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Study of the Synergistic Effects of Meteorological, Oceanographic, Biological, and Radiological Parameters (MOBR) on Marine Ecosystems Around a Nuclear Power Plant

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ABSTRACT

MOBR is the study of the synergistic effects of meteorological, oceanographic, biological, and radiological parameters on each other to monitor the state of the atmosphere, hydrosphere, lithosphere, and biosphere in a particular marine environment. In our work, 24 parameters of MOBR data were collected to assess the marine ecosystems around Madras nuclear power plant. The results demonstrated the significant influence of sea level pressure on surface air temperature, its role in wind formation, control of wind affecting sea current velocity, and subsequent effects on the cover percentage of living and non-living organisms, biodiversity, as well as the seasonal behavior of Uranium 238 (U-238) across various spheres. The observations highlighted a key aspect of the study area, which was predominantly covered by high sand ratios (76 and 88% during the pre-monsoon and monsoon seasons, respectively). This sand dominance impacted biodiversity significantly. Interestingly, the highest values of U-238 were recorded in sediment, dust, crabs, and green algae during the monsoon season, with the exception of fish. This pattern was a result of the prevailing sand dominance. This study is considered the first attempt to infer the interactions between meteorological, oceanographic, biological, and radiological parameters (MOBR) to monitor marine ecosystems.

INTRODUCTION

Water covers roughly 70% of the Earth's surface; almost 97% of that water creates marine habitats in the world's oceans. The growing demand for energy production from various sources including nuclear power plants necessitates determining the true impact of discharge from those power plants on various ecosystems, particularly marine ecosystems **(Crema & Pagliai, 1980)**. Even though there are major categories for assessing the impact, such as physical, chemical, or biological monitoring, they are often separately utilized. This investigation will concentrate on the consequences of particular meteorological, oceanographic, biological, and radiological parameters (MOBR) when they are combined.

MOBR is the study of the synergistic effects of meteorological, oceanographic, biological, and radiological parameters on each other to monitor the state of the atmosphere, hydrosphere, lithosphere, and biosphere in a particular marine environment. Despite the overlap and convergence between recent definitions and terms, this study confirms that meteorology is the interdisciplinary scientific study of the atmosphere and its phenomena, including parameters such as wind velocity, surface air temperature, sea level pressure, etc., which play an important role in the biodiversity of intertidal zones (direct effect) or the transport of pollutants (indirect effect) **(Stacey & Pond, 1997; Sen, 2020)**, while the oceanography is the study of the ocean that includes parameters such as sea surface temperature, tides, and currents, etc. **(Croker *et al.* 1975; Green, 2004; Arockiaraj & Kankara, 2019)**.

Radionuclides/ Radioactive elements are defined as elements that have unstable atoms which produce ionizing radiation through rearrangement **(Atwood, 2013)**. Uranium (U) is primeval, parent emits alpha particles, and heaviest naturally occurring element. It is redistributed on the Earth through various natural and anthropogenic processes. Furthermore, the natural U is a mixture of three isotopes: U- 234, U- 235, and U- 238. Hence, to produce fuel for nuclear reactors, the mixture of the same three is divided into natural U (mainly consisting of 99% from U- 238 by mass), which has to be enriched U (has more U- 234 and U- 235 than natural uranium) and depleted U (has very little U- 234 and U- 235 than natural uranium).

U-238 is the most common isotope with a half-life T1/2 = 4.468×10^9 years. Like all isotopes of uranium, it is radioactive and possesses chemical toxicity and physical hazards. Besides its natural presence in the marine environment, some industrial processes also contribute to increasing its concentration. These processes include the extraction of phosphorus from phosphate ores to produce phosphate fertilizers, uranium enrichment, disposal of uranium mine tailings, and uranium mining and milling to produce uranium oxides. A power plant's construction and operation can have an impact on the marine environment; these impacts can be temporary or permanent. Hence, it is crucial to assist that impact on the surrounding marine environment.

Madras atomic power station (MAPS) having two units of 220 MW was established in 1983- 85, while the construction started in January 1971 and October 1972, respectively. Few researchers have investigated the ecology surrounding MAPS. However, it is observed periodically by the Indira Gandhi Center for Atomic Research **(IGCAR, 2020)**. **Hussain *et al.* (2010)** and **Muthulakshmi *et al.* (2019)** examined the effects of water discharge on fauna, while **Satpathy *et al.* (2019)** did wide ecological studies concerning the same issue in addition to the study of **Pandion and Arunachalam (2022)** who determined the activity of natural radionuclides, the annual intake, consumption dose, and lifetime carcinogenic risk assessment in the seafood from the coastal zone of Kalpakkam. They concluded that there is no considerable radiological concern to consumers. There are two basic approaches for monitoring the impact in use, namely: measurements based on community structure, and measurements based on indicator organisms **(Washington, 1984; Salah-Tantawy *et al.*, 2022)**. **Osman and Kloas (2010)** defined biomonitoring as the use of temporal and spatial changes in selected biological systems/ parameters to reflect changes in environmental quality/ condition. Therefore, instead of conducting separate studies using physical, chemical, or biological monitoring, this study was conducted to use a combination of MOBR parameters/ data to assess the impact of nuclear power plants on the Indian marine ecosystems.

MATERIALS AND METHODS

1. Study area

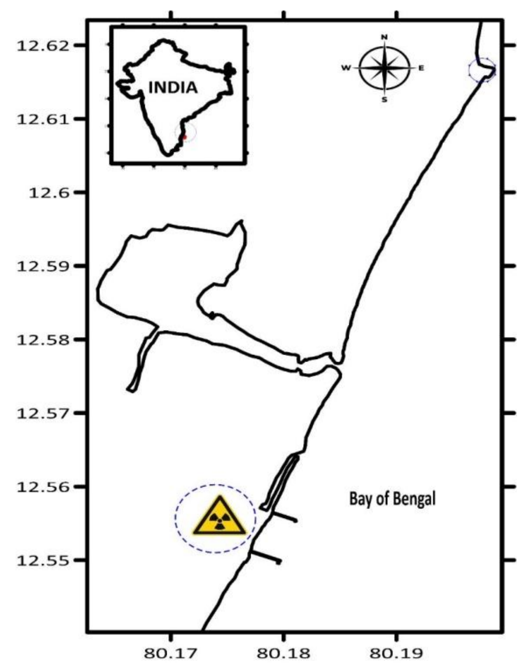


Fig. 1. Study area around MAPS

The current investigation was carried out on the eastern coast of the Bay of Bengal in India, specifically the area surrounding the Madras Atomic Power Station (MAPS), which is positioned on the beaches of Mahabalipuram and Kalpakkam. It is located 80 kilometers south of Chennai (Madras), the capital city of Tamil Nadu state. The study area spans approximately 9.1 kilometers, beginning from a sandy-rocky shore spot and extending southward along the sandy shore. It covers the marine ecosystem of the only sandy rocky point (1730m^2) and the two intake/outfall points (1180m) along the coastline of the MAPS campus (Fig. 1). The tidal zone of the studied area is characterized by a steep slope caused by the effects of tide, waves, and current. Due to India's climate, heavily influenced by monsoon winds and their impact on seasonal rainfall patterns, the study was conducted during three distinct seasons: post-monsoon (2020) (PoMon), pre-monsoon (2020) (PrMon), and monsoon (2021) (Mon).

2. Meteorological data

Wind velocity (m/ s), surface air temperature (°C), sