations capture enhanced modal interactions and spectral energy transfer, which are critical to understanding internal wave dynamics. These small-scale dynamics within the confined domain aim to inform parameterizations of internal wave-driven mixing in large-scale ocean circulation models, addressing spatially variable diapycnal mixing linked to internal wave energetics and mesoscale flow interactions. By attempting to connect detailed wave processes to bulk mixing representations, this work can contribute to improving energetically consistent, spatially variable mixing parameterizations needed in oceanographic and climate modeling. This aligns with the understanding that abyssal mixing is non-uniform and intensified near boundaries and flow structures, offering a pathway to translate confined-domain numerical insights into broader ocean modeling frameworks.

Keywords: Internal gravity waves, non-uniform stratification, mesoscale eddies, background flow, diapycnal mixing

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Ship-Board Observations Of Internal Tides Generated By Andaman Ridge

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ABSTRACT

The Andaman Sea, a semi-enclosed basin in the northeastern Indian Ocean, is widely recognized as a major global hotspot for internal tide generation. In this study, we analyze time-series observations of currents, temperature, and salinity collected at three locations (two stations on the eastern side and one station on the western side of the Andaman ridge) near the Battimalv Islands in the Andaman Sea during February 2024 to investigate the generation, propagation, and dissipation of internal tides. Surface currents were measured using an X-band radar, while subsurface currents were obtained from a ship-mounted Acoustic Doppler Current Profiler (ADCP). The observations reveal a pronounced semidiurnal signal throughout the water column, indicating strong internal tide activity originating from the nearby ridge system. Modal decomposition of isopycnal displacements and baroclinic currents shows that low modes dominate the vertical structure of the internal tides. Energy-flux estimates derived from concurrent velocity and density measurements demonstrate that the internal tides propagate offshore from the ridge. These preliminary results suggest that internal tides in this region play a significant role in enhancing vertical mixing.

Keywords: Internal tides, Andaman Sea, Ridge, Vertical mixing

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Variation of Internal Solitary Waves (ISW) amplitude in the Andaman Sea – Key findings from SWOT observations.

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ABSTRACT

Internal Solitary Waves (ISW) are highly nonlinear, nonhydrostatic gravity waves frequently observed in the world's oceans. Large-amplitude ISW, often ranging from 10 m to over 100 m, play a crucial role in vertical mixing and significantly impact underwater infrastructure and coral reef ecosystems. The Andaman Sea is a globally recognized hotspot for ISW activity, where the surface manifestations have been widely investigated using optical and Synthetic Aperture Radar (SAR) imagery. However, a critical dynamic parameter the Sea Surface Height Anomaly (SSHA) associated with ISW cannot be obtained using optical or SAR sensors. The advent of high-resolution swath altimetry from the Surface Water and Ocean Topography (SWOT) mission now enables direct observation of ISW-induced SSHA with unprecedented spatial detail. This study utilizes one year (July 2023–July 2024) of SWOT repeat-pass unsmoothed SSHA data at 250 m spatial resolution to investigate the spatiotemporal characteristics of ISW in the Andaman Sea. SWOT observations reveal distinct surface signatures of high-amplitude ISW, with SSHA exceeding 20 cm. ISW amplitude and phase speed are estimated using the Korteweg–de Vries (KdV) and Sturm–Liouville formulations for continuously stratified ocean where, numerical model derived temperature, salinity data are used. The results indicate that ISW amplitudes are modulated by spring tides and enhanced under weak stratification. Notably, this study presents the satellite-based evidence of Mach stem formation from SSHA data, highlighting SWOT's unique capability to resolve nonlinear oblique ISW interactions. An extreme ISW event with an amplitude of 60.6 m (SSHA = 42 cm) occurred during the simultaneous presence of spring tide, weak stratification, and oblique interaction. The estimated amplitudes agree well with in-situ mooring observations, while computed phase speeds (1.26–2.66 ms^{-1}) show a gradual decrease as ISW propagate from the Andaman Sea towards the coast of Thailand.

Keywords: ISW, Amplitude, SWOT, Satellite, Interaction

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Evaluation Of East Indian Coastal Salinity And Preliminary Analysis Of Salinity Structure In The Northern Head Of The Bay Of Bengal During Winter

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ABSTRACT

This study evaluates seasonal and interannual variability of East Indian coastal salinity and elucidates the physical mechanisms governing these fluctuations, with particular emphasis on winter salinity stratification in the northern Bay of Bengal using CTD profiling. Research was conducted along the Indian east coastline and the northern Bay of Bengal, utilizing seawater samples collected by the National Institute of Oceanography at eight coastal stations since May 2005, supplemented by CTD operations during January–February 2016 (Department of Oceanography, University of Dhaka). The strongest seasonal variations occur in the northern Bay of Bengal, driven by intense monsoonal precipitation (July–September) generating substantial freshwater fluxes that propagate southward via the East India Coastal Current (EICC). All stations except Kolachal display pronounced seasonal signals characterized by sharp monsoon-induced salinity drops followed by recovery. The amplitude of freshening decreases systematically southward (~10 psu at Chennai, Nagapattinam, Rameshwaram; ~1 psu at Kolachal). Phase lag increases progressively southward, ranging from zero days at Visakhapatnam and Paradeep to approximately 75 days at Rameshwaram and Tiruchendur, consistent with southward EICC advection. Interannual variations in salinity amplitude suggest local processes dominate over large-scale controls. CTD profiles reveal weak stratification along central and western sectors, while the southeastern sector exhibits three distinct patterns: unstratified conditions, thick upper layer stratification, and sharp surface stratification associated with freshwater fronts and saline water advection. These findings provide the first comprehensive description of winter salinity structure in the northern Bay of Bengal and enhance understanding of coastal–open ocean interactions.

Keywords: Bay of Bengal, freshwater flux, salinity stratification, CTD profiling, EICC

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Future Wave Climate Assessment At Nine Coastal Stations Along The Indian Coast Using Cmip5 Rcp8.5 Projections

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ABSTRACT

Future coastal conditions along the Indian coastline are expected to undergo significant transformations under a warming climate, particularly in response to changing wind and wave regimes across the Indian Ocean. Understanding how these shifts influence the nearshore wave climate is essential for resilient coastal planning, infrastructure design, and long-term shoreline management. This study investigates projected changes in the nearshore wave climate at a water depth of 20 m at nine representative coastal points for each of the coastal states along the Indian coastline using future climate projections from the GFDL-ESM2M and MIROC5 models (CMIP5) under the RCP8.5 high-emission scenario. Simulations carried out were analysed for two future windows: mid-century (2026-2045) and end-century (2081-2100) to quantify changes in significant wave height (Hs), mean wave period (Tm), and mean wave direction (MWD), as well as their decadal trend evolution. Results indicate a substantial intensification of wave heights at all nine locations, with maximum Hs increasing by 30-55% and mean Hs rising by 25 45% by the end of the century. The background sea state strengthens consistently, while extreme events show even greater amplification, particularly along the west coast sites exposed to open ocean swells. Mean wave period lengthens by 1.0 - 2.5 s, reflecting enhanced propagation of long-period Southern Ocean swells into the northern Indian Ocean. Changes in mean wave direction are comparatively small but display systematic coast-specific rotations, indicating potential implications for sediment transport pathways and shoreline stability. Decadal trends reveal alternating phases of positive and negative evolution in mid-century, transitioning to coherent late-century strengthening at most locations. Overall, the nine-point analysis highlights a robust and spatially consistent intensification of India's future coastal wave climate under RCP8.5, emphasising the need for revised coastal design standards, updated hazard assessments, and climate-informed shoreline management strategies.

Keywords: Future wave climate, Significant wave height (Hs), Mean wave Period (Tm), Mean wave direction (MWD), climate change impacts, decadal wave trends

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Development Of An Indigenous Wave-Powered Vertical Profiler For Continuous Ocean Observation

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ABSTRACT

The indigenous wave-powered vertical profiler developed at NIOT offers a sustainable solution for continuous and high-resolution observation of the upper ocean, a crucial requirement for enhancing monsoon and climate forecasting in the Indian Ocean region. The system utilises the heave motion of surface waves, converting it into mechanical energy through a cam–ratchet mechanism that drives the profiler downward along a taut wire and allows buoyancy-driven ascent. This cycle enables repeated profiling without reliance on batteries, significantly lowering operational costs and enabling long-duration deployments.

The profiler carries CTD, dissolved oxygen, fluorescence and current sensors to capture detailed vertical structure during each ascent. On surfacing, the data are telemetered through satellite links for integration with operational centres such as INCOIS. The modular, corrosion-resistant design ensures dependable functioning under a range of wave conditions, supporting both drifting and moored deployments. By providing frequent upper-ocean profiles, the system enhances the understanding of stratification, mixed-layer variability, biogeochemical processes, marine heatwaves and cyclonerelevant ocean heat content. Laboratory validation of the mechanical components is underway, with field trials planned across varied sea states. Future developments include adaptive profiling, deep-water configurations and acoustic command capability. This profiler enhances India's ocean-observation capacity through indigenous development, supporting national priorities under the Ministry of Earth Sciences and improving the quality and continuity of ocean data essential for forecasting, research, and long-term climate studies.

Keywords: Wave-powered profiler; Vertical ocean profiling; Upper-ocean observations; ocean heat content

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Application Of Mathematical Modeling For Sedimentation Challenges In A Coastal Fishing Harbour

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ABSTRACT

Coastal regions around the world face a multitude of challenges, with sedimentation being a significant issue impacting harbors, waterways, and coastal infrastructures. Sedimentation can reduce navigable depths, disrupt maritime activities and necessitate frequent dredging and maintenance efforts. In regions like Maharashtra, where numerous fishing harbors serve as critical hubs for livelihood and commerce, maintaining adequate depths and ensuring smooth navigation is vital. The present paper focuses on the sedimentation problem at a Fishing Harbor in Mulgaon village of Maharashtra. Over time, this harbour has experienced significant sediment build-up, leading to the narrowing of the harbor entrance due to littoral drift, and near closure of its creek mouth. To address these issues, a comprehensive approach involving dredging, jetty construction, and the development of an anti-sea erosion bund are required but the same has to be supported by hydrodynamic modeling to assess the effectiveness of these interventions. Through, the comprehensive mathematical modeling studies, it was found that dredging of a 2.15 km long approach channel, 80 m wide, to a depth of -2.0 m was suggested. Additionally, construction of an extended jetty near the entrance and a 1500 m anti-sea erosion bund, extending to -1.0 m below chart datum, was felt essential. This paper evaluates the hydrodynamic and sedimentation behavior of the suggested layout based on field data analysis and mathematical modelling. Study results indicated that existing inlet velocities of 0.3-0.5 m/s will decrease to 0.25 m/s after the bund's construction. It is predicted that the hydrodynamic and sedimentation conditions at the entrance and within the channel will stabilize with the proposed modifications. Capital dredging for the channel is estimated at 0.35 million cubic meters, with annual maintenance dredging of approximately 24,000 cubic meters is required to counter tide-induced sedimentation and maintain adequate channel depths. Thus it was found that with the provision of this bund, the sedimentation due to prevailing littoral drift would be largely addressed and the entrance would remain mostly open throughout the year after initial capital dredging.

Keywords: Fishing harbour, hydrodynamics, sedimentation, mathematical modeling, erosion Bund

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Accessing impacts of climate change-driven sea level rise on hydrodynamics and sedimentation in Astaranga harbour area, Odisha

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ABSTRACT

Rising sea and ocean levels can significantly impact the daily lives of residents living in coastal areas and low-lying areas. Sea level rise is expected to have profound environmental, economic and social impacts worldwide. Ports, harbours and coastal transport infrastructures form complex systems that can be highly affected by rising sea levels due to storm surges and extreme waves, which can cause permanent or temporary inundation, respectively. This problem needs to be carefully monitored so that coastal areas and existing coastal structures can be upgrade for the consequences as per sea level rise and future proposed coastal structures can be constructed appropriately. The aim of this paper is to carry out a mathematical model study for Astaranga Fishing
Harbour to estimate the sea level rise due to climate change, so that existing fishing harbours can be upgraded in accordance with the projected rise, and proposed harbours can be designed appropriately for the future. Model simulations have been carried out with existing and proposed conditions for both non-monsoon and monsoon seasons. The existing fishing jetty at Astaranga is situated at about 4 km upstream of the river inlet mouth on the right bank of the river Devi. The fishermen face difficulty in berthing their fishing vehicles in the existing jetty region during heavy river discharge from the Naraj barrage during monsoon months. Mathematical model studies were conducted to assess the hydrodynamics pattern and suggest a suitable training work to achieve the desired calmness for the berthing area at the existing jetty. The proposal of extension of existing fishing harbour adjoining the jetty region under Stage II development of the area is also incorporate in model studies. The proposed fishing harbour would be about 452 m long and 325 m wide. Hydrodynamic studies have shown that sea level rise due to climate change is likely to increase by about 0.5 m during non-monsoon season and 0.8 m during monsoon season. Mathematical model simulations also indicated that the change in current magnitude due to sea level rise caused by climate change is about 0.2 m/s during non-monsoon period and 0.25 m/s during monsoon period. The study shows that the change in direction is found to be negligible in both non-monsoon and monsoon seasons.

Key words: Climate change, Mathematical modeling, sea level rise, hydrodynamics, Current

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Application Of Swot Observation In The Estimation Of Inter-Tidal Topography For Improved Coastal Hydrodynamics Modelling

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ABSTRACT

The flooding and ebbing of inter-tidal mudflats are crucial for understanding sediment transport mechanisms and morpho-dynamics. The lack of accurate elevation data for these complex tidal mudflats hampers the ability to accurately simulate critical coastal phenomena, particularly in coastal hydrodynamic models. In this study, we evaluate the application of SWOT observations to enhance the reliability of coastal hydrodynamic models in simulating the flood-dry patterns of inter-tidal mudflats. We create high-resolution hydrodynamic coastal model domains, using SWOT-derived topography of inter-tidal mudflats from High Rate Pixel Cloud data along the Gulf of Kachchh, Gulf of Khambhat, and the northern Odisha coast of Chandipur. The SWOT-estimated mudflat topography is compared with elevation estimates derived from waterline methods using high-resolution optical imagery and ICESat-2 observations. Coastal hydrodynamics are simulated using TELEMAC, with separate domains: one based on NHO charts and the other updated with SWOT-derived inter-tidal topography. The land-water boundary of the inter-tidal mudflats is delineated from high-resolution optical images for different tidal phases and compared with the simulated flooding and drying of the mudflats. The inundation and exposure patterns of the mudflats during flood and ebb conditions are well captured in the model simulations using the SWOT-derived inter-tidal topography.

Keywords: SWOT; Inter-tidal; DEM; Coastal hydrodynamic model; Flood and Dry

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Bragg Resonance Effects Of Multiple Seabed Undulations On The Performance Of Oscillating Water Column Against Wave Currents

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ABSTRACT

In the present numerical investigation, the effect of an array of semi-circular and quarter-circular undulations (SCB and QCB) is evaluated on the performance characteristics of the oscillating water column (OWC) wave energy converter (WEC) under the influence of Bragg resonance. The influence of wave-currents is considered against the multiple undulations and OWC-WEC under the significance of Bragg resonance. The semi-circular and Quarter-circular undulations are proposed to be located at a finite distance from the OWC lip-wall; thus, the gap resonance effects on the variation of engineering coefficients can be studied. The multiple SCBs and QCBs are impermeable for most of the test conditions, and the property of permeability is added to mimic the development of natural sandbars in SCB shape, in front of the OWC-WEC. The numerical method based on the multi-domain boundary element method (MDBEM) is used to examine the boundary value problem. The numerical results are initially validated with the numerical and experimental results available in the literature. Thereafter, the effect of current velocity (in terms of Froude number), number of SCBs, QCBs, spacing between the OWC-WEC and lip-wall, OWC chamber spacing, lip-wall draft, lip-wall rotation, and incident wave length are examined on the variation of OWC efficiency, radiation susceptance, radiation conductance, and forces on the wall against the various ranges of relative water depth, clear spacing, and relative wave frequency. The effect of QCB, SCB porosity, and the number of QCBs, SCBs in the patch is studied and reported using the surface plots. Finally, a comparative study on the variation of hydrodynamic coefficients is performed between the multiple semi-circular, quartercircular undulations with a plane bottom.

Keywords: Oscillating water column, seabed undulations, efficiency, multi-domain boundary element method, Bragg resonance.

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A Relook Into The Surface Wave Climatology Off The South-west Coast Of India

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ABSTRACT

This study examines the spatial and temporal characteristics of wind-generated waves over selected shelf-sea locations along the southwest coast of India using ERA5 reanalysis data of the last 50 years (1975 – 2024). The mean significant wave height (H_s) across the study region ranges from 0.8 to 1.3 m, with maximum values reaching up to 5.9 m, while the peak wave period extends up to 22 s. A predominantly negative trend in the annual mean H_s is observed across the locations over the past 30 years, with magnitudes up to −0.28 cm/year. However, the monthly and seasonal trend of mean H_s and their decadal trends show limited spatial coherence, with robust signals emerging only at a few sites. A comparison of the ERA5 wave data with real-time data sets (from available wave rider buoy measurements) shows that the underestimation of ERA5 H_s is up to 28% during cyclonic events. The study further explores the potential influence of large-scale climate modes on the regional wave characteristics by studying the variability in wave parameters along the southwest Indian shelf sea and their relation to climate indices by establishing the correlation between them.

Keywords: Wind-waves climatology, Wave statistics, ERA-5, DWR buoy data, Climate variability

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Process-Based Modelling Of Seasonal Hydrodynamics And Sediment Transport Along The West Coast Of India

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ABSTRACT

The Sediment transport along the west coast of India is governed by a dynamic interplay of monsoonal wave climate, nearshore currents, tidal dynamics and spatially varied geomorphology. These complex interactions can be captured using an intricate process-based modelling framework that is capable of resolving wave–current interactions, tide-driven circulation, and sediment mobility across diverse coastal settings. This study employs the Delft3D modelling suite to examine seasonal sediment transport behaviour across three representative model domains spanning micro-tidal, meso-tidal, and macro-tidal environments, each characterized by distinct geomorphic conditions including open sandy coasts, headland influenced shorelines, and tidal-flat/estuarine systems. A systematic modelling workflow is implemented across all sites. The Delft3D-FLOW module is used to simulate hydrodynamics, which is calibrated and validated using available water-level and current observations. Seasonal wave forcing, reflecting the highly energetic Southwest monsoon and the relatively calm fairweather seasons, are incorporated through Delft3D-WAVE. The coupled FLOW–WAVE system is then extended to the Delft3D sediment transport and morphology modules, enabling simulation of nearshore sediment transport processes and short-term morphological changes. A morphological acceleration factor (MORFAC=4) is applied to upscale bed level changes maintaining the process fidelity and by limiting computation time. The study attempts to understand how variations in tidal range, geomorphology, and monsoon wave energy collectively influence sediment pathways across the selected study domains. By adopting a unified, physics-driven modelling approach, the work aims to generate a comparative process understanding that supports sediment budget assessment, coastal vulnerability evaluation, and management planning along the monsoon-dominated west coast of India.

Keywords: Sediment transport, Delft-3D, Microtidal–Mesotidal–Macrotidal Regimes, Seasonal
Variability, Morphological Acceleration Factor.

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Observations Of Tidal Currents Across The Cochin Barmouth

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ABSTRACT

The Cochin estuary, located along the southwest coast of India, is one of the most dynamic tropical estuarine systems. Despite its hydrographic and navigational importance, Cochin estuary remains unexplored due to lack of observational data. In this study, we present the results from the hourly observations of currents measured across the barmouth for one month (August 2024) using a vessel – towed Teledyne RDI RiverRay ADCP. The data demonstrate strong spatial and vertical variability in flow structure. Stronger currents were observed in the surface layers, with markedly weaker flows near the bottom. Horizontally, current magnitudes were highest at the central navigational channel, moderate near the northern bank (Vypin), and weakest toward the southern bank (Fortkochi). Harmonic analysis indicates that the tidal flow along the transect is mixed, with both semidiurnal and diurnal constituents contributing significantly. Overall, the major tidal constituents observed along the transect, in order of prominence, are M2, K1, followed by S2, O1, and N2. Harmonic analysis of tidal currents at different depths revealed a siginificant vertical variation in tidal currents. From the surface to a depth of 7 m, K1 dominates, with semimajor axes ranging from 8 to 12 cm/s. Below 7 m, M2 becomes the principal constituent, exhibiting semimajor axes of 11–13 cm/s. Spatially, it is observed that K1 dominates near the northern bank, whereas M2 dominates near the southern bank along the transect. At the central navigational channel the observed tidal current along-estuary weakens with increasing depth, whereas cross-estuary tidal current decreases toward mid-depth and subsequently strengthens toward the bottom. Near the surface, the maximum observed tidal currents reaches approximately 50 cm/s (along-estuary) and 70 cm/s (cross-estuary). At mid-depth, the corresponding maxima decrease to a value of approximately 40 cm/s and 30 cm/s, respectively. Near the bottom, the observed tidal current along-estuary weakens to 30 cm/s, while the cross-estuary tidal current intensify, peaking at 90 cm/s.

Keywords: Cochin estuary, RiverRay ADCP, Tidal currents, Harmonic analysis, Barmouth

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Seasonal Nearshore Bathymetric Response To Southwest Monsoon Forcing Along The West Coast Of India

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ABSTRACT

The seasonal transition associated with the Southwest Monsoon has a strong influence on nearshore morphology along the west coast of India. Rapid changes in wave energy and hydrodynamic forcing during the monsoon can significantly modify nearshore bathymetry; however, the short-term coastal response remains insufficiently quantified due to the intensive fieldwork and economic constraints associated with repeated surveys. This study examines how nearshore bathymetry varies under monsoon forcing along selected stretches of the Goa coast by comparing high-resolution pre- and post-monsoon bathymetric surveys collected using a singlebeam echo sounder. The objective is to identify spatial patterns of morphological change, including steepening, flattening, and accretion, and to assess how these reflect monsoon-driven cross-shore sediment transport. Significant wave height records at the 10-m depth contour are incorporated to characterise seasonal variations in wave forcing and relate them to observed seabed changes.

Preliminary analysis indicates that monsoon conditions cause measurable shifts in contour positions, localised profile steepening, and redistribution of sediment within the shallow nearshore zone. These patterns align with the expected increase in wave-driven sediment mobility during the monsoon season, though detailed quantification is ongoing. The study also estimates the Depth of Closure (DoC) from the bathymetric profiles and evaluates the seasonal influence on closure depth. By linking seasonal bathymetric variation with inferred DoC, the study provides a process-based understanding of how monsoon wave forcing affects nearshore profile dynamics over short timescales. The findings underscore the importance of highresolution bathymetric monitoring in accurately identifying erosion–accretion trends and in supporting the calibration of morphodynamic models in monsoon-dominated coastal systems.

Keywords: Nearshore bathymetry, Depth of closure, Coastal morphodynamics, Single beam echo sounder, Near shore profile evolution.

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Shoreline Change Assessment Of The Goa Coast Using Mike21 Shoreline Morphology Model

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ABSTRACT

Coastal regions are highly vulnerable to erosion and accretion due to changes in the sea level rise. This study focuses on the shoreline changes on the coastline of Goa, India, using the Mike21 Shoreline Morphology modelling tool. The study area has a coastline of 193 km in length, running between 14°50′N latitude and 16°00′N latitude, and 73°40′E to 74°20′E longitude. The area has sandy beaches, estuaries, river mouths and rocky headlands, which have made it an economically and ecologically important area. The database for the numerical model consists of the shoreline positions, bathymetry, tidal data, waves, wind and river discharge, obtained through different sources to create a realistic environment of the coastal processes. It has been validated and calibrated for tide, current speed and direction to ensure the model is reliable with the current scenario. The one-line numerical model uses littoral drift gradient extracted from the coupled Hydrodynamics, sediment transport, Shoreline Morphology and Spectral wave in Mike21 Sediment and Morphology Coupled model, to analyse the shoreline change for the Goa coast. The result is compared with satellite-derived shoreline analysis to ensure that the same trend is observed in both for a one-year period (2023-2024). The shoreline change analysis was carried out further for 35 years, from 1990 to 2025, and the results are classified into erosion, accretion, and stable regions along the coastline. The findings depict that the region in the northernmost Goa coast has undergone erosion at a rate of 15 m/yr contributing a total loss of 51706 sqm of the beach area closer to the river mouth, and the Galgibaga region has faced serious erosion due to Cyclone Taukte, which is also addressed in the long-term shoreline change analysis. While the majority of the coast of Goa remains stable. The calibrated hybrid model can be utilised for future predictions of the shoreline changes. This study gives more realistic estimates of the possible shoreline retreat with the use of modern modelling methodology and rich datasets to help in planning, adaptation plans and sustainable management of the vulnerable Goa coast.

Keywords: Shoreline Morphology, DSAS, Coastline Retreat, Mike21, Littoral Drift

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Island chains as Wave Modulators: WavewatchIII -Based Evaluation of Lakshadweep's Role in Shaping Kerala's Wave Climate

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ABSTRACT

The Lakshadweep Islands form a prominent chain of corals in the eastern Arabian Sea and play a critical role in modulating the wave climate along the adjacent Kerala coast. Despite their strategic position, the quantitative influence of these islands on nearshore wave transformation, attenuation, and coastal vulnerability has remained poorly constrained. In this study, we employed the third-generation spectral wave model WAVEWATCH III (WW3) to assess the impact of the Lakshadweep archipelago on wave characteristics along the Kerala coastline. Two numerical experiments were conducted: (1) a baseline simulation representing present-day bathymetry and island geometry, and (2) a sensitivity simulation in which the Lakshadweep Islands were removed from the model grid to create an "open-sea" scenario. Comparison of significant wave height and wave direction between the two configurations enabled clear isolation of the shadowing, refraction, and diffraction effects produced by the island chain. The results demonstrate that the presence of the Lakshadweep Islands substantially reduces wave energy reaching the central and northern Kerala coast, with the strongest attenuation observed during the southwest monsoon. An additional assessment of extreme events, including recent tropical cyclones, revealed that the islands play an even more critical role during high-energy conditions significantly limiting the wave heights and reducing coastal exposure along Kerala. Overall, the study highlights the Lakshadweep Islands as a natural wave barrier with major implications for wave climate regulation, extreme-event mitigation, and long-term coastal resilience. These findings provide valuable insights for regional coastal management, hazard assessment, and shoreline planning along the Kerala coast.

Keywords: Lakshadweep Islands, Wavewatch III, Wave climate, Extreme events, Numerical Modelling

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Modeling Shoreline Evolution And Sediment Transport Along The Malvan–Tarkarli Coast, South Maharashtra

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ABSTRACT

Coastal shorelines are dynamic systems that undergo continuous change under the combined influence of natural forces and human interventions. Understanding shoreline behavior through numerical modeling is essential for predicting coastal responses and developing sustainable management strategies. The present study focuses on the 13 km coastal stretch between Malvan and Tarkarli, located along the South Maharashtra coast, emphasizing the hydrodynamic influence of the historical Sindhudurg and Padmagad forts on nearshore processes and sediment transport. A numerical shoreline evolution model was developed using MIKE 21 and LITPACK modules, integrating LITDRIFT for estimating longshore sediment transport and LITLINE for simulating shoreline evolution. The nearshore wave climate was derived from ERA5 reanalysis data, temporally interpolated to 30-minute intervals using the MIKE Zero Toolbox. Bathymetry, shoreline configuration, and sediment characteristics were obtained through detailed field surveys, ensuring reliable boundary conditions for model setup and calibration. The model incorporates a median grain size of 0.25 mm, bed roughness of 0.04 m, sediment fall velocity of 0.0386 m/s, and a geometrical spreading coefficient of 1.5. A 30-year simulation period has been designed to analyze spatio-temporal shoreline changes and sediment transport patterns influenced by the forts and coastal geomorphology. The study aims to quantify longshore sediment transport, evaluate the structural influence of coastal forts on shoreline dynamics, and identify patterns of long-term coastline evolution to support effective coastal management.

Keywords: Shoreline evolution, MIKE 21, LITPACK, Longshore sediment transport, Coastal Modeling

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Analysis Of Shoreline Change Along The Goa Coast From In-Situ Measurements And Using Mike Litline.

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ABSTRACT

The coast is the dynamic transition zone where land, ocean, and atmosphere interact, while the shoreline is the narrow strip of land that meets the ocean. The total coastal stretch of Goa is approximately 160 km, characterised by diverse geomorphological settings and varying degrees of exposure to wave action and sediment transport. For the study, the shoreline along particular stations was taken, divided into North Goa (Baga to Sinquerim) and South Goa (Velsao to Mobor). The studies aim to assess shoreline change through a comparative evaluation of in-situ observations using RTK and numerical modelling of shoreline evolution using the LITLINE model within the LITPACK model of MIKE21. The key inputs of the model are bathymetric profile, initial shoreline, sediment properties and wave climate. The simulation is calibrated and validated using the satellite imagery and field data. However, the study identifies notable uncertainties related to bathymetry, as the model assumes that bathymetry remains constant over the specified period. The study analyses shortterm and long-term shoreline changes up to 2030. Overall, the study highlights the importance of integrating numerical modelling with sustained field measurements to enhance understanding of coastal dynamics and inform effective coastal zone management strategies for the Goa region.

Keywords: Shoreline change, Beach stability, LITLINE, Active depth, RTK

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Integrated Assessment Of Monsoonal Turbidity Dynamics And River-Coast Connectivity Along The Western India

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ABSTRACT

This study uses a combination of in-situ observations of two years (2022–2023) like suspended sediment load, river flow velocity, flow direction, discharge volume from Acoustic Doppler Current Profiler (ADCP) and Laser In-Situ Scattering and Transmissometry (LISST) to evaluate the monsoonal variability of turbidity dynamics in five major rivers in Goa that discharge into the Arabian Sea along the western coast of India. It focuses on the Zuari, Mandovi, Chapora, and Terekhol in Goa and the Karli river in southern Maharashtra. The integration of in-situ datasets enhanced the temporal resolution of sediment flux estimates by revealing distinct sediment signatures specific to individual rivers and highlighting areas of increased coastal turbidity. The results clearly demonstrate a seasonal trend, with monsoon conditions delivering the highest turbidity levels, often an order of magnitude higher than pre-monsoon values-due to high rainfall conditions (~3300 mm), hence increased flow turbulence and discharge. As flow regimes stabilised, post-monsoon suspended sediment loads as well as the turbidity consistently decreased in all rivers. It has been identified that turbidity plumes extending into near-shore coastal zones capture short-term variability during peak monsoon runoff. Overall, the study demonstrates that by integrating hydrological and optical measurements, a trustworthy framework for monitoring turbidity from rivers to the coastal ocean along the western Indian coast may be developed. This approach supports coastal management, improves understanding of the relationship between land and sea sediments under monsoon-driven climatic conditions, and helps identify seasons most vulnerable to erosion, reduced water clarity, and altered coastal conditions.

Keywords: Turbidity Dynamics, River discharge, River-Coast Connectivity, LISST, ADCP.

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Assessing Monthly Suspended Sediment Variability And Seabed Grain Size Along The Goa–Maharashtra Coast

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ABSTRACT

This study investigates nearshore sediment dynamics along India's west coast by analysing suspended sediment concentration (SSC) and seabed characteristics across three coastal transects in South Maharashtra, North Goa, and South Goa. Monthly SSC measurements were collected over the course of a year from surface, mid-depth, and bottom layers at five depth contours (2, 4, 6, 8, and 10 m), providing a detailed vertical and cross-shore profile of sediment suspension. Complementary seabed samples from each contour were analysed for median grain size (D_{50}) to characterise local bed material. This dataset is used to evaluate how SSC varies spatially and vertically across the shore-perpendicular profile, how its statistical distribution changes from contour to contour, and how seasonal shifts influence sediment suspension patterns. Regional wave climate data corresponding to the sampling period are incorporated to assess the influence of wave energy variability on observed SSC trends. Together, these observations enable a comprehensive assessment of the spatiotemporal behaviour of SSC and its linkage to wave forcing and seabed sediment texture.

Keywords: Suspended sediment concentration (SSC), Seabed sediments, Vertical sediment variability, Seasonal variation, Wave climate.

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Hydrodynamic Modelling And Tidal Stream Energy Assessment Of The Okha Channel, Gulf Of Kutch

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ABSTRACT

The Gulf of Kutch on India's west coast is known for its strong tidal amplitudes, yet several locations within the region exhibit relatively weak tidal currents that limit their suitability for tidal-stream energy extraction. The Okha Channel, situated at the western entrance of the Gulf, is a narrow, semi-enclosed tidal passage influenced by complex bathymetry and semi-diurnal tides. Understanding its hydrodynamic behaviour is essential for evaluating its natural tidal energy potential. A depth-averaged Delft3D FLOW-WAVE model was developed to simulate the hydrodynamics of the Okha Channel for the year 2024. The model incorporated TPXO tidal constituents, ERA5 wind and wave forcing, with high-resolution bathymetry from GEBCO combined with local survey data. Model calibration and validation were performed using historical current meter observations, ensuring accurate reproduction of tidal velocity. The validated model was used to compute spatial and temporal variations in tidal velocities and to estimate a baseline tidal-stream energy availability at five representative sites along the channel. Results indicate that the channel experiences moderate tidal currents, with depth-averaged velocities generally ranging between 0.3 and 1.0 m/s. Estimated daily tidal-stream energy typically varies from 10 to 350 kWh/day, depending on the site and tidal cycle. Although these values are insufficient for optimal turbine operation, they provide a clear understanding of the baseline hydrodynamic regime and identify zones with relatively higher tidal activity. The study establishes a reliable hydrodynamic framework for the Okha Channel and provides essential baseline data to support future assessments of flow-enhancement strategies and renewable energy planning in the region.

Keywords: Tidal energy, Hydrodynamic modelling, Delft3D, Gulf of Kutch, Okha Channel

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Spatio-Temporal Dynamics Of Alappuzha Mudbank: A Study Using Satellite Observations And Numerical Simulations

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ABSTRACT

Mudbank formation along the Kerala coast has long intrigued coastal researchers due to its unique dynamics and environmental impacts. Mudbanks form when dense benthic fluid mud in the coastal region dissipates high monsoonal waves, creating tranquil zones amid turbulent coastal waters. Under favourable conditions, in medium-high resolution optical images the sun glint makes ocean wave pattern visible. Using cloud-free optical images from 2004 to 2023, we delineated mudbanks by identifying wave tranquil zones along the coastal region where mudbanks are regularly reported. Textural analysis using the Gray-Level Co-occurrence Matrix (GLCM) was employed to demarcate mudbank boundaries. Unlike previous reports describing mudbanks as semi-circular, our study reveals a range of shapes, depending on the growth stage. Here for the first time, we report the shape of mudbank during the initial stage that gives insight on the possible genesis of mudbank. Shore perpendicular linear patches of calm regions during the months of May-July, hitherto not reported, are observed from satellite images. Modelling with XBeach, forced with wave spectra representing the combined effects of swell and wind waves, identified high wave energy zones perpendicular to the coast. We propose that this region of wave energy convergence initiates the suspension of bottom sediments and with favourable conditions forms fluid mud creating tranquil waters perpendicular to the coast as observed from the satellite images. The satellite observation over the year, have clearly brought out the consistent southward shift in the mudbank formation region. The present study brings out the application of satellite images in comprehending the complex and unique dynamics of mudbank, which has been previously underexplored. Further insight into the mudbank dynamics shall be possible by tracking the formation events with network of in situ data and simultaneous satellite observations.

Keywords: Mudbank, Sun glint, Textural analysis, Xbeach

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Adaptive Granular Barriers for Efficient Coastal Protection.

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ABSTRACT

Coastal erosion and wave-induced flooding pose increasing threats to coastal communities, often leading to major damage during storm events. Conventional rigid barriers such as sea walls often fail prematurely because they reflect, rather than absorb, incident wave energy. This work aims to develop and evaluate granular coastal barriers that can adapt to wave loading through natural energy dissipation and re-arrangement. Laboratory experiments are conducted in a custom-built wave flume equipped with a motorized wave generator to simulate real coastal conditions at a reduced scale. Various granular configurations are tested to assess their capacity for wave attenuation, reduction of overtopping, and structural resilience. Preliminary observations indicate that granular barriers dissipate a significant portion of wave energy through particle motion and compaction, reducing reflected energy and improving stability under repeated wave impact. The study demonstrates the potential of granular barriers as a sustainable, lowmaintenance, and adaptive alternative to traditional rigid coastal defenses, with promising implications for protecting vulnerable shorelines, deltas, and island regions.

Keywords: Coastal erosion, Granular coastal barriers, Wave energy dissipation, Overtopping reduction, Sustainable coastal protection

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Coastal wave during the tropical cyclone “Tauktae” in the eastern Arabian Sea

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ABSTRACT

The Arabian Sea has been reported as one of the most productive aquatic environments. The progressive and aggressive nature of cyclones in the Arabian Sea not only threatens the open ocean resources, ecosystem, and habitats, but also its vulnerability along the coastal belt, especially the west coast of India, is one of the major concerns nowadays. During the cyclone “Tauktae”, that appeared during 14-19 May, 2021, the eastern Arabian Sea was recorded in mosaic form of both short and long period waves. The sea surface in the Goa and Ratnagiri coasts is dominated by the southwest and southwest-west waves, whereas the Versova coast is predominantly observed by southwest waves. Along with the northward propagation of “Tauktae”, the Goa coast recorded a significant (maximum) wave height up to 5.6 (9.7) m, followed by the significant (maximum) wave height up to 5.6 (8.4) m in the Ratnagiri coast. Successively, the Versova coast recorded significant (maximum) wave height up to 4.8 (7.4) m. Concurrently, the half-hourly wave energy (power) during the cyclone Tauktae was intensified up to 39.1*103 J/m2 (140 kW/m), 38.7*103 J/m2 (136.4 kW/m), and 29.2*103 J/m2 (90.9 kW/m) in the coastal water off Goa, Ratnagiri, and Versova, respectively. Synchronously, the 0.5° resolution hourly ERA5 indicates that during cyclone “Tauktae”, the maximum (average) wave energy in the Goa, Ratnagiri, and Versova coasts was intensified about 26 (4), 13 (3), and 28 (4) times, while the extreme (average) wave power was 36 (5), 14 (4), and 34 (4) times as compared to the typical wave climax of dry weather conditions during May 2022. This reveals that giving a priority to implementing coastal protection measures by accounting for the probable sea surface wave vulnerability during such extreme weather will be highly effective for the Sustainable Development Goals.

Keywords: Sea Surface Wave, Wave Energy, Wave Power, Renewable Energy, West coast of India

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Characteristics And Variability Of Upwelling In The

Southeastern Arabian Sea

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ABSTRACT

The southeastern Arabian Sea (SEAS), driven by monsoonal winds, exhibits pronounced variability in both hydrography and circulation. The seasonal coastal currents and associated upwelling make this region highly dynamic enhancing biological productivity. The upwelling in the SEAS during 2013-2020 is examined utilizing the Ocean Moored Buoy Network for northern Indian Ocean (OMNI) located at 10.3 °N, 72.6 °E (AD10) deployed by National Institute of Ocean Technology (NIOT). The hourly temperature data at discrete depths from 2013-2020 forms the primary dataset for this analysis. The eight-year temperature dataset shows shoaling of isotherms, with a minimum during September–October, and clear interannual variability. To capture the broader coastal upwelling signals, six grid points along 10 °N–10.5 °N from the Copernicus Marine Environment Monitoring Service (CMEMS) were analyzed due to the lack of OMNI observations closer to the coast. Comparison of temperature data between AD10 and CMEMS indicates similar patterns and magnitudes across all depths, although CMEMS values were considerably lower in some years. The shoaling of the 26°C isotherm (D26) reached its minimum in September–October at the AD10 location, while a point closer to the continental shelf (10 °N –10.5°N, 75.3 °E –75.8°E) showed the minimum in July, indicating a temporal lag in the spreading of the upwelling signal away from the shelf region. The minimum D26 was observed during 2016 (~18 m) and 2017 (20 m). The Ekman transport and Ekman pumping velocity were estimated. The upwelling cell characteristics with the details of offshore extend and interannual variability in the southeastern Arabian Sea will be highlighted.

Keywords: Upwelling cell, SEAS, D26, propagating waves

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The Causes Of The Difference In Marine Heat Wave Conditions During The Summers Of 2019 And 2020 In The Northern Bay Of Bengal

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ABSTRACT

Time series measurements of the high-resolution vertical profile of temperature, salinity, current velocity and surface meteorological parameters from a moored buoy at 17.8°N, 89.5°E in the northern Bay of Bengal (BoB) are used to document differences in the marine heatwaves (MHW) conditions between summer (defined as June to September) 2019 and 2020 and its plausible connection with northward propagating monsoon intraseasonal oscillation (MISO). It was found that the summer of 2020 exhibited significantly warmer SST anomalies in the northern BoB with magnitudes exceeding 1°C north of 15°N, compared to the near climatological state in 2019.Consequently, MHW metrics reveal a moderate and persistent MHW state in the summer of 2020 in contrast to the sporadic and weak MHW conditions in 2019. In the summer of 2019, the northern BoB experienced progressive cooling, modulated by the sequential occurrence of MISO events with no significant break period between the events. Despite a similar number of MISO activities in 2020, seasonal cooling was absent, leading to persistent MHW conditions with a peak magnitude in August 2020. A mixed-layer heat budget analysis using flux mooring data indicates that the enhanced net shortwave radiation (NSW) was the primary factor responsible for the MHW in 2020. The westward extension of an anomalous anticyclone over the northwestern Pacific into the BoB reduced cloud cover, thereby increasing NSW heating at the ocean surface in 2020. This mechanism weakened MISO-driven cooling, allowing SST to remain anomalously warm in 2020, along with a prolonged break between the events.

Keywords: Bay of Bengal, Monsoon Intraseasonal Oscillation, Marine Heatwaves, Mixed layer
heat budget

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Classification And The Acoustical Significance Of Surface Layer Temperature Inversion In The North Indian Ocean

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ABSTRACT

Surface Layer Temperature Inversion (SLTI) is a distinctive upper-ocean feature that strongly influences air–sea heat exchange and regional climate variability. In the North Indian Ocean, SLTIs are particularly significant because of the region's unique monsoon-driven forcing, strong freshwater influx, and pronounced seasonal stratification. SLTI occurs predominantly in winter months. This study examines the spatial distribution of SLTI using a 20-year dataset obtained from the World Ocean Database 2018 and ARGO data during 2000-2020. The temperature profiles with $\Delta T>0.5°C$ and inversion layer thickness>5 m is considered for the study.

Their spatial distribution from October to March during 2000-2020 were analysed. Prominent and localized inversions first appeared in the BoB in the Krishna Godavari basin (between 13° and 19° N) during October. SLTI with a maximum ΔT of 2° C and ILT of 40–50 m is found in this region. Previous studies indicates that the formation of SLTI is governed by four primary factors which are (i) net surface heat loss, (ii) low surface salinity due to river flux, (iii) advection of cold low saline water over warmer saline water, and (iv) penetrative solar radiation. In this study the prominent SLTI regions in the North Indian Ocean are characterised based on individual and combined causative factors. Prominent areas of the Arabian sea and Bay of Bengal have been classified and grouped into different types of inversion with respect to the dominant causative factors of SLTI and its acoustic significance is presented. This study provides a comprehensive assessment of seasonal inversion dynamics in the North Indian Ocean.

Keywords: Surface Layer Temperature Inversion, North Indian Ocean

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Role Of Regional Ocean Dynamics In Intensifying Post-Monsoon Cyclones In The Bay Of Bengal

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ABSTRACT

The role of regional ocean dynamics (ROD) in intensifying post-monsoon tropical cyclones (TCs) in the Bay of Bengal (BoB) is critical due to the unique interactions between oceanographic and atmospheric processes. The BoB is particularly a site of TCs, especially during the post-monsoon season (October to December), and ROD plays a key role in determining their time evolution and intensity. During 2012 to 2018, a total of 13 cyclones formed in the BoB and maximum number of 4 cyclones occurred in 2013. In the present study, we have examined the TC induced variability in the oceanic and atmospheric responses such as sea surface temperature (SST), tropical cyclone heat potential (TCHP), wind speed, relative humidity, and sea level pressure during the period from 2012 to 2018 using data from the moored buoy deployed in the BoB. These upper ocean mixing processes play a crucial role in governing cyclone intensification. The role of large scale climatic drivers such as vertical windshear, relative vorticity anomaly is also examined to understand how these ROD impacts the life cycle of TCs.

Results indicate higher SST (~30 °C) conditions prevailed near the buoy locations for three cyclones; Hudhud, Kyant and Titli before the cyclone which subsequently cooled with maximum SST cooling of 2.6 °C in case of Titli. High humidity levels (~ 90%) during post-monsoon provide the necessary latent heat flux to drive the TCs. Significant hike in TCHP and drop in D26 are noted during the cyclones Phailin, Hudhud, Kyant at BD10 and Lehar, Nada and, Okchi at BD11. Wind speed exceeding 28 m/s was recorded in case of Phailin and Madi during 2013 and Vardah during 2016. ROD through warm SSTs, high TCHP, provide the energy reservoir that fuels cyclone growth, while cyclone-induced mixing, cooling, and changes in stratification modulate cyclone evolution and intensity.

Keywords: Tropical Cyclones, TCHP, ROD, Climatology, Bay of Bengal

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Impact Of Model Resolution On The Somali Coastal Current And Its Summer Upwelling

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ABSTRACT

The Somali Current is the strongest boundary current in the northern Indian Ocean, exhibiting intense upwelling during summer and downwelling during winter. During summer, the upwelled water brings subsurface nutrients to the surface layers, leading to one of the strongest chlorophyll blooms in the Indian Ocean. Since most observations in this dynamically active region date back to the 1960s-1970s, models are often used to describe this current system.Here, we employed two Modular Ocean Model (MOM6) simulations of varying resolution, to investigate the impact of model resolution on the Somali Current system. The coarse simulation uses a 1/12o (~9 kms) global configuration (MOM6-LR) and the high-resolution simulation uses a 1/36o (~3 kms) regional Indian Ocean configuration nested within the global model with a south open boundary exchange at 8oS (MOM6-HR). Both models are otherwise identical and forced by the JRS55-do atmospheric fluxes. Both models could simulate the seasonally reversing Somali current system with equatorward flow during winter and poleward intense current during summer. However, there are significant differences in the simulations for a given season. The coastal current is much narrower in MOM6-HR than in MOM6-LR, although both produce comparable maximum speeds of 1–1.5 m/s in August. The vertical extent differs: in MOM6-HR, the current reaches ~900 m depth during August, whereas in MOM6-LR it is limited to the top 300 m. While the poleward summer current ceases by late September in the MOM6-LR as the summr monsoon winds wane off, it persists until the end of November in MOM6-HR, driven by the late-arriving offshore Rossby waves. As a result, summer monsoon volume transport is significantly higher in the MOM6-HR transporting warm equatorial waters and resulting in relatively warmer SST off the coast compared to MOM6-LR. Moreover, the equatorward Somali undercurrent is observed in MOM6-HR during the fall, beneath the northward surface current, with a core depth of ~150-200 m. These results indicate that the horizontal resolution significantly influences the coastal current systems in the northern Indian Ocean and may affect uncertainties in the cross-basin transports and regional climate simulations.

Keywords: Somali current system, upwelling dynamics, model resolution, Rossby waves, MOM6.

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Temperature inversions in the tropical Indian ocean

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ABSTRACT

Temperature inversions (anomalous increase of temperature with depth) significantly impacts the upper ocean dynamics, oceanic heat budget and can also influence weather phenomena like cyclones, monsoon, marine heatwaves etc., Previous studies have examined the factorsresponsible for the formation and sustainability of inversions such as freshwater flux, advection,surface cooling and the influence of waves. But quantitative analysis of these inversions are still lacking. This study aims to focus on quantification as well as examine the spatial and seasonal variability of temperature inversions across four regions- Arabian sea(AS), Bay of Bengal(BoB), Central and Equatorial Indian ocean (CEIO & EEIO) where the inversions are predominant. For this purpose, more than 77,000 Argo profiles, Tropflux heat flux, AVISO sea level anomaly datasets are used. Results reveal that inversions predominantly occur during winter (November–February), with the Bay of Bengal exhibiting the strongest signatures, reaching up to 4.79°C at depths of 10–65 m, driven by intense freshwater stratification and surface cooling. In the southeastern Arabian Sea, inversions are associated with the advection of low-salinity BoB waters by the East India Coastal Current and Winter Monsoon Current. In contrast, the EEIO displays strong summer inversions linked to the Indonesian throughflow. A significant statistical relationship between temperature inversion magnitude and salinity increase demonstrates, for the first time quantitatively, that salinity plays a fundamental role in compensating density and sustaining inversion layers. This work improves the understanding of temperature inversion dynamics,highlight the importance of salinity-driven stratification in regulating regional heat content,mixed-layer processes, and monsoon variability, offering improved insights for ocean-atmosphere model representation and cyclone prediction.

Keywords: Temperature Inversions, Salinity compensation, Quantitative analysis

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High-Resolution Moored Observations Of Near-Inertial Kinetic Energy And Diapycnal Heat Flux During Tropical Cyclone Bulbul In The Northern Bay Of Bengal.

ABSTRACT

An improved understanding of the fraction of wind power input into the mixed layer (ML) near-inertial kinetic energy (NIKE) that propagates below the ML and also the relative importance of diapycnal heat flux in determining SST cooling compared to other terms in the ML heat budget is imperative for the better representation of the upper ocean response to TC in the numerical weather prediction model and operational forecasting model using for extended range predictions. However, due to shallow salt stratified ML in the Bay of Bengal, these two topics are not well explored since high vertical resolution near-surface hydrographic measurements are not available. In this study, we used time series measurements of high-resolution vertical temperature, salinity, current velocity, and surface meteorological parameters from a heavily instrumented mooring deployed at 17.8Â°N, 89.5Â°E to investigate the upper ocean response to TC Bulbul in the northern Bay of Bengal to analyze the NIKE budget of ML, and to quantify the diapycnal heat flux at the base of ML. The wind power induces a sharp rise in ML NIKE, followed by its downward propagation, with subsurface NIKE about half of the ML value and lagging by approximately two days. Radiation of NIKE at the ML base increases vertical shear of currents, leading to a fourfold enhancement of diapycnal diffusivity to 1.25 Ã— 10-3 m2s-1 compared to the pre-cyclonic value (3.3 Â± 0.04 Ã— 10-4 m2s-1). As a result, diapycnal heat flux at the ML base increased to -126.4 Â± 11.4 Wm-2 from the pre-cyclonic value of ~2.7 Â± 1.9 Wm-2. During the peak cooling phase of ML, diapycnal heat flux (-200 Wm-2) shows a comparable contribution with respect to net heat flux term.

Keywords:Tropical Cyclone, Near-Inertial Kinetic Energy, Diapycnal heatflux

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Influence Of Air–Sea Heat And Freshwater Fluxes On Water Mass Transformation In The Indian Ocean

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ABSTRACT

Air–sea fluxes and the ocean surface density field play a critical role in buoyancy-driven water mass transformation, forming a key link between atmospheric forcing and ocean circulation. In this study, we analyze the contributions of surface heat and freshwater exchanges to the transformation of surface water masses in the tropical Indian Ocean. Using the ECMWF Ocean Reanalysis System 5 (ORAS5) at a 0.25° × 0.25° resolution, we compute and examine ocean surface density fluxes for the period 1985–2015. The density flux is calculated using sea surface temperature (SST), sea surface salinity (SSS), net heat flux (NHF), and evaporation minus precipitation (E–P–R).

Building on a diapycnal framework, we assess surface density fluxes as a function of isopycnal out-cropping to identify regions and seasons of active water mass transformation. Our results reveal that surface waters in the North Indian Ocean (NIO) densify during the Post-Monsoon and Winter seasons, primarily due to net heat loss, with freshwater fluxes modulating the spatial extent of this transformation. In contrast, the Pre-Monsoon season is characterized by widespread light surface waters across the NIO, while the South Indian Ocean (SIO) south of 10°S consistently exhibits surface densification driven by strong evaporation, coinciding with the region of Indian Ocean Mode Water formation and the southern limb of the Indian Ocean Meridional Overturning Circulation (IMOC).

During the Southwest Monsoon, density fluxes intensify over the Arabian Sea and SIO, driven jointly by enhanced latent heat loss and wind-driven evaporation. The Bay of Bengal (BoB), in contrast, maintains persistently low surface density throughout the year due to substantial freshwater input from rivers and precipitation, thereby suppressing surface-driven transformation. At the conference, I will present both the annual cycle and interannual variability of surface diapycnal density fluxes across a range of isopycnals, highlighting regional contrasts in the drivers of water mass transformation between the Indian Ocean, a crucial aspect in modulating the IMOC.

Keywords: Water-mass transformation, Surface density flux, Indian ocean circulation, Air-sea interaction, Heat and freshwater flux

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Diapycnal Oxygen Flux In The Oxycline Region Of The Core Of The Arabian Sea Oxygen Minimum Zone

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ABSTRACT

This study quantified the relative contributions of double diffusion and shear-driven mixing on the diapycnal oxygen flux in the oxycline region of the core of the Arabian Sea Oxygen Minimum Zone (OMZ), a critical oceanic region regulating the local ecosystem dynamics significantly. For that purpose, we used concurrent measurements of vertical profiles of dissolved oxygen and microstructure shear collected during the scientific cruise in May 2019. It was found that the presence of a moderately strong salt finger regime in the oxycline region enhanced the downward diapycnal oxygen flux (-7.0 ± 0.5x10-2 µmol m-2 s-1) by an order of magnitude higher in contrast to traditionally considered shear-driven turbulence alone (-6.4 ± 0.7 x 10-3 µmol m-2 s-1). This difference is solely attributable to the small magnitude of diapycnal diffusivity due to shear-driven turbulence (2.8 ± 1.1 x 10-6 m2 s-1) compared to salt finger (10-5 to 10-4 m2 s-1). For the sake of comparison, the magnitude of lateral flux of oxygen due to horizontal circulation (3x10-4 µmol m-2 s-1) and oxygen consumption rates due to biological processes estimated from observation (-3x10-3 to -40 x 10-3 µmol m-2 s-1) were much smaller than salt finger induced downward diapycnal oxygen flux in the oxycline region. As a result, there was a net downward oxygen flux from the oxycline into the OMZ. These findings highlighted the need to incorporate double diffusion processes in biogeochemical models to improve the accuracy of vertical oxygen distribution simulations in the Arabian Sea OMZ.

Keywords: Diapycnal Mixing, Diapycnal oxygen flux, Double diffusion, Arabian Sea Oxygen
Minimum Zone

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Model derived eddy kinetic energy budget in the northwestern Indian Ocean

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ABSTRACT

Northwestern Indian Ocean (NWIO) is characterised by seasonal reversal of intense monsoonal wind flux that in turn governs various physical mechanisms which influence turbulent mixing in this region. In this study, the spatio-temporal variation of source and sink terms of eddy kinetic energy (EKE) budget terms are investigated using a model simulated data. The analysis shows that the mean kinetic energy (MKE) and EKE are dominant in the upper 300 m and the spatial average of MKE and EKE exhibit similar strength in winter monsoon (December to February, DJF), while in the summer monsoon (June to September, JJAS), MKE is almost 4 times of EKE in the upper 100 m. The barotropic conversion of MKE to EKE is divided into horizontal component (BTR), which results due to horizontal shear of mean flow, and vertical component (KHR) caused due to vertical shear of mean flow and Reynolds stresses. During DJF, BTR is negative along the Somalia coast indicative of energy transfer from small scale eddies to mean flow, while KHR is weak. In the same region, through baroclinic conversion (BCR), EKE is produced from eddy potential energy (EPE). It is speculated that the energy transfer from eddies to mean flow owing to negative BTR is sustained by buoyancy production of EKE. In western equatorial region, both BTR and KHR are positive, indicating energy extraction from mean flow to turbulent eddies, while buoyancy production of EKE is weak. Dissipation through eddy viscosity is typically high in regions of high EKE production, while weak dissipation could indicate turbulent energy advection. BTR is dominantly positive along the Somalia coast during JJAS indicating forward cascade and buoyancy flux assists in the production of EKE, however, dissipation remains weakest in JJAS. Similarly, other regions of dominating EKE budget terms are analysed and a comprehensive summary for identifying regional preference of mesoscale
turbulence and their seasonality is provided.

Keywords: Northwestern Indian Ocean, Eddy kinetic energy, Shear Production of EKE

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An Improved Bulk-To-Skin Sea Surface Temperature Parameterization For Rain-Affected Conditions

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ABSTRACT

Accurate skin sea surface temperature (SSTskin) estimation is essential for air-sea flux computation, satellite validation, and ocean-atmosphere modeling. This study presents a new multi-stage parameterization scheme for converting bulk SST (SSTbulk) to SSTskin, developed using high-resolution ship-based observations from the Arabian Sea. The scheme sequentially accounts for the effects of wind speed, diurnal stratification, longwave radiative cooling, and precipitation-induced surface cooling, each empirically derived from observed relationships. Unlike existing models, the proposed method explicitly incorporates rainfall effects, enhancing its accuracy during precipitation events. Evaluation against direct SSTskin measurements from the Arabian Sea shows that the new model achieves the lowest mean bias (~−0.02°C) and rmse (~0.2°C) compared to other established schemes. Independent validation using ship-borne data from the subtropical Pacific, and satellite SST validation at a Bay of Bengal mooring location, demonstrated similarly strong performance, a bias of ~0.04°C and rmse of <0.6°C. These results suggest the scheme has strong potential for improved performance in other monsooninfluenced and convectively active regions, warranting further investigation. Including a precipitation correction represents a significant advancement, enabling a more accurate representation of the surface thermal variability under convective weather. This study thus provides a practical and physically informed approach to convert the SSTbulk to SSTskin, with implications for improved air-sea interaction modeling in monsoon and convectively active regions.

Keywords: SSTskin, SSTbulk, parameterization scheme, rain-induced surface cooling, Arabian Sea observations.

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Eddy induced Upper Layer Changes in the Bay of Bengal from Satellite and In-Situ Observations

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ABSTRACT

This study investigates the eddy activity in the Bay of Bengal during 2023-2024 using a combination of satellite altimetry (gridded and tracks), high resolution (2 km) SST from the multi-satellites and observations from Argos and four moored buoys (NIOT). The analysis reveals pronounced seasonal variability in both the number and radius of mesoscale eddies across the basin. A total of 217 mesoscale eddies with a lifespan greater than 7 days were detected between August 2023 and June 2024, comprising 117 cyclonic and 100 anticyclonic eddies. The fine-strcuture of the eddies are investigated with the altimetry tracks and supported by the high resolution SST. In-situ buoy measurements show modifications to the upper-ocean thermal structure as eddies propagated across the mooring locations. Notably, the thermocline deepened significantly during the passage of anticyclonic eddies, consistent with their downwelling nature, whereas cyclonic eddies caused shoaling of the thermocline through upwelling processes. Argo observations similarly reveal strong temperature variability reflected in both shallower and deeper D26 depths. The subsurface variations were accompanied by corresponding changes in mixed-layer temperature, confirming the strong vertical coupling induced by mesoscale features. The combined satellite and in-situ datasets highlight the critical role of mesoscale eddies in modulating upper-ocean stratification in the Bay of Bengal, with implications for heat storage, air–sea interactions, and regional climate variability.

Keywords: Ocean eddies, Bay of Bengal, Satellite altimeter, Upper ocean process, Air-sea interaction

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"Monsoon Signature from Swell Waves": An Integrated Observational–Modeling Approach

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ABSTRACT

Southwest (SW) monsoon onset is a critical climatic event for the Indian subcontinent, typically reaching the Kerala coast in early June but advancing into the Andaman & Nicobar Islands by mid-May. Accurate early prediction of onset remains challenging. This study explores a new oceanographic indicator for onset prediction—the signature of long-period swells waves across the Indian Ocean—through an integrated observation-modeling framework. The wave climate of the North Indian Ocean during the SW monsoon is dominated by long-period swells generated in the Southern Hemisphere. These swells travel thousands of kilometres with minimal attenuation, carrying the imprint of their generation regions. By tracking these propagating swells, we detect precursory signals that precede monsoon development. A comprehensive dataset was assembled, including satellite altimeter wave heights, wave rider buoy records from India's east and west coasts, deep-water moorings, ERA5 reanalysis, and spectral wave model outputs. The WW3 model was run over the Indian Ocean and validated against satellite altimetry and buoy observations to ensure that modeled swell propagation remained in phase with real ocean conditions. Results reveal a distinct swell precursor to the monsoon. In April, the basin exhibits low significant wave heights (~0.5–1 m). About 10–15 days before onset, a sustained increase to 1.5–2 m is observed due to incoming long-period swells from the southern Indian Ocean. This signal is especially prominent in the Bay of Bengal and Andaman Sea, where the monsoon arrives nearly few days before Kerala, thereby extending the lead time for onset prediction. Swells generated in mid-May reach Indian coastal waters within 4–7 days, offering an oceanic early warning of the impending monsoon. This study provides the first integrated evidence that swell tracking can enhance both accuracy and lead time of monsoon onset forecasts. The consistent swell-based signature seen across observations and models demonstrates its potential as a robust precursor. Coupling ocean swell information with atmospheric indicators offers a promising pathway toward an improved early onset prediction system for the Indian Ocean region.

Keywords: Monsoon Onset, Swell Tracking, Indian Ocean, Numerical modelling, Satellite altimetry.

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Air-sea interaction processes and mixed-layer Heat budget in the Arabian Sea during the northward Propagating summer Monsoon Intraseasonal Oscillation (MISO)

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ABSTRACT

The northward propagating organized convective activity on 20–60-day timescale from the equatorial Indian Ocean (EIO) is a striking phenomenon during the Indian Summer Monsoon. This phenomenon is usually referred to as the summer monsoon intraseasonal oscillation (MISO), and it predominantly determines the active and suppressed spells of the Indian Summer Monsoon, with rainfall anomalies extending from the Arabian Sea to the western Pacific. However, the representation of MISO in the coupled models used for seasonal and extended-range prediction is still challenging. Hence, it is imperative to understand the factors that modulate them in different oceanic basins. In this study, we used a combination of in-situ, reanalysis, and field campaign data to understand the air-sea interaction processes and factors that modulate the sea surface temperature variability associated with MISO using mixed-layer heat budget analysis. It was found that net surface heat flux and vertical processes play a predominant role in determining sea surface temperature during the active phase of MISO. Conversely, the sea surface temperature state during the suppressed phase is predominantly controlled by net surface heat flux alone. In addition, the relative importance of diapycnal mixing to determine the sea surface temperature variability during the different phases of MISO is also quantified.

Keywords: MISO, Heat budget Analysis, Air-sea interaction, Net surface heat flux, Sea surface temperature

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Characteristics of Mesoscale Eddies in the South Indian Ocean and Their Impacts on Basin-Scale Heat and Salt Transport

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ABSTRACT

This study explores the mesoscale eddy dynamics of the South Indian Ocean (30-120°E, 45-5°S) using AVISO altimetry data (1/8° resolution) spanning the period 1993-2023. The results indicate a strong eddy concentration in the southeastern Indian Ocean near the west coast of Australia, decreasing toward the west. The region exhibits a distinct seasonal cycle, characterized by enhanced eddy generation from April to August (southern hemisphere inter), followed by a reduction toward summer. During the peak eddy-generation period (July–October), the mean eddy radius is comparatively small, increasing to a maximum in December-March. Eddy amplitude remains low between May and September and strengthens toward December. Moreover, cyclonic eddies show greater average lifetimes, radii, and amplitudes than their anticyclonic counterparts. Eddies with radii greater than 100 km are predominantly observed north of 25°S. High-amplitude eddies are mainly concentrated in the Agulhas and Agulhas Return Current regions, as well as off the west coast of Australia. The cyclonic eddies generated in the eastern basin tend to propagate southwards, while anticyclonic eddies tend to propagate northwards. Additionally, a greater number of cyclonic eddies persists for longer duration compared to anticyclonic eddies, with all of them originating off the west coast of Australia, and six of these even lasted for more than 4 years. Incorporating the vertical structure of these eddies, these results offer an integrated understanding of mesoscale eddy dynamics in the South Indian Ocean and highlight their importance in modulating basin-scale heat and salt transport.

Keywords: Mesoscale eddies, South Indian Ocean, Eddy heat transport

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Coupled Large-Eddy Simulations Of Air-Sea Interactions In The Bay Of Bengal

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ABSTRACT

Turbulent processes in the coupled Atmospheric Boundary Layer (ABL) and Oceanic Mixed Layer (OML) system govern the transfer of heat, mass, and momentum fluxes across the air–sea interface. These fluxes influence the stability, structure, and evolution of the coupled ABL–OML system, typically on diurnal timescales. In numerical weather prediction (NWP) and climate models, such turbulent processes are parameterized, leading to significant biases in surface fluxes. Similar biases in surface fluxes from NWP and climate models have been reported in the Bay of Bengal, underscoring the importance of understanding air-sea interactions in this region. We investigate these interactions in a 500 m × 500 m domain in the Bay of Bengal, centered around the RAMA buoy at 15°N, 90°E. We employ high-resolution, idealized coupled large-eddy simulations that explicitly resolve molecular sublayers at the interface, thereby avoiding conventional surface-layer parameterizations for the ABL and mixed-layer parameterizations for the OML. The simulated atmosphere height is 500 m, and the ocean depth is 200 m. Our central question is: How do different ocean stratification conditions (thermal and salinity) affect surface latent and sensible heat fluxes under varying atmospheric wind speeds, given identical initial atmospheric thermal stratification? The simulations assume clear-sky conditions, no solar radiation, negligible wave effects, with periodic boundary conditions. Initially, the atmosphere is dry, and the ocean is at rest. Preliminary analysis indicates that surface latent heat flux increases with stronger ABL winds, leading to cooling of the sea surface. The contribution of latent heat flux to ocean surface cooling is greater than that of sensible heat flux. Ongoing detailed analysis focuses on the coupled evolution of the ABL and OML, the mechanisms controlling surface fluxes, and the feedback processes that shape the dynamics of this system. Insights from these simulations provide a foundation for developing more accurate surface-flux parameterizations in next-generation NWP and climate models.

Keywords: Ocean-atmosphere interactions, marine boundary layer, ocean mixed layer

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Recent Reduction in the Frequency and Intensity of Rapid Intensification of the Tropical Cyclones over the West Coast of the Bay of Bengal during October-December

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Abstract

The densely populated west coast of the Bay of Bengal (BoB) is susceptible to Tropical cyclones (TCs) landfall during the post-monsoon season (October–December). Climatologically, post-monsoon TCs over the BoB undergo rapid intensification (RI) when they approach the west coast of the BoB. Analysis of post-monsoon TC data over the BoB during the last three decades (1993-2024) depicts a notable reduction in the frequency and intensity of RI events, such that the proportion of TC undergoing RI decreased from 55% during the first period (1993–2003) to 30% in the second period (2004–2014) and further to 22% in the third period (2015–2024). Multiple RI events occurred in 5% of cases during the first period, but such cases were absent during the recent period. In addition, the maximum increase in wind speed associated with RI often exceeded 50–75 kt in the first period, whereas in the recent period, it never exceeded 40 kt. It was found that a reduction in absolute vorticity intensity and a decrease in potential intensity within 300 km over the west coast of the BoB are primarily responsible for the decrease in RI frequency over the BoB during the recent period. Our analysis based on the Genesis Potential Index (GPI) indicates that the reduction in the RI cases in the BoB in the recent period is part of the decadal modulation of GPI over the BoB, which is primarily determined by the combined effect of Pacific Decadal Oscillation and Atlantic Multi-decadal Oscillation.

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Tracking Lagrangian Particles In The Ocean Mixed Layer During Tropical Cyclone

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ABSTRACT

Tropical cyclones generate intense upper-ocean mixing, driving the vertical transport of a wide range of particles, including deep-ocean nutrients, suspended materials, and dissolved gases, yet our understanding of these transport pathways remains limited. Thus, Lagrangian analysis provides a powerful approach for examining the underlying mechanisms governing such cyclone-driven processes. The cyclone-driven mixed-layer dynamics are simulated using Large Eddy Simulation, and the Lagrangian motion of suspended particles is tracked within this framework. In this approach, large ensembles of virtual particles are numerically advected through the time-dependent flow field in the ocean boundary layer during a tropical cyclone. The aim of this study is to investigate particle pathways and their associated transport characteristics in the ocean mixed layer during the passage of a tropical cyclone. Tracking how particles move through seawater reveals the pathways and timescales of tracer transport across spatial and temporal scales. The results show that key dynamical processes governing mixed-layer behaviour and associated surface properties such as temperature and salinity, can be effectively assessed during cyclone events. These findings provide new insight into how cyclone-induced turbulence shapes upper-ocean structure and tracer distributions, with important implications for ocean-atmosphere interactions, climate processes, and marine ecosystem response.

Keywords: Lagrangian analysis, Particle tracking, Ocean mixed layer, Tropical cyclone

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Effect Of Spatially Varying Scaling Depth On Estimation Of Ocean Surface Currents Using Satellite Data

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ABSTRACT

This study leverages satellite data, including Sea Level Anomaly (SLA), Sea Surface Temperature (SST), and Sea Surface Wind (SSW), to estimate ocean surface currents in the North Indian Ocean and investigate the influence of Scaling depth on these currents. While existing methods rely on a constant scaling depth of 70 m, this assumption may not accurately reflect regional variations in sea surface currents (SSC). The choice of Scaling Depth, which is similar to mixed layer depth, directly influences the magnitude and direction of the wind-driven surface currents, as a deeper Scaling depth typically results in a weaker surface current response to wind stress, while a shallower layer amplifies the effect of wind stress. As such, using a constant Scaling depth may lead to inaccurate SSC estimates, particularly in regions with significant variations in stratification and mixed-layer dynamics. To address this limitation, we tested a range of scaling depths (10 m to 70 m) to evaluate their impact on wind-driven surface current estimates. Sensitivity experiments were conducted for the year 2020 to assess the effects of varying scaling depths on the computed currents. Based on these results, spatially varying Mixed Layer Depth (MLD) fields, obtained from a numerical ocean model, were incorporated to develop a region-specific scaling depth distribution across the North Indian Ocean. This approach provides a more physically consistent response to local stratification and vertical mixing conditions. The currents estimated by using spatially varying scaling depth are compared with observations and the detailed results will be presented in the conference.

Keywords—Sea Level Anomaly (SLA); Sea Surface Temperature (SST); Wind Stress; Ekman Current; Scaling Depth; Mixed Layer Depth (MLD); Ocean Surface Currents

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Recent oxygenation of oxygen minimum zone in the Arabian Sea and possible causes

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ABSTRACT

Oxygen minimum zones (OMZs) are regions in the global ocean where mid-depth oxygen concentrations remain persistently low. These zones naturally develop in areas characterized by high rates of sinking organic carbon and limited water column ventilation. The Arabian Sea (AS) contains the second most intense OMZ globally, following the eastern tropical Pacific. Dissolved oxygen (DO) in the ocean is vital for the survival and distribution of marine life, and prolonged exposure to sub-optimal DO levels can significantly impacts their life and alter species distributions. Climate change is projected to intensify ocean deoxygenation within OMZs, potentially leading to their strengthening, spatial expansion, or both. In a warming ocean, DO levels are expected to decline due to reduced oxygen solubility at higher temperatures and enhanced upper ocean stratification, which further impedes vertical mixing and ventilation. Recent measurements from 2019 to 2023 in the rapidly warming Arabian Sea (AS) reveal a notable deviation from the prevailing understanding of climate-driven deoxygenation. Contrary to expectations, the oxygen minimum zone (OMZ) in the AS exhibited a significant increase in dissolved oxygen (DO) concentrations and a concurrent reduction in its vertical extent. This unexpected oxygenation trend is attributed to two primary mechanisms: (1) advection of oxygen-rich waters from the source regions of mid-depth water masses entering the AS, and (2) a decline in the in-situ production of organic carbon, which reduces oxygen consumption. Our findings contradict prevailing views on climate-driven deoxygenation, prompting a reassessment of biogeochemical responses and water mass dynamics in the rapidly warming AS.

Keywords: Oxygen minimum zone, Chlorophyll a, Arabian Sea, Red Sea water mass, South Indian Central water mass

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Basin-Wide Circulation in the bay of bengal-Seasonal cycle and Impact of IOD

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ABSTRACT

Seasonality constitutes the most prominent mode of variability in the northern Indian Ocean, wherein the upper-ocean currents undergo semiannual reversals. While this reversal in surface currents occurs synchronously with the seasonal reversal of winds over the Arabian Sea, such correspondence is not observed in the Bay of Bengal (BoB). Numerous previous investigations, employing both in-situ observations and numerical model simulations, have demonstrated that the BoB circulation is governed by a complex interplay of local and remote forcings. Although these studies have substantially advanced our understanding of the BoB circulation, theseasonal evolution of the basin-wide flow field and its associated boundary currents remains incompletely characterized.The present study is motivated by this knowledge gap. Utilizing satellite-derived remote sensing data and re-analysis data, the seasonal variability of the surface circulation in the BoB has been examined. The analysis reveals that during the summer and winter monsoons, when basin-wide winds are strongest and most spatially coherent, the surface circulation within the BoB is highly disorganized. Conversely, during the spring and fall intermonsoon periods, when winds are weak and variable, the surface circulation exhibits its highest degree of organization. We refer to this intriguing feature as the circulation paradox of the Bay of Bengal and seek to elucidate the underlying mechanisms governing its seasonal evolution. In addition, the seasonal development of the boundary currents along the northern and eastern margins of the BoB, hereafter referred to as the North Bay of Bengal Coastal Current (NBCC) and the Myanmar Coastal Current (MCC), respectively were characterised. Finally, the influence of the Indian Ocean Dipole (IOD) on the basin-wide circulation of the BoB and its boundary current systems is also investigated.

Keywords: Bay of Bengal circulation, seasonal cycle, boundary current, subtropical gyre, Indian Ocean Dipole

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Variability of thermocline currents on the continental slope in the eastern Arabian Sea

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ABSTRACT

We present an analysis of the variability of sub-surface, essentially thermocline, currents on the continental slope in the eastern Arabian Sea, i.e., off the Indian west coast. This analysis is based on data from ADCP (acoustic Doppler current profiler) measurements; the near-surface (roughly top 200 m) currents have been described earlier (Amol et al. 2014, Chaudhuri et al. 2021), but the thermocline currents have not been analysed yet. We show that the thermocline currents from these ADCPs present a challenge owing to periodic data gaps that were not seen in the near-surface currents. Inspection of the data shows that these gaps occur during the night, i.e., from dusk to dawn, and they follow a diurnal cycle, suggesting a link to the diel vertical migration (DVM) of zooplankton. These gaps are more prominent at ADCP moorings located within the oxygen minimum zone (OMZ) in the eastern Arabian Sea (EAS). For moorings outside the OMZ, such as Kanyakumari or Okha, these periodic gaps are absent, pointing to the OMZ's role in reducing the zooplankton population in the thermocline and thus limiting the backscatter signal necessary for viable ADCP measurements. Our analysis focuses on sub-inertial currents. To ensure reliable interpretation of thermocline variability at these timescales, gap-filling methods were carefully optimised. The objective was to preserve the spectral characteristics at longer periods while avoiding artificial high-frequency noise caused by the Gibbs phenomenon. Several interpolation schemes, including the Mukhopadhyay et al. (2020) approach, were evaluated; in many cases, alternative methods proved more effective in suppressing Gibbs-related artefacts. A further refinement was developed to control aliasing: the gap-filling was performed on de-tided records, and the tidal component was subsequently added back. The improved method successfully mitigated both the Gibbs effect and aliasing, resulting in a cleaner and more reliable reconstruction. The gap-filled records provide a remarkable data set of currents. A brief description of the variability of the sub-inertial thermocline currents will be presented.

Keywords: ADCP, Diel Vertical Migration, Oxygen Minimum Zone, Wavelet, Thermocline Currents

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Evaluating the Influence of Non-Breaking Wave-Induced Mixing on Upper-Ocean Dynamics During Tropical Cyclones in the North Indian Ocean

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Presentation mode- POSTER
Theme - Ocean in motion;
Proposer- Ocean processes and dynamics in the Northern Indian Ocean

ABSTRACT

Tropical cyclones (TCs) generate intense air–sea interactions that strongly modify the upper ocean's thermal and dynamical structure. While the effects of wave breaking and wind-driven turbulence are well known, the role of non-breaking waves—particularly Stokes drift and Langmuir circulations—remains less explored. This study examines the influence of nonbreaking wave-induced mixing on the upper-ocean response during Very Severe Cyclonic Storm Vayu (10–17 June 2019) over the Arabian Sea. Using ERA5 reanalysis winds, satellite observed sea surface temperature (SST), and wave simulations from WAVEWATCH III, we analyze variations in mixed-layer depth (MLD), Stokes drift velocity, and SST along the cyclone's track.

Results reveal that non-breaking wave processes substantially enhance vertical mixing and entrainment beneath the cyclone, deepening the mixed layer (up to few meters) and intensifying SST cooling in certain regions. Inclusion of wave-driven turbulence in model simulations produces deeper MLDs and stronger SST cooling, aligning more closely with observations compared to wind-only scenarios. The Stokes drift–induced shear and Langmuir turbulence inject additional turbulent kinetic energy, eroding stratification and promoting enhanced ocean-atmosphere coupling. Consequently, the strengthened cooling reduces surface heat flux to the atmosphere, potentially limiting cyclone intensification. These findings demonstrate that non-breaking wave-induced mixing plays a critical role in modulating the ocean's thermal response to TCs and should be incorporated into coupled atmosphere–ocean models for improved simulation of SST cooling, mixed-layer dynamics, and cyclone intensity forecasts across the North Indian Ocean.

Keywords: Non-breaking Waves; Stokes Drift; Langmuir Circulation; Tropical Cyclone; Mixed-layer Depth; SST Cooling; North Indian Ocean.

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Offshore Wind Energy In India Under Climate Change: Linking Potential With Practical Feasibility

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ABSTRACT

India's extensive Exclusive Economic Zone (EEZ) provides a vast offshore domain to support low-carbon power growth. However, realistic offshore wind planning cannot rely only on wind speed or wind power density. A more integrated approach is required that links projected changes in atmospheric forcing, evolving turbine technology, spatial marine constraints, and real energy output metrics. In this work, climate-driven shifts in offshore wind resources are combined with advancements in turbine scaling to estimate realistic energy harvests throughout the 21st century. Wind data from ten CMIP6 Global Climate Models (GCM) are bias-corrected using a Weibull-based quantile mapping approach, and the corrected outputs are combined into a multi-model ensemble to reduce single-model uncertainty. Analysis highlights strong seasonal behaviour, with the monsoon (June–August) emerging as the primary resource window and additional enhancement during September–November. The southern offshore domain is consistently identified as the most favourable zone due to its rich and stable wind regime. Practical feasibility is assessed through capacity factor (CF) and annual energy yield (AEY) calculations, while also considering bathymetry, exclusion zones, and siting limitations. Medium-rated turbines (6–8 MW) provide stable performance, whereas 15 MW turbines yield the highest AEY in moderate-depth waters, reaching values near 10,266 PWh toward the end of the century. Normalised AEY gains range from +2.2–2.5% under SSP2-4.5 and +3.4–3.9% under SSP5-8.5. Overall, the integration of bias-corrected climate projections with turbine-specific behaviour provides a more realistic evidence base for India's offshore wind planning, policy, and investment decisions.

Keywords: Offshore wind turbines, CMIP6, Bias correction, Annual energy yield, India

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A Wave-Powered Unmanned Coastal Surveillance System

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ABSTRACT

Unmanned coastal surveillance systems (UCSSs) powered by ocean wave energy can be deployed along coasts where close observation is needed to prevent infiltration or observation of unknown objects that could threaten a country's security. Existing systems generally use solar power, which requires a large battery. A wave energy converter (WEC) extracts energy from ocean surface waves and reduces the battery requirements of a UCSS. This paper describes a WEC, Sindhuja-I, that supplied power to UCSS. The Sindhuja-I is portable and can be deployed at 10 m to any water depth in the sea. The UCSS was designed and tested in the wave basin facility at IIT Madras. System performance was recorded under different wave conditions. A few objects were detected and identified using an image-processing strategy. The WEC produced varying power, reaching up to 20 W, and the camera consumed around 2 W under different laboratory test conditions.

Keywords: Wave energy, Surveillance, wave energy converter, energy, Unmanned.

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Economic Feasibility Of Offshore Wind Energy Along The Indian Exclusive Economic Zone Under Climate Change Scenarios

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ABSTRACT

The offshore regions across India's Exclusive Economic Zone (EEZ) present significant opportunities for renewable energy generation through wind power. Evaluating the economic feasibility of such projects requires careful consideration not only of present wind resource availability, but also of how these resources may shift under varying climate change trajectories.

In this study, we assess offshore wind farm viability by analyzing electricity generation costs under both current climatic conditions and two future scenarios characterized by moderate and pronounced climate change. Using RCP4.5 and RCP8.5 emission pathways, we evaluated the spatial distribution of LCOE across the Indian coastline and quantified climate change impacts on wind power economics. The findings reveal that the southern Tamil Nadu and Gujarat coasts offer the lowest LCOE values (10-20 ₹/kWh), making them optimal locations for offshore wind development. Climate change projections indicate a 2-5% average increase in LCOE across the Indian EEZ, with significant regional variations, which increases of 5-13% in northern regions and decreases of up to 4% in southern regions. Sensitivity analysis demonstrates that interest rates exert the strongest influence on LCOE, followed by capacity factor and project lifespan, while operational costs have minimal impact. This comprehensive economic assessment provides valuable insights for policymakers and investors to make informed decisions regarding offshore wind energy development in India, highlighting the importance of considering future climate scenarios in long-term energy planning.

Keywords: Offshore Wind Energy, Climate Change, Economic Analysis, Indian Exclusive Economic Zone, Sensitivity Analysis

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Offshore Wind Farm Layout Optimization For Enhanced Power Output At A Site In Gujarat, India

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ABSTRACT

The Gulf of Khambhat along the Gujarat coast is known for its strong and consistent winds, making it an extremely promising area for offshore wind farm development. However, the actual power generation from a wind farm depends not only on the wind resource but also on how effectively the turbines are arranged within the site. Wake effects generated by upstream turbines significantly reduce the power output of downstream units, necessitating an optimized layout strategy. In the present study, an optimization-based approach is proposed to design an efficient wind farm layout at a selected site in Gujarat, India, considering the local wind conditions and environmental constraints. The Passing vehicle search (PVS) optimization algorithm is employed to minimize wake losses, improve inter-turbine spacing, and determine the most effective turbine arrangement to maximize energy yield. A grid-based layout and staggered turbine configuration are evaluated utilizing existing wind data and simulation tools. The results indicate that the optimized layout can significantly enhance the annual energy output while maintain feasible construction and maintenance costs. The findings support the large-scale deployment of offshore wind projects in the region and contribution to the advancement of clean energy generation for the state of Gujarat.

Keywords: Offshore wind turbines, Wind farm layout optimization, Renewable energy planning, Wake effect reduction, Turbine spacing

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Unveiling The Hidden Shells: New Taxonomic Insights On Molluscs Of Lakshadweep Islands, India

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ABSTRACT

Marine molluscs form a highly diverse and ecologically crucial component of tropical reef ecosystems, yet many regions of the Indian Ocean remain poorly documented. The Lakshadweep Archipelago, India's only chain of true coral atolls, provides habitats that support a rich molluscan assemblage but lacks recent systematic assessments. This study documents the molluscan diversity of selected islands of Lakshadweep through habitat-based sampling carried out across coral rubble, sandy areas, and seagrass beds in lagoonal and reef-flat environments. Specimens collected during low-tide surveys were preserved following standardized protocols and identified using contemporary taxonomic references. A total of 80 species were recorded, representing two major classes, Gastropoda and Bivalvia that are distributed across nine orders and 27 families. Gastropods formed the dominant group, particularly reef-associated taxa such as members of Cypraeidae, reflecting the structural complexity and productivity of islands such as Kavaratti, Kadmat and Kalpeni islands and seagrass habitats. Bivalves, though less abundant, contributed important ecological roles, including sediment binding and water filtration. The species composition showed clear Indo-Pacific affinities, consistent with patterns observed across other atoll systems in the region. Increasing pressures from reef degradation, resource extraction, and pollution highlight the need for focused management interventions. The findings of this study establish a contemporary baseline for molluscan biodiversity in Lakshadweep and support future monitoring, conservation planning, and sustainable use initiatives.

Keywords: Cypraeidae, Kavaratti, biodiversity, Coral reef, ecosystem.

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Integrated Taxonomy Of A Deep-Sea Sponge, Hyalonema Sp.

(Porifera: Hexactinellida) From The Andaman Sea

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ABSTRACT

Glass sponges (Hexactinellida) are key deep-sea organisms with notable geological and materials science relevance. Emerging molecular data helps getting clarity in their phylogeny, showing better alignment with traditional morphology-based classifications. Sampling was conducted during January 2024 using Sindhu Sankalp (SSK 183) at a depth of 2,247 m from the Andaman Sea. The specimen displays a siliceous dictyonal framework accompanied by a brown trabecular network, with spicule types including hexactines, micro-hexactines, pentactines, and macramphidiscs consistent with members of the Family Hyalonematidae. However, the occurrence of exceptionally long basal spicules (~60 cm), forming an extended anchoring tuft, exceeds the typical dimensions reported for known hyalonematid taxa. This unusual basal architecture suggests that the specimen may represent a morphologically divergent form within the family, potentially indicative of an undescribed or previously uncharacterized lineage. Glass sponges play critical ecological roles in deep-sea ecosystems, including modulating benthicpelagic coupling, enhancing local water filtration, and providing structural habitat for associated fauna. The discovery of a morphologically distinctive form in this poorly studied region underscores the ecological and evolutionary significance of Hexactinellida in deep-sea environments. Integrative analyses, including spicule morphometrics and molecular sequencing, were used to resolve the specimen's phylogenetic position. These findings highlight both the biodiversity potential of the eastern Indian Ocean and the importance of continued exploration to understand the functional roles of glass sponges in deep benthic ecosystems.

Keywords: Andaman Sea, spicules, Porifera, Hexactinellida, Hyalonema

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Length–weight relationship and condition status of *Gerres oyena (Forsskål, 1775)* (Family: Gerreidae) from the Parangipettai coastal waters

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ABSTRACT

Gerres oyena is an important coastal fish species supporting local fisheries across the Indian Ocean and western Pacific Ocean. Understanding its growth dynamics and physiological condition is crucial for effective stock assessment and sustainable fisheries management. The present study examines the length–weight relationship (LWR) and condition status of *G. oyena* collected from Parangipettai coastal landing sites between October 2024 and September 2025. A total of 100 specimens representing males, females, and immature individuals were measured for morphometric parameters and body weight. and the growth exponent (*b*) was compared across sex groups. Results indicated negative allometric growth in males ($b = 2.71$) and females ($b = 2.79$), whereas immature individuals exhibited near-isometric growth ($b = 3.07$). The pooled sample showed strong positive allometry ($b = 3.34$) suggesting strong growth at the population level. The relative condition factor (Kn ≈ 1.0) indicates a stable and healthy population, reflecting generally favourable feeding conditions and supportive environmental parameters throughout the study period. Overall, the findings provide baseline biological information essential for monitoring stock health and guiding sustainable management strategies for this commercially significant species.

Keywords: *Gerres oyena*, length–weight relationship, growth exponent, condition factor, coastal fishery management

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Metagenomic bacterial, archaeal and viral diversity associated with the photosynthetic, Sacoglossan sea slug *Elysia bangtawaensis* Swennen, 1998 from mangroves habitats

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ABSTRACT

The present study reveals the bacterial, archaeal and viral communities associated with *Elysia bangtawaensis*, which were collected from the mangrove ecosystems of Goa, India. The *E. bangtawaensis*, is a photosynthetic sea slug, as it is capable of retaining the functional chloroplasts or kleptoplasts from its algal diet. It serves as a unique model for studying host–microbe interactions in coastal and estuary ecosystems. The Whole-genome metagenomic sequencing was performed and high-quality assemblies were obtained for comprehensive characterization of the microbial communities associated with the organism and from the surrounding sediment and water of the mangrove habitat. The taxonomic classification showed that bacterial reads dominated all the samples with Proteobacteria, Cyanobacteria, Bacteroidetes, and Firmicutes as the most abundant phyla. Among Archaea, Thermodesulfobiota, Euryarchaeota, Thermoproteota, and Nitrososphaerota were prevalent, while viral communities were primarily represented by Uroviricota, Peploviricota, and Nucleocytoviricota. Alpha diversity analyses revealed exceptionally high microbial richness, indicative of mature, complex community structures. Functional profiling identified pathways for nitrogen, sulfur, carbon, and metal cycling, reflecting broad metabolic versatility within the microbial consortia. These functional traits suggest active roles in nutrient transformation and ecosystem stability. The integration of taxonomic and functional data demonstrates that the microbiome associated with *Elysia bangtawaensis* harbors diverse and metabolically active microorganisms. Collectively, these findings provide new insights into the ecological interactions and biogeochemical potential of marine microbial communities associated with this species, and the water and sediment habitat of the mangrove regions, in which they thrive in; contributing to a deeper understanding of their roles in marine ecosystem functioning and resilience.

Keywords: *Elysia bangtawaensis*, Microbiome, OMICS, Nudibranchs, West Coast of India, Goa

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The Great Architects Of Our Ocean: How Marine Sponges (Phylum: Porifera) From Kerala, India, Enhance Biodiversity

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ABSTRACT

Sponges (Phylum: Porifera) are among the earliest multicellular animals and play vital roles in marine benthic ecosystems. This study surveys the sponge diversity along the southwest coast of India. A total of 51 species were collected by snorkelling and SCUBA diving from the rocky reef habitats of Muttom-TamilNadu and Kovalam-Kerala, India. The sponges were identified using morphological and skeletal architecture along with their varied spicule categories using light and scanning electron microscopy. Most of the sponge species recorded in this study were dominated by the Orders Poecilosclerida and Haplosclerida followed by Dictyoceratida, Keratosa, Bubarida and many others which are reported for the first time in India. The study highlights the diversity of sponge fauna in these understudied regions, contributing valuable taxonomic data to Indian marine biodiversity records and India Biodiversity Portal. Moreover, these findings provide a foundation for further ecological, biogeographical, and conservation research on marine sponges in tropical Indian waters.

Keywords: Muttom, TamilNadu, Kovalam, Kerala, taxonomy

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Uncovering New Records Of Octocorallia From Muttom, Tamilnadu, India.

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ABSTRACT

Gorgonian corals (Class: Octocorallia) are important structural and ecological components of coral reef habitats. This study presents a preliminary assessment of gorgonian coral diversity collected at Muttom, Tamil Nadu. A total of 20 species were obtained from a depth of ~25 m through SCUBA diving.The preserved samples were examined for morphological characters and the sclerites were isolated from the base, surface of the stalk and polyps using standard procedures. Diagnostic characters including sclerite shape and size variation were examined under light microscopy and scanning electron microscopy. Further documentation and comparison of sclerites with established taxonomic descriptions to support initial species identification were done.Preliminary observations reveal notable interspecific variation, particularly in spindle morphology and surface textures, highlighting the value of sclerite-based traits in differentiating closely related taxa. These findings underscore the importance of detailed sclerite examination for resolving taxonomic ambiguities and strengthening biodiversity assessments of gorgonian assemblages. As this work represents the initial phase of an ongoing investigation, further morphometric analyses and expanded sampling will be incorporated in subsequent stages. Overall, this study provides a foundational dataset for understanding the octocoral diversity in the region and supports broader efforts in reef taxonomy, monitoring, and conservation.

Keywords: Gorgonian corals, sclerites, taxonomy, coral reef, biodiversity

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Marine Pollution and the Plastic Menace: An Interdisciplinary Approach to Oceanic Sustainability

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ABSTRACT

Oceans, covering more than 70% of Earth's surface, are crucial regulators of climate, biodiversity, and human survival. Yet, escalating anthropogenic pressure—particularly through synthetic polymer pollution—has transformed these ecosystems into sinks of persistent waste. Global plastic production exceeds 400 million tonnes annually, and approximately 8–12 million tonnes enter the marine environment each year (Jambeck et al., 2015). Through photodegradation and fragmentation, plastics form micro- and nano-particles, infiltrating food webs and disrupting marine biogeochemistry.Nearly 80% of marine plastics originate from land-based activities such as municipal wastemismanagement, urban runoff, and riverine discharge from the Ganga and Brahmaputra basins. Theremaining 20% arises from maritime transport, lost fishing gear, and offshore operations. Ocean gyresand current convergence zones aggregate floating plastics into massive "plastic smog" regions,altering oceanic nutrient cycles.Over 700 marine species face entanglement or ingestion hazards (Gall & Thompson, 2015).Plastic-associated chemicals and persistent organic pollutants accumulate in tissues, causing endocrinedisruption and bio-magnification across trophic levels. Coral reefs experience up to 89% higher diseaserisk due to plastic-induced microbial colonization (Lamb et al., 2018). According to UNEP (2021),marine debris results in US $13 billion in annual economic losses globally.India's Plastic Waste Management Rules (2022) and Swachh Sagar, Surakshit Sagar campaign alignwith SDG 14 – Life Below Water. Globally, MARPOL Annex V, the UN Clean Seas Campaign, and theforthcoming Global Plastics Treaty promote circular-economy interventions.Marine plastic pollution is a multifactorial crisis at the intersection of chemistry, ecology, andgovernance. Its mitigation demands biodegradable innovation, blue-economy integration, andcross-sectoral cooperation. Sustainable ocean governance must merge science, policy, and civic action toensure the long-term resilience of marine ecosystems and the future of life on Earth.

Keywords: Marine pollution ¦ Microplastics ¦ Ocean governance ¦ Sustainability ¦ Blue Economy

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Cetacean Observation From Opportunistic Visual Surveys In The Indian Exclusive Economic Zone And Adjacent Seas

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ABSTRACT

India's coastal and offshore waters host a rich diversity of cetaceans, yet significant knowledge gaps persist due to uneven and limited survey efforts. To address these distributional gaps, approximately 1,600 hours of opportunistic visual surveys were conducted aboard *FORV Sagar Sampada* across six research cruises between February 2024 and February 2025, covering extensive sectors of the Indian Exclusive Economic Zone (EEZ) and adjacent waters. A total of 41 sightings comprising 1,604 individuals were recorded, representing nine confirmed species across multiple ecological groups, including baleen whales, deep-diving odontocetes, oceanic and coastal dolphins, and killer whales. Key observations included blue (*Balaenoptera musculus*, n = 5) and Bryde's whales (*B. edeni*, n = 1); short-finned pilot whales (*Globicephala macrorhynchus*, n = 264); Risso's dolphins (*Grampus griseus*, n = 10); killer whales (*Orcinus orca*, n = 4); Indian Ocean humpback dolphins (*Sousa plumbea*, n = 15); offshore and nearshore bottlenose dolphins (*Tursiops aduncus*, n = 150; *T. truncatus*, n = 25); and spinner dolphins (*Stenella longirostris*, n = 1,117). Additionally, 13 unidentified dolphin sightings were recorded. The community composition was dominated by spinner dolphins (*Stenella longirostris*), which accounted for nearly 70% of all individuals, followed by short-finned pilot whales (*Globicephala macrorhynchus*, 16.5%) and Indo-Pacific bottlenose dolphins (*Tursiops aduncus*, 9.4%). The remaining species occurred infrequently, with Bryde's whale (*Balaenoptera edeni*) represented by a single sighting, reflecting a pronounced dominance by a few species and low evenness within the observed cetacean assemblage.

Keywords: Marine mammals, visual surveys, Indian EEZ, opportunistic observations, Northern Indian Ocean

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From Obscurity to Insight: Unveiling the Hidden Diversity of Ophidiiformes in IndianWaters.

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Presenting author

ABSTRACT

The order Ophidiiformes, commonly referred to as cusk-eels, brotulas, and pearlfishes, represents one of the most taxonomically diverse groups of deep-sea fishes, comprising over 570recognised species in 6 families and 119 genera. They constitute a significant group representedin deep-sea trawl catches from Indian waters. Despite their prevalence in abyssal habitats, thetaxonomy of Ophidiiformes remains challenging owing to their cryptic characteristics andgeographic intraspecific variation. Few studies focus on Ophidiiformes taxonomy, with only 45species documented in Indian waters. Despite more discoveries, molecular data still remainlimited for many. In this study, samples were collected from various sources across India,including deep-sea cruises conducted on board FORV Sagar Sampada, and from different fish landing centers. A total of 16 species were identified, comprising 1 new species, 4 new distributional records, and 1 species rediscovered from Indian waters after more than a century.Recent molecular investigations have revealed hidden genetic diversity within the taxa,suggesting the presence of cryptic lineages and possible regional endemism.The increasing
abundance of Ophidiiformes along India's southeast coast highlights their potential as an emerging marine resource. These findings underscore the remarkable but often overlooked biodiversity of the Indian deep sea and emphasize the need for integrated taxonomic approach to uncover its full extent.Understanding the biogeographic patterns of Ophidiiformes provides valuable insights into deep-sea ecosystem connectivity and evolutionary processes.Such knowledge is essential for guiding conservation priorities, improving biodiversity assessments,strengthening the scientific basis for sustainable deep-sea resource management and contributing to global goals under SDG 14: Life Below Water.

Keywords: Ophidiiformes, Deep-sea Biodiversity, Taxonomy, Molecular analysis, Conservation.

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Fucoidan From Sargassum Spp. (Brown Algae): Physico-Chemical Characterization And Fermentative Production Of Fucoidan Oligosaccharides For Their Nutraceutical Application

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ABSTRACT

Fucoidan is a sulfated polysaccharide found in seaweeds, gaining greater attention as an important nutraceutical and pharmaceutical molecule. The current study focused on extracting fucoidan from a brown alga, Sargassum spp., characterizing it, and producing fucoidan oligosaccharides (FOSs). The proximate composition of Sargassum spp. powder (SSP) showed it is rich in carbohydrates (65%). SSP was subjected to cold-water extraction, yielding 10 g of crude fucoidan. The extracted fucoidan contained 1.86% moisture, 0.55% protein, 0.65% fat, 76.6% carbohydrate, and 19.89% ash. FTIR spectroscopy revealed the characteristic pattern of fucoidan and the presence of sulfate groups. Monosaccharide composition analysis by GC showed the presence of fucose (48.49%), rhamnose (1.66%), arabinose (7.38%), xylose (2.06%), and glucose (40,49%). Different Lactobacillus strains were used to observe the utilization of fucoidan as a carbon source and the induction of fucoidanase production to produce FOSs. Among the Lactobacillus spp., Pedicoccus pentosaceus showed the highest production of fucoidanase during the fermentation of extracted fucoidan. Furthermore, FOSs produced by Pedicoccus pentosaceus fermentation were characterized and showed various degrees of polymerization. Monosaccharide analysis using HPAEC-PAD coupled with a CarboPac PA1 column revealed the presence of free and sulfated fucose residues. The FOSs showed potent antioxidant activity, as studied by DPPH, ABTS, and FRAP assays. The antioxidant activity increased with fermentation time and FOS concentration. The current study demonstrated the extraction of fucoidan and FOSs through Lactobacillus spp. fermentation. These molecules have great potential in the pharmaceutical and nutraceutical sectors. The FOSs can be used for functional food development. The current study also warrants a detailed study.

Keywords: Fucoidan; Brown algae; Nutraceutical; Oligosaccharide; Pedicoccus pentosaceus

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Extraction And Characterization Of Proteins From The Red Seaweeds

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ABSTRACT

India is bestowed with a wide array of seaweeds, yet its application as an alternative dietary protein is highly neglected. The present study aimed to extract and characterize proteins from red seaweeds of the southeast coast of India, namely, Gracilaria corticata (GC), Hypnea valentiae (HV), and Acanthophora spicifera (AS). GC protein extract (GCPE) exhibited the highest protein yield (14.73%) with 64.56% protein content and 73.68% in vitro protein digestibility compared to HVPE and ASPE protein, respectively. Further, GCPE and HVPE showed distinct bands of α, β, and γ subunits of R-phycoerythrin and RuBisCO proteins. GCPE displayed higher a* color value (13.11) close to R-PE (19.66). Further, extraction of protein from Gracilaria corticata was optimized using ultrasound technique. Highest protein yield of 26.64% was obtained at 60 min of time, 30ºC temperature, 80% amplitude, and a solid-to-liquid ratio of 1:50 (w/v). The protein extract (UAPE) exhibited essential amino acid content of 39.24 g/100g protein. The total phenolic acid, flavonoid, phytic acid, and iron content were found to be 19.27 µg GAE/mg, 7.75 µg QE/mg, 0.13%, and 76.43 mg/100g, respectively. Heavy metals, such as arsenic, cadmium, and mercury, were not detected in UAPE. Furthermore, SDS-PAGE pattern revealed presence of R-phycoerythrin. FTIR spectrum showed a parallel β-sheet as the secondary structure. UAPE exhibited good protein solubility (>90%) above pH 5 with good emulsifying and foaming characteristics across neutral to alkaline pH levels. Therefore, the extracted proteins with good iron and antioxidant potential, as well as functional properties, make them an attractive protein ingredient in anemic food formulations.

Keywords: Red seaweeds, Protein extraction, Physicochemical characterization

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Lab-Based Swarm IoT Devices for Studying Coastal Water Processes.

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ABSTRACT

Coastlines are affected by natural hazards and human activities, including storms, erosion, and infrastructure development. To study these changes in a controlled environment, this work proposes swarm controlled IoT devices in a laboratory water tank. IoT devices are smart sensors or instruments that can measure environmental parameters, process data, and communicate the information wirelessly in real time. Swarm controlled IoT devices are multiple interconnected smart sensors that operate together using programmed coordination rules, communicating in real time to collect and share data efficiently over a defined area. Multiple devices, each equipped with temperature, salinity, and water level sensors, move and operate together following simple swarm rules like maintaining safe distances, aligning with neighbors, and covering the tank efficiently. In the laboratory experiments, controlled surface heating and freshwater–saline injections are applied to simulate thermal stratification and salinity variations. Depth resolved sensors continuously record the resulting temperature and salinity profiles, which are transmitted wirelessly to a central server for logging and analysis. The novelty of the framework lies in the use of swarm algorithms to coordinate multiple IoT devices, allowing simultaneous monitoring of the entire water column and improving spatial coverage, efficiency, and data resolution compared to single device setups. This repeatable, cost effective, and scalable laboratory platform provides a practical method to study thermal and salinity driven coastal processes and supports the development of predictive models and data driven strategies for managing changing coastlines.

Keywords: Swarm Intelligence, IoT Sensor Networks, Thermal Stratification, Salinity Dynamics, Coastal Water Processes.

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Vagaries Of Temperature And Precipitation On Nesting Of Olive Ridley Turtles In Western Bay Of Bengal

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ABSTRACT

Marine turtles inhabit tropical and temperate seas worldwide. Adult turtles of most species are commonly found in shallow coastal waters, bays, lagoons and estuaries, although some species also explore the open ocean. Rushikulya Beach and Gahirmatha Marine Sanctuary, known for their coastal environments, host the globally renowned Olive Ridley turtle nesting ground. Situated in the vicinity of Rushikulya River in Ganjam and Bhitarkanika Wildlife Sanctuary in Kendarapara, a protected zone, this area visualizes the maximum number of turtles nesting in the State and the country. Climatic factor variations have led to changes in the sea level rise and frequent cyclonic storms leading to a recession of 272m in the southern part of the Bhitarkanika wildlife sanctuary. Apart from the shoreline change study, focus was also made on the climatic variations particularly temperature and precipitation in order to understand the impact of these variables in the mass nesting of turtles in the western Bay of Bengal. Similarly, the climatic data were procured from IMD, Bhubaneswar and some online sources. The study showed that the trend of temperature over the years is decreasing, rainfall is more or less uniform with a rise in the recent decade, whereas the wind speed has a rising trend. Cyclonic data also shows that over the past 2 decades, there have been increased cyclones on the coast of western Bya of Bengal. The study, however, shows that turtle nesting increased during 2016-18 but again decreased during 2019-20, which may be due to Cyclone Fani and also the erosion of the coastline. Considering future and ongoing natural phenomena, it is crucial to comprehensively understand, evaluate, and study shoreline changes and related processes to ensure the conservation of signature species and their habitats.

Keywords: Climatic change, Olive Ridley turtle, Precipitation, Shoreline change, Temperature

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Development Of An Open-Sea Submerged Fish Cage And Fish Biomass Estimation System For Sustainable Marine Aquaculture

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ABSTRACT

Open-sea mariculture in exposed locations demands robust cage structures and quantitative biomass assessment to optimise feed management, reduce environmental impact and enhance economic returns. This work presents an indigenous submerged fish cage system integrated with a non-invasive fish biomass estimation framework, developed and demonstrated by the National Institute of Ocean Technology (NIOT), Chennai, for deployment in the Andaman region. The 165 m³ prototype cage operates at around 10 m depth and employs an adjustable buoyancy mechanism for submergence and resurfacing, enabling safe operation under rough sea conditions while reducing surface-wave loading. The mooring and structural configuration were designed to withstand local hydrodynamic forces, and the cage is supported by a solar-powered surface platform for surveillance and system control.

To address the critical need for in situ stock assessment, a fish biomass estimation system has been conceptualized around multi-sensor observations. The approach combines underwater video imaging and acoustic sensing to derive size distribution and abundance, which are converted to biomass using species-specific length–weight relationships. These data streams are planned to be integrated with environmental and feeding records to develop decision-support tools for feed optimization and health monitoring.

The submerged cage has been successfully deployed at North Bay, Andaman, and is presently under observation to evaluate structural behaviour, operability, and fish response over an extended period. The combined cage and biomass estimation system is expected to enhance the sustainability and profitability of open-sea mariculture in Indian waters, thereby supporting national priorities in food security, coastal livelihoods, and the growth of the blue economy.

Keywords: Submerged fish cage; Open-sea mariculture; Fish biomass estimation; Underwater imaging; Acoustic sensing

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A Phase Change Material Based Buoyancy Control System For Autonomous Ocean Profiling Floats

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ABSTRACT

Autonomous ocean profiling floats play a vital role in long-term ocean monitoring. However, their operational lifespan is often limited by the use of mechanically driven pumps and high onboard power consumption for buoyancy control. This research paper presents an energy-efficient buoyancy modulation system that utilizes the natural vertical temperature gradient of the ocean to reduce dependence on conventional power-intensive mechanisms. The proposed approach is based on the use of a Phase Change Material (PCM) that exchanges heat with the surrounding seawater as the profiler ascends and descends through different depth layers. The PCM undergoes reversible phase transitions in response to ambient temperature variations, resulting in a volumetric and density change of approximately 10–12 percent. This physical change is coupled to a closed hydraulic circuit, where the expansion and contraction of the PCM generate hydraulic pressure. The generated pressure is used to charge a hydraulic accumulator containing a working fluid, which in turn enables controlled adjustment of the profiler's buoyancy. This process allows vertical motion without the need for electrically driven pumps or additional external energy sources.

By harvesting thermal energy directly from the ocean environment, the proposed system significantly reduces energy consumption and mechanical wear while improving system reliability. The simplified design enhances durability and supports extended deployment durations. The proposed buoyancy control mechanism is therefore well suited for long-term autonomous oceanographic observations, climate monitoring, and deep-sea research applications where low power consumption and operational longevity are critical.

Keywords: Buoyancy Control, Closed Hydraulic Circuit, Ocean Profiling Float, Phase Change Material, Thermal Energy Harvesting

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Impact Of Intensive Grading On Growth Performance And Reducing Cannibalism In Nursery Rearing Of Asian Seabass In Open Sea Conditions

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ABSTRACT

This study examines the effects of intensive grading on mitigating cannibalism and enhancing the survival and growth performance of fish in open-sea conditions over a 90-day rearing period (90 days of culture). A total of 2,100 fingerlings, with an initial mean weight of 0.3 grams and a length of 2 centimetres, were stocked in a marine cage system. Periodic grading was implemented to maintain uniform size distribution, thereby minimising aggressive interactions among individuals. Upon harvest, the fish exhibited a mean final weight of 31.04 grams and a length of 12.02 centimetres, with weight and length distributions ranging from 12 to 61 grams and 10 to 15.2 centimetres, respectively, indicative of consistent health and growth across the stocked population. The intensive grading protocol significantly minimised size variation and suppressed cannibalistic behaviour, a prevalent challenge under open sea conditions due to environmental variability and competition for resources. After the nursery rearing period, a survival rate of 79.42% recorded. This highlights the effectiveness of the grading strategy in promoting a stable environment. A total feed consumption of 64,603 grams facilitated a final biomass of 51,774.72 grams, achieving a favourable feed conversion ratio (FCR) of 1.25. The daily growth rate (DGR) and specific growth rate (SGR) were calculated to be 1.02 grams/day and 2.24% day^{-1}, respectively, reflecting a robust and uniform growth performance across the graded groups. These findings highlight the critical role of periodic and intensive grading as a management strategy for preserving size homogeneity, reducing dominance-related aggression, and enhancing overall production efficiency in sea cage culture systems. The study emphasises the importance of timely stock segregation and appropriate husbandry practices in optimising survival rates, minimising losses attributed to cannibalism, and promoting sustainable and profitable aquaculture under open sea conditions.

Keywords: Lates calcarifer, Cannibalism, improved FCR, DGR, SGR

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Real-Time Surveillance & Health Monitoring System For Open-Sea Fish Cage Culture: Insights From North Bay, Andaman Sea Trials (April 2025)

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ABSTRACT

This study presents a next-generation with real time surveillance and health parameters specifically engineered for open-sea conditions and validated through field testing at North Bay, Andaman in April 2025. The system integrates a multi-sensor with multiparameter approach combining real time both underwater and surface surveillance with real-time environmental data acquisition to deliver a comprehensive and non-intrusive assessment of health of the fish stock within cages. The device deploys high-resolution underwater cameras and multiparameter sensors for monitoring and surveillance to avoid poaching, theft, fish stress etc.,

The North Bay test campaign demonstrated the system's resilience to open-sea challenges, including high turbidity, biofouling, wave-induced motion, and interference from wild fauna. The unit's corrosion-resistant materials, impact-absorbent housing, and adaptable mounting proved reliable during 96 hours of uninterrupted operation. Real-time data streaming to the shore-based aquaculture management console enabled continuous monitoring and responsive feed-management decisions, significantly reducing lag inherent in manual sampling. Preliminary results showed up benefits over operational efficiency, the device enhances environmental stewardship by preventing overfeeding, reducing nutrient discharge, and mitigating ecological stress around fish cages. Positioned as a robust, scalable, and economically viable solution, the real time monitoring device sets a new benchmark for data-driven aquaculture management. The successful outcomes from the Andaman sea trials confirm its readiness for large-scale deployment and highlight its potential to contribute to sustainable open-sea fish cage culture, both nationally and globally.

Keywords: Open-sea aquaculture, Health monitoring of fish, Surveillance system, Underwater imaging, Machine learning, Feed optimization, Sustainable aquaculture, Real-time monitoring.

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Development Of A Boat-Based Towed Profiling System For High-Resolution Coastal Ocean Observations

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ABSTRACT

Reliable, high-resolution measurements of coastal and estuarine waters are essential for understanding freshwater influx, stratification, biogeochemical variability and climate-driven changes, yet conventional ship-based profiling is expensive and logistically demanding. This work presents an indigenous boat-based towed profiling system that enables continuous Conductivity–Temperature–Depth (CTD) observations from small survey boats, specifically tailored for shallow-water and nearshore environments. The towed profiler comprises a hydrodynamically shaped tow fish housing a CTD sensor, an automated electro-mechanical winch, an EM tow cable, GPS receiver, onboard controller and operator console. Using real-time depth feedback and inputs from an echo sounder, the winch executes repeated profiling cycles between user-defined minimum and maximum depths while the boat is underway, providing quasi-synoptic vertical sections of temperature and salinity along the track. Automated depth control avoids seabed contact, permits adaptive operation in variable bathymetry, and minimises manual intervention, which is particularly advantageous in narrow channels and river mouths.

Sea trials conducted off Chennai and adjacent Bay of Bengal waters have demonstrated robust performance, with repeated profiles acquired to depths of about 80 m from small boats under realistic sea conditions. The modular design allows rapid replacement of the sensor head, enabling future integration of additional sensors for turbidity, chlorophyll, dissolved oxygen and nutrients to transform the platform into a comprehensive coastal water-quality observatory. The boat-based profiling system thus offers a cost-effective, flexible and scalable solution for strengthening India's coastal and estuarine observing network, supporting national priorities in climate studies, ecosystem management and operational oceanography.

Keywords: freshwater influx, stratification, high-resolution measurements, estuarine waters

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Path Following Of Wave Glider

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ABSTRACT

Wave glider is an unmanned marine surface vehicle which is propelled by wave energy. The onboard electronics is powered by the solar energy. Due to its non dependency on external power source, this versatile wave glider is popularly utilised in diverse applications such as long term in situ ocean surveys, air sea interaction studies and defence surveillance etc. wave glider architecture is designed and is under development. The paper addresses the way point based path following problem of the wave glider by utilising Line Of Sight (LOS) algorithm. The path following simulations are conducted under different condition to investigate system performance. The simulation with kinematics results demonstrate satisfactory convergence to prescribed waypoint sequences and maintained cross-track error performance within acceptable operational thresholds, thereby validating the efficacy of the proposed LOS-based guidance methodology for autonomous wave glider navigation.

Keywords: Marine surface vehicle, wave glider, path following, LOS.

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Sea Fans Associated Ophiuroids (Echinodermata) Of Gulf Of Kachchh, India

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ABSTRACT

The Gulf of Kachchh is a marginal reef region that is less explored than any other major coral reef region in India. The present study was conducted in 2025 to find the relationship between Sea fans (Cnidaria: Octocorallia) and Brittle stars (Echinodermata: Ophiuroidea) in the Gulf of Kachchh. A total of six genera of sea fans were studied, namely Echinogorgia sp., Ellisella sp., Euplexauara sp., Junceella sp., Menella sp. and Pseudopterogorgia sp. The brittle star, Ophiothela mirabilis (Verrill, 1867), is the only species found associated with sea fan colonies, and it is also the first distribution record in the Kachchh with different color morphs, depending on the host color pattern, i.e., orange and dark orange, maroon, and sandal with white-banded (sometimes with dark blue) forms. Out of 86 sea fan colonies studied, only 21% colonies recorded with an associated ophiuroid. Maximum association was recorded in the sea fan Echinogorgia sp. (63%) followed by Junceella sp. (25%) and Pseudopterogorgia sp. (12%) and Euplexauara sp. (1%). The genera Ellisella and Menella were recorded with no associated ophiuroids. Likewise, no sea fan-echinoderm association was observed in depth above five meters. The ophiuroids were associated with all the forms of sea fans, irrespective of their growth forms such as single, multi & reticulate branch forms. This behavior may be to avoid immersion from the sedimentation of the sea floor, as the ophiuroids were observed clumping together as well as searching and resting on new hosts while separated from their hosts in the ex-situ. The association appears to be commensalism in nature, as no apparent benefit is observed for sea fans, but the echinoderm strategically obtains shelter and suitable ground for filter feeding in the most turbulent water environment. The present study is the first of its kind attempt to study the sea fan – echinoderms association, employing SCUBA in Indian waters. Further such studies may result in more interesting associated and cryptic species from this poorly studied reef region.

Keywords: Gulf of Kachchh, North-west coast of India, Ophiuroids, Sea fans, Symbiosis.

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Mitochondrial Marker-Based Insights Into Genetic Diversity And Phylogenetic Relationship Of The Himalayan Snow Trout Schizothorax Plagiostomus From The Tons River, Uttarakhand.

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ABSTRACT

Genetic diversity and phylogenetic relationships of threatened freshwater fishes are crucial for their effective management and conservation. Schizothorax plagiostomus (Cyprinidae), a vulnerable snow trout inhabiting the Himalayan rivers, faces severe anthropogenic pressures and habitat alterations in the Tons River, Uttarakhand. This study examines the Phylogenetic relationship and genetic differentiation of S. plagiostomus populations inhabiting the Tons River, a tributary of the Yamuna in Uttarakhand, inferred from Mitochondrial Markers. In this study, 40 COI (450 bp) and 40 Cyt b (312 bp) sequences of *Schizothorax plagiostomus* from four riverine sites were analysed to assess genetic diversity and evolutionary relationships. COI revealed 10 haplotypes with moderate haplotype diversity and low nucleotide diversity, while Cyt b showed 12 haplotypes with high haplotype diversity and low nucleotide diversity. The concatenated dataset (COI + Cyt b) identified 20 haplotypes, indicating overall high genetic diversity across populations. Phylogenetic reconstruction clustered haplotypes with conspecific populations reported from other Himalayan drainages, indicating both shared ancestry and potential river-specific lineages. while also identifying unique haplotypes restricted to the Tons population. Although *Schizothorax plagiostomus* is regionally vulnerable, it still retains considerable genetic variation, likely due to its historically large population and recent decline. Conserving this existing genetic variation is essential for the species's long-term survival. The findings support fisheries management by emphasising the need to maintain habitat connectivity, reduce anthropogenic pressures, and prevent genetic erosion. The study also highlights the value of mitochondrial markers in detecting cryptic diversity and providing essential baseline data for conservation. Overall, maintaining river connectivity and habitat integrity is crucial for preserving the evolutionary potential of *S. plagiostomus* in the Tons River.

Keywords: Genetic diversity, Phylogenetic Relationship, Schizothorax plagiostomus, Cytochrome oxidase I, Cyt b, Tons,

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Optimisation Of Biosurfactant Production Using Agro-Industrial Waste For Sustainable Oil Recovery

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ABSTRACT

Microbial biosurfactants represent an eco-friendly and sustainable alternative to synthetic surfactants for marine oil spill remediation and enhanced oil recovery (EOR) under saline environments. Produced by microorganisms such as Bacillus subtilis, these amphiphilic compounds are biodegradable, exhibit low toxicity, and originate from renewable sources. Biosurfactants efficiently lower surface and interfacial tensions, promote emulsification, reduce the critical micelle concentration (CMC), and modify wettability, thereby aiding in the efficient mobilisation of oil. Despite their advantages, the low yield and high production costs of biosurfactants have limited their wider application in reservoir fields. To address this, the present study utilised sugarcane molasses as a carbon source and corn steep liquor (CSL) as a nutrient supplement to enhance biosurfactant production by an isolated strain, Bacillus subtilis RSL-2. The optimisation of production parameters—including molasses concentration (1–5% w/v), pH (6–8), and temperature (25–45 °C)—was conducted using response surface methodology-central composite design (RSM-CCD). Under optimised conditions, the maximal biosurfactant yield was obtained with 3% (w/v) CSL and sugarcane molasses. The resultant biosurfactant, confirmed as a stable lipopeptide via FTIR, MALDI-TOF, and high-resolution mass spectrometry, demonstrated excellent surface activity (surface tension: 28.52 ± 0.06 mN/m; interfacial tension: 0.1 ± 0.5 mN/m; emulsification index: 59 ± 1%; CMC: 100 ± 1 ppm). Application in core flood experiments achieved ~78% oil recovery, highlighting its potential as a sustainable agent for microbial enhanced oil recovery and the remediation of oil-polluted marine systems.

Keywords: Agro-industrial waste, Biosurfactants, optimization, oil recovery

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AI Based Marine Biosensor System For Detecting Ocean Borne Pathogens

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ABSTRACT

The increasing prevalence of ocean-borne pathogens poses serious risks to public health, marine ecosystems, and coastal economies. Traditional laboratory-based diagnostics are often slow, resource-intensive, and unable to provide real-time insights into rapidly changing marine environments. Oceans support countless life forms, yet they are threatened by harmful pathogens, making the rapid detection of these microbes critical. The system integrates advanced electrochemical, acoustic, and photothermal sensing modules with machine-learning algorithms to identify microbial signatures with high sensitivity and accuracy. AI models process electrochemical and acoustic detection data streams, filter noise arising from dynamic marine conditions, and deliver early warnings through adaptive pattern-recognition techniques. By combining robust biosensing hardware with intelligent analytics, the system minimizes false positives, reduces response time, and enables scalable deployment across coastal monitoring stations, research vessels, and aquaculture sites. This approach supports proactive environmental surveillance, helping communities and policymakers respond quickly to contamination events.
The proposed AI-enhanced biosensor platform represents a significant step toward safeguarding marine health through smart, automated, and real-time pathogen monitoring.

Keywords: Electrochemical sensor, Marine toxins, Ocean-borne pathogens, Acoustic detection, photothermal sensing, Biosensors

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Preliminary Archaeological Exloration Of Coastal Settlements Between Khambhat And Ghandhar In The Gulf Of Khambhat, Gujarat.

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ABSTRACT

Gujarat has long held a decisive position in the maritime trade networks of ancient India, with both the Gulf of Khambhat and the Gulf of Kachchh functioning as major centres of commerce. The Gulf of Khambhat, known for the highest tidal range in India, hosted several significant ports from the Harappan period onwards, including Lothal, Padri, Hanuman no Timbo, Vallabhi, Hathab, Khambhat or Cambay, Gandhar, and Bharuch. This study presents the results of a preliminary archaeological exploration conducted between 9 and 14 November 2022 across nine sites located between Khambhat and Gandhar. The investigation aimed to assess the potential of these locations, which are Khambhat Dariya, Ralej, Nagra, Vadgam, Badalpur, Kavi, Kamboi, Isanpur, and Gandhar, as ancient maritime centres.

The methodology combined literature review, on-foot surveys, photographic documentation, and interviews with local communities, particularly fishermen and priests from Sikotara Mata temples. The exploration documented site conditions, local traditions, fishing practices, and surviving cultural landscapes. Preliminary observations reveal a striking continuity between historical descriptions and present-day settlements. Khambhat remains a trading hub, Gandhar is industrialising, and villages such as Vadgam, Kavi Kamboi, and Isanpur continue to rely on fishing, though the occupation is declining. Local legends, especially the Mahisagar narratives, and the enduring significance of Sikotara Mata temples suggest long-standing cultural linkages with maritime activity.

This investigation offers the first systematic documentation of several coastal sites in this region and highlights their potential for future archaeological excavation. It provides crucial preliminary insights into the maritime history of the Gulf of Khambhat and its cultural resilience over time.

Keywords: Gulf of Khambhat, Maritime Archaeology, Ancient ports of Gujarat, Coastal exploration, Fishing communities and folklore.

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Assessment Of Spatial And Temporal Dynamics Of The Noctiluca Scintillans In Goan Coast

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ABSTRACT

Noctiluca scintillans is widely reported for producing algal bloom and bioluminescence and is common in coastal waters of Goa. The occurrence of Noctiluca scintillans bloom is often linked with physical, chemical and biological activity. The presence of the species in coastal waters of Goa is due of coastal upwelling, nutrient enrichment and hypoxic conditions. The present research mainly focuses on monitoring the growth of Noctiluca scintillans along the coast of Goa and understanding how the various physico-chemical and biological parameter contribute in its growth. Water samples are collected from 4 stations two of which are the transition zone that are favourable for its growth directly or indirectly. The key parameters, monitored are temperature, salinity, ph, turbidity, dissolved oxygen, nutrient concentration and population of the bloom. These are measured using standard chemical, physical and biological parameters. The distribution and fluctuation of Noctiluca scintillans along the coast of Goa can provide further insight for improving coastal monitoring and can assist in forecasting bloom events.

Keywords: Noctiluca scintillans, algal bloom, bioluminescent, physico-chemical, nutrient dynamics, bloom monitoring, Goa coast

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Century-Scale Variability and Characteristics of Heavy Rainfall over Indian Capital Cities and Surrounding Regions

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ABSTRACT

Climate change has led to a noticeable rise in the intensity and frequency of heavy rainfall events (HREs) across the Indian region. Despite this, the variability of such events over the capital cities of India remains insufficiently explored. This study addresses this gap by examining HREs across different Indian capital cities and their surrounding regions (within a 100 km radius), representing various homogeneous rainfall zones. Long-term daily rainfall datasets from the India Meteorological Department (IMD) spanning 100 years (1922–2022) were analyzed to assess spatial and temporal variability. Results indicate that the North-Eastern (NE) and Central India (CI) regions—including cities such as Panaji, Gangtok, Mumbai, Dispur, and Shillong—have emerged as prominent hotspots of HREs and very heavy rainfall events (VHREs), characterized by high frequency and intensity. In contrast, the Southern Peninsular (SP) and North-Western (NW) regions exhibit relatively stable trends. The region-wise probability density functions reveal that HREs and VHREs predominantly occur within the ranges of 65–75 mm/day and 125–150 mm/day, respectively. Decadal analysis highlights a distinct increase in the number of HREs and VHREs per decade for Mumbai (7.29, 3.03), Shillong (18.49, 19.71), Dispur (7.98, 3.95), and Panaji (13.71, 5.29), signalling an escalating prevalence of severe rainfall events in these regions. Most HREs and VHREs appear localized; however, cities in CI and NE exhibit notable instances of spatially widespread events. Analysis of consecutive two-day rainfall events further reveals substantial volumetric contributions over major cities, including Mumbai, Panaji, Gangtok, Shillong, and Dispur. Trend analyses of rainfall anomalies under HRE and VHRE conditions show a significant intensification of VHREs in Mumbai and Shillong during recent decades (2002–2022). These findings underscore the increasing hydrometeorological risks associated with extreme rainfall in rapidly urbanizing centres of India.

Keywords: Heavy rainfall events, very heavy rainfall events, localized heavy rainfall events

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Development Of A Low-Cost Submarine For Subsurface Surveillance And Monitoring

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ABSTRACT

Our work presents the design and construction of an economical Remotely Operated Vehicle intended for inspection and environmental observation in shallow aquatic environments. The platform was developed to provide research groups and academic institutions with a cost-effective tool for routine underwater data acquisition, particularly in contexts where commercial systems are financially prohibitive.
The vehicle integrates a reconfigurable layout and off-the-shelf components, resulting in an approximate build cost of ₹20,000. Its architecture supports multiple payload options, allowing the system to be adapted for visual surveys, sampling-based measurements, and exploratory operations.
Emphasis on simple assembly, component availability, and ease of modification enables rapid iterations during field deployment. These characteristics make the platform suitable for sustained monitoring efforts in locations where traditional underwater technologies are impractical. This paper describes the structural design, hardware choices, and engineering considerations that guided the development of this accessible and adaptable ROV.

Keywords: Remotely Operated Vehicle (ROV), Underwater inspection, Low-cost marine technology, Environmental monitoring, Modular payload architecture

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Evaluation Of The In-Vitro Probiotic Characteristics And Antibiotic Potential Of Bacillus Paramycoides And Micrococcus Luteus From Marine Sediment

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ABSTRACT

The marine ecosystem harbours vast microbial diversity, with marine bacteria standing out for their metabolic versatility and ability to thrive in diverse conditions. Marine probiotic bacteria have gained attention for their potential to promote health and prevent diseases in both marine organisms and humans. Marine sediments, in particular, serve as rich reservoirs of novel and beneficial microbes. Recent research has increasingly focused on isolating probiotic bacteria from these sediments, especially due to their promising applications in aquaculture. The study focused on exploring marine sediment microbial derived bacteria with probiotic potential. The sediment sample was collected at a 15 cm depth in Palk Bay, Southeast India and stored at 4°C before analysis. The sampling location, depth, time, and environmental conditions (e.g., temperature, salinity) were recorded for metadata documentation. The isolated bacteria were identified as Bacillus paramycoides and Micrococcus luteus using 16S rRNA sequencing which was then screened for probiotic properties. The study assessed the antibiotic activity, acid-base tolerance, temperature resistance, and auto-aggregation properties of B. paramycoides and M. luteus. For Antibiotic activity, both bacteria showed no inhibition zone for ampicillin and penicillin, while Bacillus paramycoides was most sensitive to gentamicin with highest zone (3.7 mm) and least to tigecycline (2.6 mm), and M. luteus had the highest zone for erythromycin (4.2 mm) but also the lowest (2.5 mm) for tigecycline. While for Acid tolerance test M. luteus was more resistant to HCl than B. paramycoides, whereas both displayed high base tolerance, though M. luteus had slightly reduced growth at 5% and 7% NaCl and Temperature tolerance assay the both strains survived at 45°C, indicating strong heat resistance. Auto-aggregation test revealed good aggregating properties for both bacteria, suggesting potential biofilm formation or adhesion capabilities. Overall, the two species exhibited distinct antibiotic resistance profiles, with Micrococcus luteus being more acid-tolerant, while both were alkali-resistant, heat-stable, and capable of aggregation. Both the bacteria exhibit beneficial traits such as stress tolerance, antibiotic activity, and gut colonization ability, making them promising candidates for aquaculture probiotics.

Key words: Marine sediment, Bacillus paramycoides, Micrococcus luteus, aquaculture, probiotics.

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Spatio-Temporal Analysis Of Heat Waves In India (1969-2019): A Focus On The Top 10 Affected States

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ABSTRACT

Heatwaves represent one of the most significant emerging threats in the coming decades; hence, their long-term assessment and past analysis are essential for understanding future implications. This study implicates a long-term evaluation of heatwave occurrences across India, highlighting clear spatial and seasonal disparities. The analysis reveals that heatwaves predominantly occur during the pre-monsoon months of April, May, and June, with May contributing the largest share of the national heatwave footprint. Ten states, such as Andhra Pradesh, Rajasthan, Odisha, Telangana, Bihar, Punjab, Madhya Pradesh, Gujarat, Uttar Pradesh, and West Bengal, emerge as the most heatwave-prone, reflecting the influence of regional climatic dynamics, surface characteristics, and monsoon behaviour. Distinct temporal patterns are observed, as several northern and eastern regions experience heatwaves extending into the onset of the monsoon season. Inter-annual fluctuations in intensity, particularly in Bihar, Jharkhand, and Uttar Pradesh, point to the interplay between monsoon variability and large-scale climatic oscillations. Conversely, coastal and northeastern states such as Kerala, Goa, and the Himalayan regions remain comparatively less affected due to maritime moderation and early monsoon onset. The findings underscore the growing vulnerability of central, eastern, and northern India to prolonged heat stress and highlight the need for localised early warning systems, climate-resilient urban planning, and adaptive measures to mitigate socio-economic and ecological risks in a warming climate.

Keywords: Heatwaves, Spatio-Temporal, Pre-monsoon, Top 10 affected states, Adaptive measures.

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Integrative Multi-Omics Analytics For Accelerating Marine Natural Product Research And Drug Discovery

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ABSTRACT

Marine ecosystems are among the most abundant sources of structurally varied and biologically active natural compounds. However, the extensive chemical and genomic potential of these metabolites is not fully utilized. Efficient translation of this chemical diversity into therapeutic candidates is hampered by difficulties in identifying novel and pharmacologically significant structures due to the limited integration of chemical, biological, and taxonomic data despite the increasing but fragmented information available. Our research introduces an all-encompassing data analytics framework that combines genomics, metabolomics, taxonomic data, and network biology. This integration is designed to systematically examine marine natural product datasets with the aim of advancing research in marine natural products and expediting the discovery of drugs derived from marine sources.

Existing databases contain fragmented taxonomic, genomic, chemical and bioactivity annotations for marine natural products and their scale and heterogeneity impede systematic prioritization. We developed an integrative analytics pipeline that leverages two complementary datasets: one comprising bioactivity profiles and the other containing genomic and taxonomic information. Our framework quantitatively assesses chemical scaffold relatedness and novelty between marine natural products and approved drugs, mapping their relationships to known therapeutic targets and bioactivity profiles.

By integrating multidimensional data, including genomics, metabolomics, taxonomy, and network-biology analyses, we developed a predictive and scalable method to assess newly identified marine compounds within the framework of existing pharmacological knowledge, such as associated targets, scaffolds, bioactivity profiles, pathways, and potential disease associations. This approach of integrating various data types into a single analytical framework addresses significant challenges in marine natural product research and provides a more efficient route from discovery to therapeutic application. Our results highlight the potential of computational methods to exploit the extensive chemical diversity found in marine ecosystems and to accelerate the translation of marine-derived compounds into therapeutically relevant drugs.

Keywords: Marine natural products, Big data analytics, Multi-omics data integration, Novel chemical-scaffold prioritization, Marine therapeutics.

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The City Hums Under The Water: Analysis Of Urban Marine Soundscape Using Passive Acoustic Monitoring

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ABSTRACT

Mumbai, the commercial capital of India, is teeming with a huge population. To support the sustenance and livelihood of these people, lots of industrial and commercial activities are ever-present, contributing to the anthrophony of the marine soundscape. In this study, we investigated how the biophony co-exists with the other two components of the marine metropolitan soundscape of Mumbai: geophony and anthrophony, despite the latter being quite dominant. Using passive acoustic monitoring, we aimed to monitor the underwater soundscape of the Mumbai Metropolitan Region (MMR). A Loggerhead underwater passive acoustic recorder equipped with an HTI 96-min hydrophone was moored at a depth of 15 m and 3.5 km away from the coastline near the Mumbai Coastal Road (south) construction project during the period of 22nd February to 7th March, 2024. The acoustic signatures of cetacean Sousa plumbea, fishes such as Terapon spp. and snapping shrimps are identified by analysing spectrogram, waveform and power spectral density (PSD) of individual occurrences. The fish chorus shows a particular diurnal pattern, which also helps us identify the organisms further by comparison with existing literature. Acoustic indices such as root mean square sound pressure level (SPL_{RMS}) and acoustic complexity index (ACI) are measured to get an idea about the overall soundscape diversity. This study highlights the dynamic interplay of biophony, geophony, and anthrophony in the marine environment of MMR, demonstrating the potential of passive acoustic monitoring as an effective tool for assessing coastal soundscape health in urbanised marine settings.

Keywords: Biophony, Anthrophony, Geophony, Marine soundscape, Fish chorus, Acoustic indices

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Sustainable Approach: Utilizing Insoluble Chitin Substrates With Bacillus Aryabhattai For Producing Bioactive Chitin Oligomers And Chitinase And Enhancing Sustainable Tomato Cultivation

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ABSTRACT

Globally, large amounts of chitin rich waste are produced during the processing of seafood, and this trash frequently contaminates the Coastal environment. Using Bacillus aryabhattai, a novel marine bacterium with chitinase activity that can act on insoluble chitin without any acid pretreatment. Moreover, It converts insoluble chitin into bioactive chitin oligomers which reduces the chemical usage on chitin oligomers production. This study focuses on developing an economical process for producing chitinase and chitin oligomeres and assessing their potential as biostimulants and antifungal agents on tomatoes (Solanum lycopersicum). Bacillus aryabhattai is cultivated in an optimized media containing insoluble chitin for chitinase and chitin oligomers production. Spent media containing chitin oligomers were then characterized using biochemical and chromatographic techniques to identify the essential metabolites which helps chitin oligomers to enhance plant performance. The biological efficacy of these oligomers will be evaluated in terms of seed germination, plant growth performance, resistance to fungal infections such as Alternatia solani and Caldosporium fulvum, as postharvest coatings to prolong fruit shelf life, improved root and shoot growth, increased phenolic and chlorophyll content, and better preservation of fruit quality parameters including acidity and vitamin C. This study promotes the concepts of the circular bioeconomy by combining sustainable agriculture with the additional value of marine waste. It is anticipated that the results will show how Bacillus aryabhattai derived chitin oligomer can be used as biostimulants and bioprotectants, lowering the need for chemical fertilizers and fungicides while promoting sustainable tomato production and environmental preservation.

Keywords: Bacillus aryabhattai, Chitin oligomer, Biostimulant, Antifungal, Postharvest treatment.

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A Wave Power Machine To Generate Electricity From Ocean Waves And Tides

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ABSTRACT

There is provided a wave power machine comprising: a cylinder (1) containing a piston (3) attached with a piston rod (4) provided with air seals (3a, 4a) and fixed buttons (5, 5a) for airtight movement; a flexible pipe (2) having an upper mouth being connected with the cylinder (1), a tap (2a) being configured to fill water into the pipe (2) from an external source and a removable cap (2b) to be removed from the lower mouth (2b) being immersed into the sea after the pipe (2) is filled with the water; an exhaust pump (6) for creating and maintaining vacuum above the piston (3) within the cylinder (1); a pulley (7) being connected with a generator

(8) by a belt (8a); an electrical motor (9) configured to push the piston rod (4) in conjunction with the piston (3). Principle of atmospheric pressure is implemented therein.

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Integrated Analytical Framework For Cyclone Hazard, Structural Fragility, And Socio-Economic Vulnerability Assessment In Coastal Tamil Nadu

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ABSTRACT

Cyclonic hazards along India's east coast have intensified in recent decades, leading to severe structural damage, economic losses, and repeated disruption to coastal communities. Existing studies, including cyclone-proneness mapping for Tamil Nadu, largely depend on historical track density and broad zonation, without translating cyclone histories into spatially varying wind or surge intensities or linking them to the fragility of real buildings and the socio-economic vulnerability of exposed communities. Addressing these gaps, this research develops a comprehensive analytical framework that integrates hazard modelling, structural fragility assessment, and socio-economic vulnerability analysis for cyclone-prone coastal Tamil Nadu.

An updated cyclone hazard catalogue from 1891 to the present is used to reconstruct spatial wind fields, storm surge levels, and combined hazard layers for multiple return periods. At the structural scale, five critical components of rural and semi-engineered buildings—openings, roof cover, secondary roof members, roof-to-wall connections, and walls—are evaluated for their likelihood of failure under varying wind intensities. Probability distributions derived from field evidence and literature, together with Monte Carlo simulation, are used to develop a Damage Probability Matrix (DPM). Wind speed distributions including Gumbel, Frechet, Weibull, and Lognormal models help estimate expected damage and assess the influence of wind variability and material strength.

At the community scale, data from cyclone-exposed households are analyzed to construct a Multidimensional Vulnerability Index (MVI) incorporating social, economic, physical, institutional, and awareness indicators. Results show that weak economic and physical conditions, combined with only moderate institutional capacity, significantly heighten community vulnerability. A detailed building inventory—generated using field surveys, remote sensing, and structural classification—further supports the development of analytical vulnerability indices and loss estimates for **dominant** typologies.

Probabilistic loss modelling is used to quantify expected physical damage, economic loss, and spatial risk at the building and block levels. Model outputs are validated using historical post-cyclone damage records and field observations. Findings highlight critical weak structural typologies, high-risk coastal corridors, and the need for targeted retrofitting strategies such as improved roof anchorage, component strengthening, and found

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stabilization. The study identifies key research gaps, including limited field validation, insufficient representation of non-engineered structures, lack of terrain-sensitive wind modelling, and inadequate integration of resilience indicators.
By combining hazard intensities, structural fragility, socio-economic vulnerability, and retrofit prioritization in a single analytical framework, this research supports evidence-based decision-making for cyclone risk mitigation and contributes a scalable methodology for future coastal resilience planning.

Keywords: Cyclone Vulnerability Assessment, Structural Fragility Modelling, Damage Probability Matrix (DPM), Multidimensional Vulnerability Index (MVI), Probabilistic Loss Analysis**.**

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Modulation Of Northwest India's Rainfall During Indian Summer Monsoon By Indian Ocean Dipole Phases.

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ABSTRACT

Indian Ocean Dipole (IOD) is a large-scale ocean-atmosphere phenomena which affects Indian Summer Monsoon Rainfall (ISMR). With the observed northwestward shift of ISMR in recent decades, the influence of IOD on rainfall over Northwest India (NWI) has become increasingly important. Using IMD rainfall observations and ERA5 reanalysis, we examine 29 IOD years (15 positive, 14 negative) during 1958–2023 to quantify how IOD phases shape rainfall variability across Gujarat and Rajasthan. Rainfall anomalies between the two phases reveal a tripolar pattern: deficits across northern Rajasthan and southern Gujarat and surpluses along the Gujarat-Rajasthan border region and the central interior plains. Dominant empirical orthogonal function (EOF; ~40% variance explained) reveal positive loading across most of the region with higher concentrations over southern Gujarat which decreases meridionally. Dynamical diagnostics show that phase-dependent changes in the regional Hadley circulation and vertically integrated moisture transport play a central role in driving these rainfall anomalies. Detailed spatial patterns and associated mechanisms will be presented and discussed.

Keywords: Indian Ocean Dipole, Indian Summer Monsoon Rainfall, Northwest India, Rainfall Variability

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Eco-Engineered Concrete For Dual-Purpose Floating Infrastructure

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ABSTRACT

Coastal development is harming marine life. We're addressing this by turning necessary "hard" infrastructure into active habitats. Our research developed innovative concrete materials for floating structures. These aren't standard cement; minor tweaks to the mix composition and the addition of surface texture dramatically improve biological outcomes.
What we found: Significantly higher growth and settlement of marine life. Increased diversity, especially for key species like oysters and corals. Crucially, this ecological boost is balanced with performance. The modified concrete maintains the durability and stability essential for harsh marine environments.
The takeaway: By embedding ecological design directly into floating structures, we can use our infrastructure to actively support marine ecosystems, finding a practical balance between human coastal needs and vital environmental preservation.

Keywords: Ecological Engineering, Marine Infrastructure, Concrete Innovation, Coastal Biodiversity

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Antibiotic And Antagonistic Potential Of Sponge Associated Bacteria Vibrio Diabolicus And Lysinibacillus Odysseyi From Palk Bay, India

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ABSTRACT

Sponges house numerous microorganisms which can provide novel drugs and assured bioactivities. Even after the sponge associated bacteria were studied, the possibility of discovering novel drugs seems higher. Thus, in the study two different bacteria associated with marine sponges were analyzed and characterized. Vibrio diabolicus, one of the studied bacterium expressed complete resistant against Ampicillin. Another bacterium, Lysinibacillus odysseyi exhibited several enzyme activities in biochemical assays, including amylase, oxidase and catalase secretions. These bacteria were analysed for antagonistic activity against several pathogens including Vibrio cholarae, Bacillus subtilis, Salmonella typhi and Mycobacterium segmatis and resulted with remarkable zone of inhibition (7-11mm). This work concludes with the further scopes of the present study.

Keywords: Sponge associated bacteria, Palk Bay, Drug resistance, bioactive compounds.

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Beach Morphological And Shoreline Changes In Tavsal Beach In The Ratnagiri District, Maharashtra Coast.

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ABSTRACT

Tavsal Beach, situated in the Ratnagiri district of Maharashtra, India, is accessible by ferry from Jaigad. Beach profiling was conducted at eight stations across a 7 km stretch from February 2024 to November 2024, at three-month intervals over one year. Beach volumes were calculated for each profile, and variations in beach volumes were assessed for the shortest measured profile. The volumes and their differences compared to the previous month's profile are presented. Coastline dynamics showed more significant changes during the post-monsoon phase. Erosion was more pronounced than during the monsoon period, despite minimal coastline change, while accretion was more severe compared to the pre-monsoon period, with the largest coastline change being accretion. The findings indicate that shoreline dynamics varied considerably throughout the study area. The results revealed that the strongest accretion occurred at Stations 7 and 8, while the most severe erosion was observed at Stations 4 and 5. Wave energy along the Tavsal coast is notably high.

Keywords: Profile, Shoreline, Volume, Erosion , Accretion

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Spinach Under Arsenic And Microplastic Stress: Role Of Rice Straw Biochar And Rice Straw As Soil Amendment In Arsenic Mitigate And Growth Response

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ABSTRACT

Arsenic (As) contamination is a huge challenge for a country like India, where lots of places are contaminated with the Arsenic along with this, due to bad plastic management, plastic pollution has become common, and plastic remains in the environment for long. Arsenic Contamination and Microplastics are studied separately, but combined study is still limited, and their effect on soil and food material is poorly understood. To bridge the gap, we try to study the combination of both with the help of a pot experiment where we try to see the combined effect of Arsenic and Polystyrene not only that, even the mitigation of Arsenics by rice straw and rice straw biochar. We conducted the control study in the climate Incubator for 5 days, keeping the temperature at 25°C, Relative Humidity 65% and 12/12 hours day/Night. Soil was spiked with the Arsenic and treated and Biochar (2% w/w) and Microplastics (0.25% w/w). Arsenic concentrations in plant tissues were quantified using ICP-OES. Results show that Arsenic-spiked soils created a 20-fold increase in shoot Arsenic concentration and reduced plant weight by approximately 50% compared to the control. However, both polystyrene MPs and rice-straw biochar significantly reduced As accumulation in the spiked soil case, indicating their potential role as effective amendments. Biochar is more effective than raw rice straw.

These results show the importance of understanding Arsenic interaction with microplastics. This study also emphasizes that the role of cheaper rice straw can become a potential solution for high toxic contaminants. Such insights are highly relevant for regions facing problems of microplastic pollution and Arsenic and have broader implications for soil health, food security, and environmental management in terrestrial and coastal systems.

Keywords: Arsenic, Microplastics, Rice Straw Biochar, Mitigation, Growth Responses

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Marine Bacterial Metabolites As Promising Larvicidal Agents Against Mosquito Vectors.

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ABSTRACT

Mosquito-borne diseases such as malaria and dengue remain major global health concerns. The World Malaria Report 2023 estimated 249 million malaria cases worldwide. Vector control efforts are increasingly challenged by widespread insecticide resistance reported in mosquito populations across 88 countries. Since current interventions such as long-lasting insecticide-treated nets (LLINs) and indoor residual spraying (IRS) rely mainly on pyrethroids, their prolonged use has accelerated resistance development, highlighting the urgent need for novel and eco-friendly alternatives to chemical insecticides. This study evaluated the larvicidal potential of marine bacteria isolated from diverse coastal regions of India. 55 bacterial isolates were cultured, and metabolites present in their culture supernatants were screened against larvae of major mosquito vectors, including Anopheles stephensi, Aedes aegypti, An. subpictus, and An. culicifacies. 12 extracts demonstrated strong larvicidal activity, achieving 90–100% mortality at 250 ppm against An. stephensi. Notably, strains NIO 707 and NIO 706 showed robust activity against Aedes aegypti and An. subpictus, respectively. Extracts from NIO 701, 707, and 710 also significantly reduced egg hatching in An. stephensi and An. culicifacies, indicating possible reproductive inhibition. None of the extracts showed anti-malarial activity or cytotoxicity against Plasmodium falciparum, confirming selective action on mosquito larvae. Phylogenetic analysis revealed that most active isolates belonged to the Bacillus genus, with a notable finding of a larvicidal Enterococcus species. These results highlight marine bacteria as promising sources of natural, eco-friendly bio-larvicides.

Keywords: Larvicidal activity**1**, Marine bacteria**2**, Mosquito vectors**3**, Insecticides resistance**4** and Bio-larvicides**5**

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Sediment Geochemistry, And Environmental Assessment Of Trace And Rare Earth Elements In The Vettar River Estuary, Cauvery River Basin

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ABSTRACT

To understand the spatio-temporal patterns, weathering intensity, provenance, and environmental status, eighty-one bulk bed sediment samples were analysed from the Vettar River Estuary. The sediments are examined for grain size, major oxides, trace elements, and rare earth elements. The sediments are sand-dominated (~70%), with low to moderate weathering intensity and low compositional maturity. The chondrite-normalised sediment is LREE-enriched with a positive Eu anomaly. The REEs showed a positive correlation with Ti and the fine fraction, indicating control by titaniferous minerals. The provenance ternary plots display data distributed in a mixed field, characterized by a felsic-mafic signature. The UCC normalised REE signals are strikingly similar to the upstream delta head bed sediments. Although the REE pattern of massive Charnockite hills resembles that of estuarine sediments, the REE concentration in the estuarine sediments is relatively low. The quartz and feldspar have diluted the signals in the sediments. REE pollution is not evident in the sediment; instead, Cd, Hg, and Cr are the contaminants that are accumulated and pose a threat to the ecosystem. Quantitative source apportionment of elements, carried out using Positive Matrix Factorization. Three-factor sources have been identified, accounting for felsic source rock, alkali-earth and clay minerals, with minor mafic minerals. The third factor has ~30% of anthropogenic input absorbed onto Fe-Mn oxyhydroxides. This is a baseline study employing a comprehensive approach for examining estuarine sediments.

Keywords: Sediment Geochemistry, Rare Earth Elements, Environmental Risk Assessment, Positive Matrix Factorization, Vettar River Estuary

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Towards Sustainable Microplastic Remediation: Advanced Technologies, Nature-Based Solution Operational Barriers, And Future Opportunities

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ABSTRACT

Microplastic contamination has emerged as a global challenge threatening marine, terrestrial, and freshwater ecosystems while inducing risks to human and animal health. An estimated million tons of plastic enter the oceans annually, significantly contributing to microplastic concentration across marine, riverine, and wastewater environments. Conventional treatment systems are usually inefficient in capturing microplastics due to their diverse nature, size, polymer type, buoyancy properties, and interaction with other emerging contaminants, which hinder effective separation and removal. In the context of ocean and coastal protection aligned with the World Ocean Science Congress, this review critically evaluates advanced microplastic removal technologies and their application across wastewater, stormwater, river, and marine systems.

This insight gives a comprehensive overview of advanced techniques for microplastics removal, integrating recent knowledge innovations with practical applications. It also compares the physical, chemical, and biological treatment processes, including electrocoagulation, advanced oxidation process, membrane filtration, biofilm-mediated degradation, and photocatalysis, assessing removal efficiency, secondary pollution risk, scalability, operational feasibility, and environmental implications. We are specifically emphasizing nature-based solutions (NBS) such as constructed wetlands, biochar-assisted adsorption, and algae-based remediation —low-cost, low-energy, and ecologically resilient alternatives suitable for coastal and estuarine systems.

The role of artificial intelligence and machine learning is also explored for improving microplastic detection, real-time monitoring, predictive modelling, and optimizing treatment performance.

By integrating interdisciplinary research to identify critical knowledge gaps and proposing a performance-comparison framework for technology selection, this review provides a strategic road map for developing scalable and sustainable microplastic mitigation solutions. Further, this work aims to guide researchers, policymakers, and practitioners towards advanced next-generation ocean protection strategies through hybrid approaches, circular economy models, and green engineering innovations.

Keywords: Microplastic removal, Nature-based solutions, Environmental sustainability, Hybrid approach, Advanced treatment technology.

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Impact Of Weathering And Environmental Parameters On The Microplastics-Nanoplastics Interaction In Natural Water Systems

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ABSTRACT

The rapid accumulation of plastics in the environment has raised significant concerns about the interactions between microplastics (MPs) and nanoplastics (NPs), which serve as vectors for pollutants and disrupt ecosystems. Primary NPs, released directly through industrial activities, and secondary NPs, formed via fragmentation of larger plastics, are pervasive in aquatic systems. Environmental weathering, including UV radiation and abrasion, alters MP surface properties, enhancing their potential to interact with NPs. However, the mechanisms driving these interactions under varying environmental conditions and in natural water systems such as river and sea water remain poorly understood. This study investigates the sorption of polystyrene nanoparticles (PS-NPs) onto polyethylene, polypropylene, and polyethylene terephthalate MPs, focusing on the impact of weathering. Weathered MPs exhibited increased surface roughness, microcracks, and functional groups, leading to enhanced sorption compared to pristine MPs. Sorption kinetics revealed slower equilibrium times for weathered MPs due to increased active sites. Key environmental factors, including pH, dissolved organic matter (DOM), and ionic strength, were also assessed. Sorption was highest at low pH due to electrostatic attraction but decreased with elevated DOM, which stabilized NPs. Divalent ions like calcium enhanced sorption via ion-bridging, with weathered MPs demonstrating the strongest interactions. In addition, sorption behaviour was evaluated in natural river and sea water, where river water showed the highest level of interaction followed by DI water and sea water. The findings demonstrate that weathering-induced surface changes amplify MPs ability to sorb NPs influencing their transport, persistence and ecological impact. This study highlights the multifaceted role of environmental conditions in shaping plastic interactions, offering insights in the fate of plastic in aquatic ecosystems.

Keywords: Microplastics, Nanoplastics, Surface weathering, Sorption, Dissolved organic matter

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Development Of Wound Healing Scaffold Using Ocean Living Resources

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ABSTRACT

The global market for chronic wound management necessitates sustainable, high-performance, and domestically sourced biomaterials. This study directly aligns with the Ocean-Based Seaweed phycocolloids by converting them to a proprietary hydrogel patch fromRhodophyceae and Pheophyceae. The major objective is to create a clinically effective prototype and establish a robust commercialization roadmap for its scale-up of biobased woun healing scaffold in the Indian market.

The study focusses on the locally available seaweed Sargassum spp . and Gracilaria spp. for bioactive compound isolation, we extract medical-grade alginate. The core innovation involves cross-linking this alginate into a porous hydrogel matrix, which is then loaded with a characterized marine antimicrobial agent. The methodology focuses on optimizing formulation to ensure sustained release and ideal physical characteristics necessary for advanced wound care. Rigorous in vitro characterization confirms superior performanceby Scratch test assay. Antimicrobial Efficacy of the patch achieves a significant 4.1±0.3 log reduction in bacterial load for Staphylococcus aureus and other wound based clinical isolates within 24 hours, demonstrating potent bactericidal effects. Sustained Release of Optimized formulation exhibits only 15% burst release, with 80% of the active compound released uniformly over 72 hours, maximizing therapeutic duration. Cytotoxicity assays confirm high biocompatibility, with human dermal fibroblast viability measured at >95% and cell proliferation increased by 18% compared to controls.

This research successfully translates marine biopolymer science into a high-value, market-ready biomedical product. from research to commercial success.

Keywords: Seaweed Alginate, Antimicrobial Hydrogel and wound healing scaffold

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Microplastics In Agricultural Soils And Msw Compost: Occurrence, Characterization, And Impacts On Soil And Plant Health

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ABSTRACT

Microplastics (MPs) contamination is an emerging environmental concern, occurring across aquatic, air and terrestrial ecosystems. Despite this, most existing studies focus on marine and freshwater environments, leaving soil contamination comparatively underexplored. In terrestrial ecosystems, MPs contamination increasingly threatens soil health and agricultural productivity. In this study, the occurrence, fate and ecological impacts of MPs on agroecosystems from municipal solid waste compost and agricultural soil have been examined. The samples were collected from class-I and class-II cities of India (Delhi & Bareilly), as well as rural agricultural fields of Madhya Pradesh and Uttarakhand. Microplastics were extracted using Wet Peroxide Oxidation and density separation, followed by identification and characterisation through stereomicroscopy, micro-Raman spectroscopy and scanning electron microscopy. Moreover, an impact analysis of MPs on plants and soil have been performed using a field and pot experiment. The analysis revealed microplastics of different shapes (fibres, fragments, beads, and films) and sizes (1mm-5mm), with various colours (red, blue, transparent, green, and others), indicating different sources. Further, different polymers were identified using micro-Raman spectroscopy such as polyethylene (PET), low-density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), and high-density polyethylene (HDPE). To assess impact analysis of soil health, key physico-chemical properties, including pH, electrical conductivity (EC), nitrogen, phosphorus, potassium, organic carbon and water-holding capacity, were analyzed. The presence of MPs led to variations in soil pH and EC, potentially disrupting nutrient availability and microbial activity. MPs also influenced soil water retention, which could impact plant root development and overall soil characteristics. These changes may contribute to soil degradation, affecting its long-term fertility and productivity. The impact of MPs on plants was evaluated by measuring chlorophyll content and heavy metal uptake. A decline in chlorophyll content indicated stress in plants exposed to MP-contaminated soil, potentially affecting photosynthesis and growth. Additionally, increased heavy metal accumulation in plant tissues suggested that MPs could act as carriers for toxic elements, further affecting plant metabolism. These findings highlight the risks associated with MPs in agricultural systems, as they can compromise soil health and plant development.

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"**Replacing Toxic Coatings with Vibrations: an Insights into Low-Power Ultrasonic Biofouling Prevention Methodology**"

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ABSTRACT

Biofouling on submerged structures remains a persistent challenge, leading to increased maintenance demands and reduced system performance in marine environments. This work investigates a non-chemical antifouling strategy based on low-power, high-frequency mechanical excitation generated by piezoelectric actuators. The proposed system delivers vibrations through solid surfaces to early stages of biofouling. Both experimental trials and numerical simulations were conducted to evaluate its effectiveness. Finite element modeling was used to examine wave propagation and identify regions of enhanced vibrational response. These results were correlated with laboratory and field observations, showing reduced biofilm formation in actively excited areas. Intermittent operation at low energy levels was sufficient to achieve measurable antifouling effects. The study demonstrates that controlled ultrasonic vibrations can delay microbial colonization without inducing cavitation or material damage. This approach offers a promising, environmentally responsible alternative for protecting marine instrumentation and submerged infrastructure.

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Spatial Distribution, Morphology And Ecological Risk Profiling Of Microplastics In The Water Column And Sediments Of The Cochin Estuary, India

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ABSTRACT

Microplastic (MP) pollution in aquatic environments has emerged as a critical global concern due to its adverse implications for ecosystem integrity and human health. Although extensive research has documented in marine and freshwater systems, investigations focusing on estuarine environments remain comparatively limited; focusing on this research gap the current study was conducted in Cochin Estuary (CE) which is a part of Vembanad Lake (VL) a Ramsar site in Kerala, India. Water and sediment were collected from ten selected locations of CE (water samples, sub surface (SSW) and bottom water (BW) samples on each location). The findings of this study indicate the ubiquitous distribution of MPs with the mean abundance of 33.97±8.02 p/L and 25.57±3.83 p/L and 1407.5±4366.05 p/kg dw in SSW, BW and sediment samples respectively. Five morphotype of MPs were identified: fiber, fragment, film, foam and beads; among these, fragments were predominant in both SSW and BW. Whereas fiber was the major morphotype in sediment samples. Polyamide (PA), polypropylene (PP), low density polyethylene, poly-ethylene terephthalate, polyvinyl chloride (PVC), polystyrene and highdensity polyethylene (HDPE) were the polymers identified through Raman spectroscopy. PA, PP were dominant in SSW; PVC and HDPE were dominant in BW and HDPE, PE were dominant in sediment samples. Over 50% of MPs in SSW and BW were 100–500 µm, while sediments contained about 46% in this size range. These small size particles are more bioavailable to the aquatic organisms and pose a risk of entering in to the food chain, web of the estuary ecosystem and get transferred to the higher trophic levels. The transfer of MPs in to human is also possible through consumption of the contaminated sea food items such as: fishes, clams, prawns and crabs. The MPs pollution level in the CE was analyzed using pollution load index.

Keywords: Plastic Pollution, Risk assessment, Sea food, Trophic transfer, Pollution load index

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ESTUARINE GREEN MUSSELS AS BIOINDICATORS OF MICROPLASTIC POLLUTION IN GOA.

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ABSTRACT

Microplastic pollution in coastal ecosystems poses a significant threat to both marine life and human health. In this study, the green mussel *Perna viridis*, a popular shellfish delicacy in Goa and other coastal regions of India, was collected from four Goan estuaries: Sal, Zuari, Mandovi, and Chapora. Mussels were dissected, and their tissues were analyzed for the presence of microplastics (MPs). Results revealed the presence of polyethylene, polypropylene, polyester, and polystyrene microplastics. Individual mussels contained around 10 MPs, while tissue concentrations ranged from less than 1 to around 10 MPs per gram. Fibrous microplastics dominated over other shapes, highlighting the prevalence of fiber pollution in these estuarine systems. Pollution indices indicated elevated contamination levels, suggesting potential ecological and human health risks. Since shellfish are filter feeders and can bioaccumulate microplastics from the water column, consumption of *Perna viridis* may pose significant exposure risks to humans. These findings underscore the urgent need for monitoring and mitigation strategies to manage microplastic pollution in Goan estuaries.

Keywords: microplastic, estuary, Goa, Green Mussels, pollution

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Winter Convection Dynamics In The Northwestern Arabian Sea And Their Ecological Implications

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ABSTRACT

The Arabian Sea is a strongly atmospherically driven region of the North Indian Ocean, characterized by pronounced seasonal forcing and intense surface cooling during boreal winter. Among the processes governing its upper-ocean dynamics, winter convection plays a critical role in regulating thermal structure, nutrient supply, and marine productivity. However, its interannual variability and associated ecosystem response remain insufficiently explored.

In this study, we examine the interannual variability of winter convection during the core winter period (November–February) over the northwestern Arabian Sea (55°E–75°E, 17°N–30°N) for the period 1994–2024. This region represents the primary convective zone of the basin, where surface cooling and vertical mixing are most pronounced during winter months.

Using satellite-derived and reanalysis datasets, we assess variability in key surface and upper-ocean conditions and explore how these changes are reflected in biological productivity during the winter season. Preliminary analysis indicates that year-to-year fluctuations in winter cooling strongly influence biological response patterns over the region, with clear signatures observed in surface phytoplankton biomass and higher trophic indicators.

Furthermore, regional fishery statistics show a measurable correspondence with winters of stronger convection, suggesting that variability in winter physical processes leaves an imprint on ecosystem productivity and fishery yields. This study provides a focused seasonal perspective on the role of winter convection in controlling interannual variability of the western Arabian Sea ecosystem and offers insights into its broader implications under ongoing climate variability.

Keywords: Winter convection, Arabian Sea, Interannual variability, Marine productivity, Fisheries response.

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Bioprocess Optimization For High-Yield Fucoxanthin Production In Marine Diatoms: Biotechnological And Industrial Perspectives

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ABSTRACT

Marine microalgae represent an immensely diverse and ecologically significant group of photosynthetic microorganisms. Their vast taxonomic and functional diversity underpins a wide spectrum of pigment molecules such as chlorophylls, carotenoids (fucoxanthin, β-carotene, astaxanthin), and phycobiliproteins (phycoerythrin, phycocyanin) that play crucial ecological roles in light harvesting, photoprotection, and adaptation to variable marine environments. This natural diversity, shaped by ecological and evolutionary pressures, offers an invaluable reservoir for biotechnological exploitation. Marine microalgae have remarkable potential for sustainable industrial applications, including nutraceuticals, cosmetics, pharmaceuticals, food colorants, and aquaculture feeds, providing natural and renewable alternatives to synthetic dyes. Among microalgal pigments, fucoxanthin a high-value carotenoid primarily synthesized by diatoms, is increasingly sought after for its antioxidant, anti-inflammatory, and metabolic health benefits. Yet, scalable and efficient production strategies remain limited. In this study, a comprehensive framework was developed to enhance fucoxanthin bioproduction through integrated species selection, culture optimization, and refined downstream processing. A diverse collection of marine diatom strains was isolated and screened for pigment productivity, followed by systematic optimization of growth media and environmental parameters to maximize fucoxanthin yields. Downstream processes, including biomass harvesting and pigment extraction, were further refined. The pigment was subsequently identified and characterized using high-performance liquid chromatography. The optimized approach developed here for fucoxanthin production from marine diatoms demonstrates significant promise for scalable and sustainable industrial production of natural pigments, offering health-promoting alternatives to synthetic dyes and additives.

Keywords: Marine microalgae, Fucoxanthin extraction, Pigment characterization, Carotenoids, Biotechnological applications

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Short-Term Beach Sand Volume Variation Assessment Using Rtk-Gnss Surveys.

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ABSTRACT

Coastal zones are among the most dynamic environments on Earth, continually reshaped by the interaction of waves, tides, and currents. Monitoring these morphological changes is vital to understanding erosion–deposition processes and maintaining coastal stability. Miramar and Caranzalem Beaches, located along the Mandovi River mouth on the west coast of India, undergo significant seasonal transformations influenced by hydrodynamic forces and sediment transport. Assessing beach volume variations through high-precision geospatial techniques provides key insights into these evolving coastal systems. The study focuses on utilizing GNSS RTK surveys to quantify volumetric changes along Miramar and Caranzalem Beaches. Monthly surveys were conducted between December 2023 and March 2024, using a GNSS RTK rover system to generate detailed elevation models referenced to Mean Sea Level. The results highlight a clear seasonal trend: initial erosion occurred in transition between December to January, particularly in the northern and southern beach segments, where elevation dropped below 1.00 m. Subsequent months (February–March) showed gradual sediment accumulation in the central zone, with elevations rising up to 4.20 m. This pattern reflects a cyclic erosion–deposition regime governed by wave energy and tidal dynamics. GNSS RTK surveys offer an integrated perspective of beach morphology and sand volume change, proving vital for accurate coastal change detection and long-term monitoring.

Keywords: GNSS-RTK, Beach Profiling, Coastal Geomorphology, Sand Volume, Beach Topography.

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Glacial Sea-Level Drop Triggers Volcanic And Hydrothermal Activity Over The Carlsberg Ridge During Interglacial Cycles

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ABSTRACT

The elemental and isotopic analyses of detrital sediment and authigenic Fe-Mn oxyhydroxide coatings were carried out in the gravity core, SSD77-G03, to investigate magmatic and hydrothermal activity at the Carlsberg Ridge over glacial-interglacial timescales and their relationship with global sea-level changes. The core records a sedimentation history of 7-48 ka, revealing significant variation in their isotopic and trace element composition. The Sr-Nd isotopic composition of the detrital sediment indicates a little variation during the Holocene and MIS 2, the primary sediment sources being the Arabian and African deserts. The elevated radiogenic Nd and less radiogenic Sr isotopic signatures, along with an approximate 12% increase in basalt fragment input, observed during the MIS 3 period suggest an increase in mid-ocean ridge magmatic activity along the Carlsberg Ridge. The vesicular glass shards present in the core during this period resulting from volatile (CO2) enriched magma indicate substantial CO2 degassing from these magmas throughout their ascent and crystallization. Fe-Mn oxyhydroxides and trace elements, such as Co, Ni, and Cr, also exhibit elevated concentrations during MIS 3. The Pb isotopic ratios of Fe-Mn coatings align with the mid-ocean ridge basalt (MORB)-like isotopic composition during this period, further indicating heightened hydrothermal activity.

The SSD77-GC03 core displays a deglacial peak of magmatic-hydrothermal activity around 45 ka (MIS 3), following a sea-level low stand during 60–70 ka (MIS 4). This temporal lag of ~15 ka reflects the time required for magma produced by mantle decompression to ascend to the upper crust and demonstrates the influence of global sea-level fluctuations on mantle melting, mid-ocean ridge volcanism, hydrothermal activity, and mantle CO2 degassing into the ocean. This study signifies the potential use of isotopic proxies to reconstruct Earth's magmatic processes over glacial-interglacial cycles.

Keywords: Mid-Ocean Ridge Magmatism, Hydrothermal Circulation, Glacial Sea-level drop, Sr-Nd-Pb isotopes, Carlsberg Ridge

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Theme

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1. **Integrated socio-ecological vulnerability of Indian coast for SDG-aligned resilience**

2. **Socio-economics of the Blue growth: Emerging opportunities and challenges**

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Theme- Socio-Economics of Oceans

Session Title: Integrated socio-ecological vulnerability of Indian coast for SDG-aligned resilience

Session Convener: Dr. Ravinder Dhiman

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2.	AI/ML Enhanced Coastal Infrastructure Resilience Index (CIRI) -Coupling Geospatial Intelligence And Socio- Ecological Resilience For Megacity Of Mumbai, India
3.	Strengthening Sustainable Coastal Governance Through Stakeholder Engagement In Shoreline Management Plans

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Ai-Driven Assessment Of The Socio-Economic Impacts Of Tropical Cyclones

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ABSTRACT

This study involves understanding of socio economic vulnerability caused by Tropical Cyclones (TC) in the North Indian Ocean basin. The major TCs striking the Indian coast and adjacent delta impose profound and multifaceted socioeconomic consequences across coastal and inland communities. Using a data-driven framework integrating machine learning and deep learning methods, multi-year demographic and economic datasets were analyzed to assess how broader social conditions and regional economic patterns shift around cyclone events. Although these storms have common features like- high winds, high storms and heavy rainfall impacting dense and coastal regions, they are distinct in landfall locations, damage patterns and recovery outcomes.

The findings indicate differing patterns in the socioeconomic conditions in terms of multiple data streams- such as demographic vulnerability, infrastructure damage, crop and livelihood loss and post event recovery metrics. The cyclones reveal interconnected patterns of severity across the east coast of India, like agricultural loss and damage to fisheries and infrastructure collapse. The results further demonstrate the impact of TCs on urban-rural connections and supply chains. The results are observed to be affected by physical damage along with other factors like preexisting resilience, governance capacity, livelihood diversification and depth of long term socioeconomic recovery pathways. The study underscores that various methodologies and machine learning tools can reveal differences in communities' vulnerability and highlight how various socioeconomic groups are at risk during cyclones. The framework developed a scalable basis for anticipating future impacts and supporting evidence-driven planning aimed at reducing long-term vulnerability.

Keywords: Tropical cyclones, Socioeconomic impact, Vulnerability assessment, Machine learning, Post event recovery, Community resilience

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AI/ML Enhanced Coastal Infrastructure Resilience Index (CIRI) – Coupling Geospatial Intelligence And Socio- Ecological Resilience For Megacity Of Mumbai, India

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ABSTRACT

Almost all future population growth is expected to occur in urban areas, particularly across coastal regions in the Global South. These cities frequently face intersecting challenges from accelerating urbanization, aging infrastructure, and climate-driven hazards including sea-level rise, storm surges, coastal erosion and recurrent flooding. These risks are exacerbated by unique socio-economic stressors, informal settlements, and infrastructure fragility that conventional vulnerability indices like CVI fail to capture. Mumbai, home to over 23 million people with significant coastal populations, exemplifies these multi-dimensional vulnerabilities where marginalized communities face compounding threats from natural hazards and infrastructure development pressures. This study proposes to advance a previously developed Coastal Infrastructure Resilience Index (CIRI) by integrating Artificial Intelligence and Machine Learning technologies to achieve hyperlocal accuracy. The original CIRI framework built on remote sensing, field observations, and socio-economic data classified Mumbai's existing coastal infrastructure into natural, hybrid, and built categories using GIS-Multi-Criteria Decision Analysis. It assessed resilience through five integrated layers: infrastructure typology, elevation, erosion-accretion patterns, flood locations, and population density, providing stakeholders with actionable insights on hotspots. This study aims to leverage AI/ML algorithms to automate infrastructure classification from large-scale datasets including Google Street View imagery, Google Buildings footprints, and high-resolution satellite data. By employing deep learning models for feature extraction and pattern recognition, the enhanced framework will enable rapid, scalable, and cost-effective assessment of coastal infrastructure resilience across coastal cites.

The AI/ML-augmented CIRI will support evidence-based decision-making for climate-resilient infrastructure solutions that integrate ecosystem-based disaster risk reduction principles. By coupling advanced geospatial intelligence with granular socio-ecological data, this framework addresses critical knowledge gaps in urban coastal vulnerability assessments. The outcomes will serve as a science-policy instrument localizing UN Sustainable Development Goals 11 (resilient cities), 13 (climate action), and 14 (marine ecosystem protection), while empowering marginalized coastal communities through inclusive, environmentally-centered infrastructure planning that balances ecological sustainability with economic development imperatives.

Keywords: Coastal Resilience, Geospatial Intelligence, Climate Change, AI/ML, GIS-

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Strengthening Sustainable Coastal Governance Through Stakeholder Engagement In Shoreline Management Plans

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ABSTRACT

Stakeholders form the backbone of shoreline management, contributing lived experience, traditional knowledge, and a deep understanding of how coastal changes influence their livelihoods, safety, and everyday life. Extensive field work and stakeholder consultations were carried out for the preparation of the Shoreline Management Plan (SMP) of the Tamil Nadu coast, aimed at understanding coastal conditions and collecting insights from people who directly depend on the coast for their daily income and well-being. These interactions included fishing communities, tourism operators, coastal business groups, local institutions, NGOs and civil society organisations, and field-level government officials. The SMP is primarily intended to protect, restore, and strengthen coastal livelihoods; hence, the needs, priorities, and aspirations of these coastal users form the foundation of its planning framework. People living and working along the coast often possess a more detailed and practical understanding of shoreline dynamics, seasonal changes, and local challenges than what can be obtained through engineering-based or model-driven approaches alone. Their observations and experiences, gathered over generations, bring authenticity, balance, and local relevance to shoreline management. All field interactions were geolocated, voice-recorded, and structured using a customised KoboToolbox platform, ensuring that every issue, concern, and recommendation was systematically integrated into the SMP's spatial and thematic database. Recognising and embedding community knowledge in this way not only enhances the scientific and social value of the SMP but also ensures that it remains inclusive, implementable, and widely accepted. This participatory approach strengthens local resilience and promotes sustainable coastal development in line with the United Nations Sustainable Development Goals (SDGs) on climate action, sustainable communities, and life below water.

Keywords: shoreline management plan, Tamil Nadu coast, stakeholder engagement, coastal livelihoods, NGOs, sustainable development.

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Theme- Socio-Economics of Oceans

Session Title: Socio-economics of the Blue growth: Emerging opportunities and challenges

Session Convener: Dr Shri N. Nagaraja Kumar

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2.	Fish Consumption Behaviour Of Indian Households: Evidences From Nationwide Consumption Data
3.	Decoding Thermal Fronts Vis-A-Vis Coastal Capture Fishery: Evidence From Citizen Science And In-Situ Fishery Data
4.	Techno Economic Analysis Of Hybrid Offshore Floating Wind Turbine Platform
5.	Life Cycle Assessment Of Seven Dolnet Designs Along The Maharashtra Coast, India
6.	Light-Controlled Bioreactors And Photoreceptor-Based Insights: Towards Sustainable Biomass Valorization
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The Future We Choose: Leading The Global Transition To A Sustainable Blue Economy

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ABSTRACT

The world's oceans are entering a defining moment. As pressures from climate change, overexploitation, and rapid coastal development intensify, the choices made today will determine whether marine ecosystems continue to decline or become a foundation for shared global prosperity. The Blue Economy offers a pathway through which nations, industries, and communities can chart a direction toward ocean stewardship that supports both environmental integrity and economic resilience. It is not merely a sectoral opportunity but a guiding framework for long-term sustainability.

Such an approach emphasises the need for science-based management of ocean resources, equitable access to benefits for coastal populations, and investment in innovative technologies that reduce environmental harm while creating new avenues for growth. Central to this transition is the recognition that the health of the ocean and the prosperity of societies are inseparable. Achieving a balanced Blue Economy requires strengthening marine governance, aligning financial systems with sustainability goals, and advancing climate-resilient industries such as offshore renewable energy, sustainable aquaculture, and low-carbon maritime transport. It also calls for valuing traditional knowledge and community leadership in shaping resilient coastal futures.

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By bringing together environmental responsibility and economic ambition, the Blue Economy framework guides us toward the future we choose, one that depends on collaborative action, bold policy decisions, and a shared commitment to restore and protect marine ecosystems. The vision for the future is a Blue Economy that is inclusive, innovative, and capable of sustaining life and livelihoods for generations to come.

Keywords: Sustainability; Climate Change; Blue Economy

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Fish Consumption Behaviour Of Indian Households: Evidences From Nationwide Consumption Data

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ABSTRACT

Malnutrition—including anaemia and micronutrient deficiencies such as stunting, underweight, wasting, and low birth weight—remains a significant concern and a major developmental challenge in India. Fish, being a rich source of high-quality protein and essential micronutrients such as vitamin A, iron, and iodine, holds substantial potential to address these nutritional gaps. This study examines the fish consumption behaviour of Indian households using data from the Household Consumption Expenditure Surveys of 2011–12 and 2022–23 conducted by the National Sample Survey Office. The total sample size of the survey consists of 101662 households in 2011-12 and 261746 households in 2022-23.

The findings indicate a marginal decline in the proportion of households consuming fish at the national level over the past decade, with a slight reduction in rural areas and a modest increase in urban areas. Despite this, per capita monthly fish consumption has increased in both rural and urban households. Considerable interstate variations were observed in the share of fishconsuming households, the quantity consumed, and the contribution of fish to total monthly consumption expenditure. The study further reveals a decline in the share of average MPCE allocated to fish across most states, including coastal regions, and across different caste and religious groups. Income shows a positive association with both the likelihood and level of fish consumption, with higher-income households consuming more fish in both quantity and value terms. Empirical results suggest that higher MPCE, larger household size, and rural residence increase the probability of fish consumption, while education and regional characteristics exert significant influence, with coastal and northeastern states displaying much higher consumption than northern and inland regions. The rising costs and limited access, coupled with cultural preferences, have negatively impacted fish consumption. The paper highlights potential strategies to enhance fish consumption in India, including targeted subsidies, im

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distribution systems, and strengthened cold-chain and storage infrastructure to improve accessibility and affordability.

Keywords: Fish consumption, Malnutrition, Consumer behaviour, Fish demand, Fish quality and safety

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Decoding Thermal Fronts Vis-A-Vis Coastal Capture Fishery: Evidence From Citizen Science And In-Situ Fishery Data

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ABSTRACT

Ocean thermal fronts provide ambient conditions that facilitate the growth of primary producers and the subsequent development of the food chain, resulting in favourable foraging grounds for fish. Near-shore fisheries of the Indian EEZ contribute about ~70% to the total landing. This study examines the impact of sea surface temperature fronts on fish availability in India's coastal waters. Thermal fronts were identified from satellite (MODIS-Aqua) and model (CMEMS) datasets by employing the Cayula and Cornillon algorithm. Multi-sourced, in-situ, geo-tagged fishery datasets, including citizen science information (INCOIS' Android-based mobile application: FISH), were analysed to decipher the interrelation between fish availability, catch variability, and frontal appearance. A lead-lag approach was also employed to assess frontal persistence and evidence of food chain development. Preliminary analysis indicated the consistent appearance of thermal fronts 2-3 days prior to the fish catch, which reaffirms that thermal fronts considerably influence the fish aggregation in Indian coastal waters. Analysis of fronts availability derived from MODIS and CMEMS data surrounding the catch locations revealed a moderate (R2=0.54) to strong (R2=0.88) linear relationship across the gradient thresholds and lag days. This underscores the potential of modelled data for delineating Potential Fishing Zones. However, differences in resolution, as well as potential smoothing effects, necessitate algorithmic calibration, particularly for near-shore zones influenced by monsoonal dynamics. Insights from the study are critical in improving Potential Fishing Zone advisories.

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Keywords: Thermal Fronts, Nearshore Fishery, Satellite Remote Sensing, Ocean Model, Citizen Science

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Techno Economic Analysis Of Hybrid Offshore Floating Wind Turbine Platform.

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ABSTRACT

The study presents a preliminary capital expenditure (CAPEX) assessment for a hybrid offshore wind–wave energy system consisting of a submerged tension-leg platform (STLP) integrated with six point-absorber wave energy converters (STLP+6WEC) for Indian coastal waters. Rony and Karmakar (2022) have shown that the STLP+6WEC configuration leads to reduced platform motions and tower base moments compared with other WEC layouts, motivating an economic extension of that study. The study only considers the capital cost of the floating platform system, excluding operation, maintenance and decommissioning costs. The CAPEX calculation follows the methodology of Martínez and Iglesias (2022), adapted to Indian bathymetry, distance-to-shore and grid-connection conditions. The total investment is decomposed into development and consenting costs (site investigations, environmental studies and project management), turbine and substructure costs (including the modified STLP supporting structure and WEC foundations), mooring-system costs (anchors, chains and line lengths dependent on local water depth), and transmission costs (export and inter-array cabling and offshore/onshore substations). Installation costs are estimated using simplified vessel-time algorithms that account for towing distance and number of offshore operations. By applying this structured CAPEX framework to potential STLP+6WEC deployment sites along the Indian coast, the study aims to identify the dominant cost drivers for hybrid floating platforms and to provide a basis for comparing alternative locations and design options in subsequent techno-economic analyses.

Keywords: Submerged Tension Leg Platform; point absorber wave energy converter; Capital cost; techno-echnomic analysis;

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Life Cycle Assessment Of Seven Dolnet Designs Along The Maharashtra Coast, India

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ABSTRACT

Theme – Socioeconomics of Ocean
This study evaluates the environmental performance of seven dolnet fishing gear designs along the northwest coast of India using Life Cycle Assessment (LCA). Dolnets, a dominant passive fishing method, have not previously been assessed for their carbon footprint. Primary data on vessel design, fuel use, and gear fabrication were collected from five coastal districts. LCA modelling was performed in SimaPro 9.0 following ISO 14040/44 standards and CML 2001 and IPCC (100-year) methodologies. The designs assessed included Karanja, Rewas-Bodni, Bokshi, Dabang, Pachubandar, Mosquito, and Sajachi dolnets. Results showed wide variation in Global Warming Potential (GWP): Dabang recorded the highest emissions (1,060.81 kg CO_2 eq $tonne^{-1}$), while Mosquito had the lowest (311.86 kg CO_2 eq $tonne^{-1}$). Fuel use and polymeric materials were identified as key emission sources. Sensitivity analysis indicated that replacing 15% virgin HDPE with recycled material could reduce emissions by 10–12%. The study establishes India's first GHG baseline for dolnet fisheries and recommends low-impact gear using biodegradable or recycled materials, alongside improved fuel through use of electric,solar sources of energy to promote climate resilient and sustainable fishing practices aligned with Sustainable Development Goal 14.

Keywords: Dolnet fisheries, Life Cycle Assessment (LCA), Global Warming Potential (GWP), Sustainable fishing, Carbon footprint

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Light-Controlled Bioreactors and Photoreceptor-Based Insights: Towards Sustainable Biomass Valorization

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ABSTRACT

Our ongoing research combines molecular photobiology with algal biotechnology to develop efficient, light-driven bioresource systems. Building on our development of the custom-designed photobioreactors1 capable of delivering microsecond-scale, multi-wavelength illumination, we aim to use precisely modulated light to influence photosynthetic and metabolic performance in algae. Insights from our mechanistic studies on the photoreceptor domain of phototropin, revealed microsecond folding–unfolding transitions that govern light activation2, and on the algal quiescence regulator CHT7, whose CXC domain mediates selective DNA interactions3, provides molecular basis for this approach. By translating these photoreceptor kinetics into programmable illumination regimes, we are exploring light conditions that mimic native photocycle rhythms to evolve algal strains for enhanced growth, stress tolerance, and metabolite yield. Through linking optogenetic principles, reactor engineering, and evolutionary adaptation, we aim to scale up the cultivation building modular reactors suitable for near-shore and offshore operations. Our approach shall advance technology readiness and contribute toward sustainable marine bioresource utilization.

Keywords: Photobioreactor, AsLOV2, CHT7, Adaptive Laboratory Evolution, marine algae, Blue Bioeconomy

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From Ocean To Oil: Analytical Insights Into Pomfret's Nutrient-Rich Extract

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ABSTRACT

Fish are universally acknowledged as a rich source of high-quality protein with superior biological value and digestibility. Their musculature, characterized by minimal connective tissue, offers a soft texture, rapid digestibility, and efficient nutrient assimilation, making fish an essential component of human and animal nutrition. In addition to their protein content, fish oils are an important source of long-chain polyunsaturated fatty acids, notably eicosapentaenoic acid and docosahexaenoic acid, which play crucial roles in cardiovascular health, neural development, and immune regulation. Marine fish oils further exhibit antioxidant, anti-inflammatory, and antimicrobial properties, enhancing their utility in nutraceutical, pharmaceutical, and cosmetic industries. The analytical evaluation of pomfret oil in this study includes determination of acid value, iodine value, saponification value, peroxide value, and specific gravity, which collectively indicate lipid oxidation, fatty acid composition, and overall oil quality. Gas Chromatography-Mass Spectrometry was employed for profiling individual fatty acids, including palmitic acid. These analyses aim to provide comprehensive insights into the nutritional composition and stability of pomfret oil, emphasizing its potential application as a functional ingredient in health supplements and aqua feed formulations. Furthermore, the study underscores the valorisation of fish by-products as a sustainable approach to marine resource utilization. The lipid content in fish muscles varies across species and is influenced by intrinsic factors such as metabolism, life stage, and reproductive condition and extrinsic factors including diet, season, habitat, and water temperature. The present investigation provides analytical insights into the nutrient-rich extract of pomfret, highlighting its significance for nutritional enhancement and sustainable aquaculture practices.

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Keywords: Pomfret oil, fish protein, polyunsaturated fatty acids, nutritional analysis, marine bio resources, functional ingredients

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Fish For Food And Nutrition Security In India: A Comprehensive Framework Analysis.

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ABSTRACT

Food and nutritional security (FNS) are essential for the overall well-being and development of individuals and communities. The availability of food does not automatically translate into food and nutrition security. Even when food is available, it may not be accessible to everyone who needs it; and when it is both available and accessible, it may still fail to meet all nutritional and dietary requirements. Fish, as an important food source, is equally affected by these challenges. Fish provides essential protein, micronutrients, and fatty acids to food-insecure populations. However, its contribution to household or individual nutrition depends on its availability, accessibility, utilization, and stability. This study examines the role of fish and fisheries in promoting food and nutritional security in the Indian context. The analysis is based on the FNS framework, focusing on the four pillars: availability, access, utilization, and stability. It undertakes a comprehensive review of the literature to understand FNS as a critical concern and evaluates how fisheries can support sustainable availability, equitable access to nutritious fish, and stability amid physical, economic, and social challenges.

The study also highlights risks such as climate change, seasonality, and price volatility, which can undermine fish availability and consequently affect food security. The analysis shows that fish plays a crucial role in complementing plant-based diets in India. However, a filled stomach is not enough; fish and fish products must be safe, nutritionally balanced, and consistently available. Availability alone cannot guarantee FNS unless access, nutrient adequacy, utilization (quality and safety), and long-term stability are addressed. Achieving FNS requires strengthening all four pillars, which are hindered by high fish prices, poverty, poor market infrastructure, inadequate transportation, climate-related disruptions, and weak policies on fish quality and safety. Given these complexities, reforms in the fish supply chain are essential. Improvements in infrastructure, market facilities, transportation, pricing mechanisms, and quality control are needed to enhance availability and affordability. Economic investments can help stabilize prices, especially for low-income consumers. The study also recommends stronger regulations and supply chain management, including minimum or maximum [illegible] for key species, to reduce market volatility and promote sustainable fishing practices.

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Keywords: Food security, nutritional security, food environment, food safety and quality, small scale fisheries

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Evaluation Of The Fate Of Environmental DNA (Edna) In Aquatic Ecosystems For Biodiversity Assessment Of Shrimps

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ABSTRACT

Environmental DNA (eDNA) has emerged as a powerful tool for detecting species with high accuracy, efficiency, and is a non-invasive alternative that has revolutionized biodiversity monitoring. In aquatic ecosystems, eDNA is found in different matrices such as water, sediment, as well as in biofilms, and its degradation is influenced by various abiotic and biotic factors. Moreover, the extracellular nucleases secreted by microbial communities have been considered an important pathway for eDNA degradation. Understanding the degradation kinetics of eDNA across various aquatic matrices is vital for eDNA-based biomonitoring and biodiversity assessment.

The present study evaluated the degradation of shrimp eDNA in water, sediment (clayey and sandy), and biofilms through microcosm experiments carried out for a period of 60 days. It was evident that the fate of eDNA was dependent on the type of sediment and was better preserved in clayey sediment. The eDNA concentration was maximum on day 10 in both the ambient water as well as in the sediment, whereas its signatures were absent in the biofilms until day 10 and detected only after day 15. The eDNA was higher in the biofilms, followed by sediment and water till day 30, after which its concentration started declining and was negligible on day 60. Metagenomic analysis of the source water revealed *Vibrio* spp. to be dominant, suggesting their contribution to eDNA degradation as they are known to secrete nucleases, leading to enzymatic degradation of eDNA. These findings underscore that microbes can modulate eDNA persistence, and biofilms can act as a significant sink for eDNA. Microbes actively secrete extracellular polymeric substances (EPS) that stabilize and bind biofilms, promoting microbial adhesion and aggregation while shielding embedded eDNA from enzymatic degradation and environmental stressors by restricting access to degradative agents.

This work advances our understanding of matrix-specific eDNA degradation and its fate in different aquatic ecosystems and the ecological significance of microbes which needs to be considered in eDNA-based monitoring, which will be of great use when integrated in ecological models for developing sustainable management of marine fishery resources and conservation.

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Keywords: Environmental DNA (eDNA), water column, sediment, biofilm, *Vibrio* spp., biomonitoring, biodiversity assessment

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Marine Collagen- A Potential Antioxidant And Nutraceutical

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ABSTRACT

Fish being the staple food of Goa generates 5 tonnes of waste with no proper disposal. This can be a potential source of biomolecules like collagen, heparin, gelatin. The study involves valorisation of fish waste to get collagen, and its study as a potential molecule exhibiting antioxidant, nutraceutical and sun protection activity.

Collagen was extracted from prawn and anchovy waste using 0.5 M acetic acid, 1% pepsin and 1% papain enzyme. The percentage yield obtained from 0.5 M acetic acid, 1% pepsin and 1% papain for prawn waste was 30.90 ± 0.36%, 35.17 ± 0.61% and 32.43 ± 0.21%, respectively and for anchovy waste was 32.50 ± 0.26%, 39.53 ± 0.38% and 35.27 ± 0.38%, respectively. UV spectra showed peaks at 237 nm corresponding to C=O, -COOH & –CONH2 groups, 274 nm for aromatic amino acids. FTIR spectra peaks at 3400 cm-1, 2924 cm-1, 1700 cm-1, 1625 cm-1, 1400 cm-1 confirmed presence of collagen.

SPF values were determined by method of Baby et al, 2017. SPF value for prawn collagen extracted using acetic acid, pepsin and papain was 30.90 ± 0.001, 28.62 ± 0.000, and 28.84 ± 0.002, respectively and for anchovies was 24.30 ± 0.002, 24.18 ± 0.002 and 24.30 ± 0.002, respectively. Amino acid, proline, hydroxyproline estimation, revealed that extracted collagen had a good balance of essential and non essential amino acids, making it a good source of nutraceuticals. DPPH antioxidant assay for prawn collagen extracted using acetic acid, pepsin and papain showed IC50 values of 14.100 ± 1.433µg/mL, 4.826 ± 0.486µg/mL, 17.693 ± 0.562µg/mL, respectively; and for anchovy collagen values of 3.959 ± 0.175µg/mL, 6.990 ± 0.835µg/mL, 10.251 ± 0.439µg/mL were noted, making both these collagen an excellent antioxidant source.

Keywords: Marine, Collagen, Antioxidant, Amino acid, Biomolecule

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Theme- Socio-Economics of Oceans

Session Title: The Coastal Regulatory Zone: The Scientific Basis Of And Sustainable Development

Session Convener: Dr. Sushant Suresh Naik

S.R. No.	Title of Abstract
1.	Aligning Coastal Zonation Science with Practical Community Realities in Goa
2.	Coastal Sand Dune Restoration As A Tool For Strengthening Crz Governance And Sustainable Coastal Management
3.	Rewilding The Marine Edge: A Management Initiative For Biodiversity Restoration Along The Tropical Urban Seascape, Mumbai, India
4.	Enhancing Coastal Resilience Through Navic-Based Short Messaging Services
5.	Multi-Decadal Mangrove Classification In Bhitarkanika And Cyclone-Induced Wave Dynamics During Severe Cyclonic Storm Dana
6.	Understanding Coastal Changes As Per CRZ 2011 And 2019 On Land Use
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Aligning Coastal Zonation Science with Practical Community Realities in Goa

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ABSTRACT

Coastal areas around the world are home to many people, important resources, and key economic and cultural activities. In recent years, growing populations, fast urbanisation, and increased development have put more pressure on these regions, making coastal ecosystems highly stressed and more vulnerable. In Goa, the demarcation of Coastal Regulation Zone (CRZ) is guided by scientific assessments such as High Tide Line (HTL) mapping, hazard line delineation, shoreline change analysis, and the identification of ecologically sensitive areas. These tools play a critical role in regulating development, conserving fragile habitats, and addressing climate-related risks. However, when these scientific boundaries are applied on the ground, they often clash with the daily realities of coastal communities whose homes, traditions, and livelihoods depend on the shoreline. Many villages report mismatches between zonation maps and traditional land-us patterns, long-established habitation, or essential livelihood activities such as fishing and tourism. These discrepancies can lead to confusion, resistance, and conflict. The study draws on multiple case studies and emphasizes the necessity of an approach that blends scientific accuracy with community involvement. Strengthening dialogue, enhancing methodological transparency, and integrating local knowledge can help close the gap between technical coastal zonation and community realities, thereby improving the legitimacy and effectiveness of coastal regulation in Goa.

Key Words: High Tide Line (HTL), Hazard Line, Coastal Ecosystems, Community Livelihoods, Coastal Regulation Zone (CRZ)

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Coastal Sand Dune Restoration As A Tool For Strengthening Crz Governance And Sustainable Coastal Management

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ABSTRACT

Coastal Regulatory Zone (CRZ) areas represent some of the most ecologically sensitive and socio-economically valuable landscapes in India. Among these, coastal sand dunes play a vital role in shoreline protection, maintaining sediment balance, supporting biodiversity, and enhancing climate resilience. However, unregulated development, recreational pressures, and recurrent violations of CRZ norms have resulted in significant degradation of dune systems along the Goan coastline. Effective restoration in such regulated zones requires scientific diagnostics, legally consistent approaches, and site-specific ecological interventions.

Drawing on field experience from the Goa State Biodiversity Board (GSBB), this study presents a series of case studies where restoration actions were undertaken following CRZ violations. The cases were categorized by disturbance type, such as vegetation clearance, alteration of dune morphology, dumping of extraneous material, and construction-induced destabilization, and by the geomorphological setting of each site. Restoration strategies included bamboo-based windbreaks, bio-fencing, dune slope reformation, debris removal, and facilitation of natural regeneration. Native sand-binding species (Ipomoea pes-caprae, Spinifex littoreus, Sesuvium portulacastrum) were reintroduced to accelerate dune stabilization consistent with CRZ ecological guidelines.

The findings indicate that minimal, yet scientifically guided interventions, supported by periodic monitoring and strict protection against further disturbances, lead to effective ecosystem recovery. The study also highlights regulatory gaps, enforcement challenges, and the need for integrating ecological science into CRZ compliance and decision-making. Community involvement, awareness campaigns, and transparent monitoring mechanisms emerged as critical enablers of long-term success.

This paper provides evidence-based recommendations for strengthening CRZ implementation through ecological restoration practices, offering a scalable model for sustainable coastal governance in India and globally.

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Keywords: CRZ, Coastal sand dunes, Ecological restoration, Sustainable development

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Rewilding The Marine Edge: A Management Initiative For Biodiversity Restoration Along The Tropical Urban Seascape, Mumbai, India

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ABSTRACT

Rapid coastal urbanization degrades marine habitats, necessitating robust management and eco-engineering initiatives for restoration and sustainable development. Urban structures like seawalls are typically featureless, contributing to reduced biodiversity. This study, a first-of-its-kind initiative in India, investigated the ecological benefits of deploying various Artificial Reefs (ARs) along an intertidal seawall on the Mumbai coast. We implemented an effective management plan and monitored the diversity, abundance, and frequency of occurrence of marine invertebrates on different AR types monthly for one year. ARs, designed with water-retaining features, offered crucial hydrated shelter and cooling during low tide exposure. Results show notably higher recruitment of invertebrates and algal beds on ARs compared to the homogeneous seawall. AR-associated rocks supported significantly more macroalgae (Phaeophyceae and Rhodophyceae), while dominant invertebrates on the reefs included limpets (*Lottia* sp.) and striped barnacles (Amphibalanus sp.). Significant monthly variations in biodiversity were also observed ($p < 0.05$). This research demonstrates that implementing an eco-engineering management framework, through the installation of structurally complex ARs, can significantly contribute to restoring marine biodiversity and enhancing ecosystem function within an anthropogenically altered urban coastal environment, providing a model for sustainable coastal development.

Keywords: Artificial Reef; Eco-engineering; Marine biodiversity; Biological restoration; Seascape

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Enhancing Coastal Resilience Through Navic-Based Short Messaging Services

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ABSTRACT

Navigation with Indian Constellation (NavIC) has emerged as a transformative indigenous satellite navigation system, extending beyond positioning services to deliver vital communication support for India's remote and underserved coastal regions. One of its most impactful applications is the NavIC-based Short Messaging Service (SMS), which ensures the dissemination of critical information in areas lacking reliable cellular or internet connectivity. This capability is extensively leveraged by agencies such as the Indian National Centre for Ocean Information Services (INCOIS) and the India Meteorological Department (IMD) to broadcast life-saving alerts and advisories.

NavIC-based SMS plays a pivotal role in issuing cyclone warnings, high wave alerts, tsunami notifications, and Potential Fishing Zone (PFZ) advisories to fishermen and coastal communities. Messages are prioritized based on urgency and transmitted via NavIC 1A and 1E satellites in a time-shared or concurrent mode, ensuring timely, reliable, and uninterrupted delivery of critical alerts even during adverse weather conditions.

A key technological enabler in this initiative is "Satarkabarta," a software developed by Climate Research Services (CRS), IMD Pune. The system facilitates real-time transmission of severe weather alerts through NavIC, enhancing preparedness and response. Satarkabarta has successfully supported monitoring and dissemination during major events such as Cyclone Michaung (December 2023) and Cyclone Remal (May 2024), utilizing data from the INSAT-Automatic Weather Stations (AWS) Laboratory, Pune.

Together, Satarkabarta and the NavIC messaging system constitute a critical backbone for early warning dissemination and severe weather monitoring. Their integration has significantly strengthened India's disaster resilience framework, safeguarding lives, livelihoods, and marine resources in vulnerable coastal and oceanic regions.

Keywords: NavIC, Early Warning System, Disaster Resilience, Severe Weather Monitoring

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Multi-Decadal Mangrove Classification In Bhitarkanika And Cyclone-Induced Wave Dynamics During Severe Cyclonic Storm Dana

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ABSTRACT

Tropical cyclone intensification under climate change poses increasing risks to coastal ecosystems and communities. Mangrove forests act as critical natural buffers by dissipating wave energy, reducing storm surge, and limiting shoreline erosion. Severe Cyclonic Storm Dana, which formed over the Andaman Sea, rapidly intensified between 22 and 26 October 2024, reaching wind speeds of 100–120 km/h. This study investigates long-term changes in mangrove cover across the Bhitarkanika region of Odisha and examines cyclone-induced wave characteristics along the adjacent coast. Using Google Earth Engine, a supervised Random Forest classification was applied to Landsat and Sentinel-2 datasets to map land-use/land-cover changes from 1990 to 2024. Results show an increase in mangrove extent from 136.28 km² to 156.54 km² with classification accuracies exceeding 86% across all years. Additionally, ERA5-derived wave parameters and directional wave spectra were analysed to characterise wave conditions before, during, and after Cyclone Dana. Peak significant wave heights reached up to 4 m along mangrove-fringed shorelines, highlighting the cyclone's strong influence on nearshore wave dynamics. Spectral analysis highlighted that before the cyclone, the spectra showed low-to-moderate wave energy dominated by a stable swell system from the south and seas from the northwest. Whereas, during the cyclone, the wave energy intensified sharply with a broader directional spread and a strong peak from the southwest, followed by a rapid return to lower-energy, swell (from south) dominated spectra after the cyclone passage. The findings underscore the importance of conserving and restoring mangroves as effective nature-based solutions for reducing wave hazards and enhancing coastal resilience in cyclone-prone regions of the Bay of Bengal.

Keywords: Mangroves, Cyclone Dana, Bhitarkanika, Wave dynamics, Remote Sensing

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Understanding Coastal Changes As Per CRZ 2011 And 2019 On Land Use.

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ABSTRACT

This study focuses on examining how changes in the Coastal Regulation Zone (CRZ) policy affect patterns of land use and the health of coastal ecosystems. It aims to understand and shape coastal development, resource management, and environmental sustainability. By studying these relationships, the research seeks to provide valuable insights for improving coastal planning and ensuring a balance between human activities and natural ecosystem protection. The findings of this study can help policymakers, environmental managers, and local communities make more informed decisions that promote sustainable coastal development while conserving fragile marine and shoreline habitats. There are many studies have examined coastline changes; there remains a research gap in understanding how changes in the CRZ policy have influenced land use and land cover between the 2011 and 2019 CRZ notifications. Although some studies have shown how coastal areas and ecosystems change or have discussed CRZ policy, very few studies of them directly link the change made in the 2011 and 2019 CRZ notifications with actual land use and land cover changes using remote sensing techniques. This study aims to understand how changes in the Coastal Regulation Zone (CRZ) policy, especially between the 2011 and 2019 notifications, have affected land use, land cover (LULC), and natural landscapes within 500 meters HTL, these policy changes have affected coastal areas over time study will examine and compare changes in land use, vegetation, built-up areas, and other environmental features along the coast. Satellite imagery from LISS-IV and Landsat is utilized to examine the region within 500 meters of the High Tide Line. These images undergo analysis to determine various forms of land use and land cover (LULC) to observe their changes over time, and to investigate the configuration and location of the shoreline. The future scope of this study may encompass an examination of coastal developments that have occurred following the 2019 CRZ notification. This study will help evaluate how well the recent CRZ policies have protected coastal areas over time. The study could also look at factors like local social and economic conditions, rising sea levels, and the impacts of climate change to better understand how different coastal areas are vulnerable. Using tools like machine learning, high-resolution satellite images, and drones can help detect small changes in coastal land use and the environment. This information can guide policymakers and local authorities to manage coastal areas better, protect ecosystems, and plan sustainable development.

Keywords: HTL, Remote Sensing, CRZ, LULC

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Evaluating Recreational Beach Health Along The Goa Coast Using A Water Quality Index Based On Blue Flag Criteria And Multiple Antibiotic Resistance (MAR) Derived Microbial Risk

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ABSTRACT

Coastal recreational areas face growing human pressure, but regular monitoring of microbial water quality is still limited along many beaches in India. In this study, we examined physicochemical parameters, bacteriological indicators and antibiotic-resistance risk across 18 recreational beaches along the Goa coastline during the monsoon season. The surface waters showed typical tropical conditions (~27 °C), moderate monsoon-diluted salinity (~31 PSU), alkaline pH (~8.1) and a wide range of dissolved oxygen levels (5–9 mg L^{-1}), mainly due to freshwater inflow and local organic inputs. Microbial indicators varied greatly among the beaches. Total Viable Counts (TVC) were much higher in sediments (6000–8000 CFU g^{-1}) than in water (500–1200 CFU mL^{-1}), showing that sediments act as important microbial reservoirs. Coliform and fecal coliform levels were highest at beaches with heavy tourism or close to river mouths, especially Benaulim, Cavelossim and Bogmalo, suggesting occasional sewage entry during monsoon runoff. Even so, the Water Quality Index (WQI) for all beaches remained below 100, which places them in the 'good water quality' category. To better understand microbial risk, we also applied the Multiple Antibiotic Resistance (MAR) index to 96 bacterial isolates. During the monsoon, 26% of isolates were in the low-risk group, 47% in the high-risk group and 27% in the very-high-risk group. Several beaches showed MAR values above 0.2, indicating long-term exposure to pollution sources and the survival of antibiotic-resistant bacteria even with strong monsoon flushing. Overall, monsoon freshwater flow increased microbial loads and reduced water clarity, while beaches affected by tourism, sewage leakage, or urban runoff showed poorer microbiological conditions. Using a WQI based on Blue Flag criteria together with MAR-based microbial risk provides a simple and effective approach for assessing beach health and improving coastal water-quality management in Goa.

Keywords: beach profiling, antibiotic resistance, monsoon, pathogen, water quality

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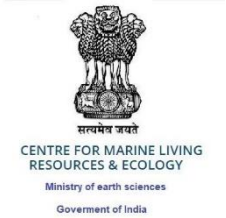

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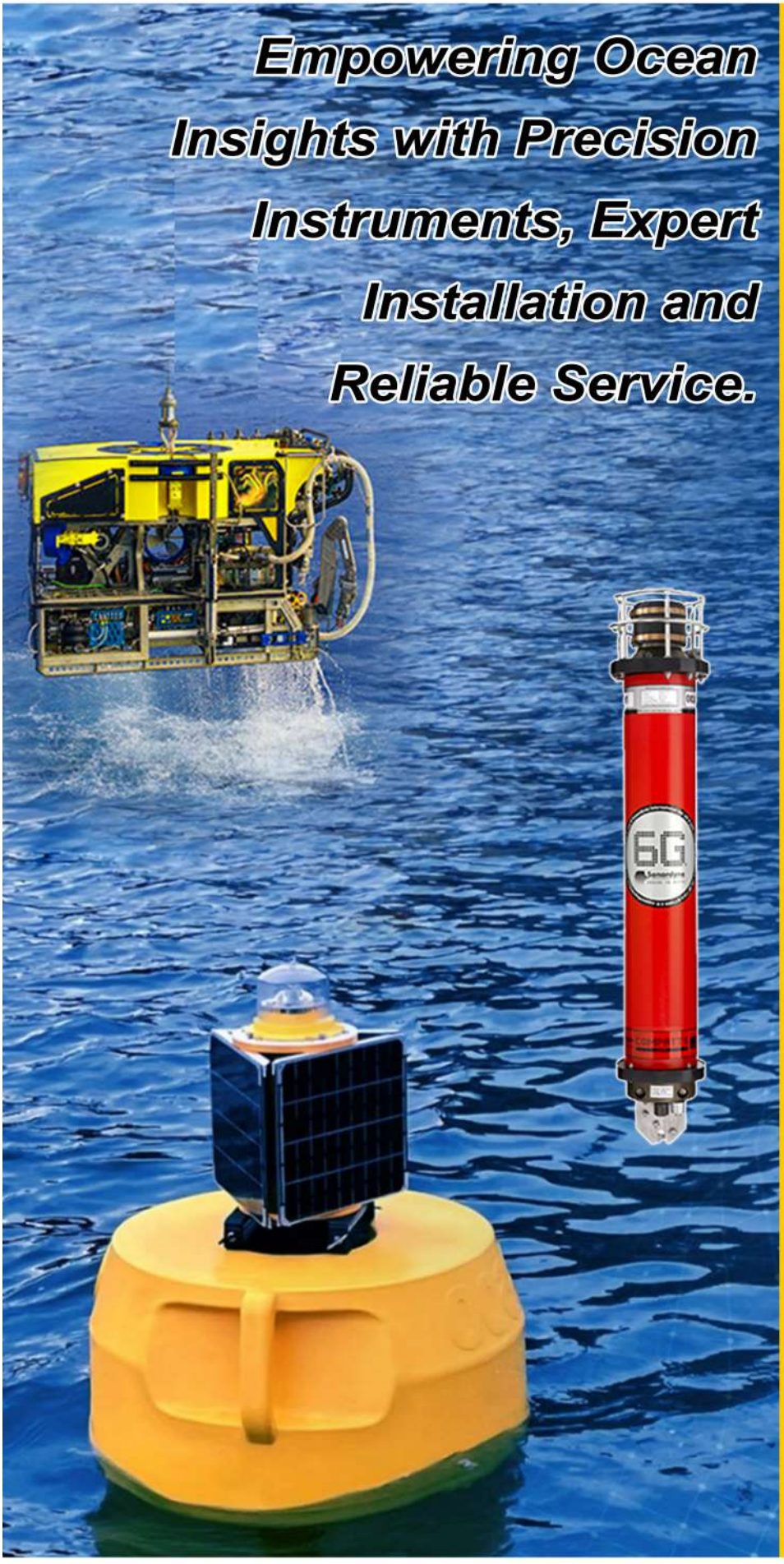

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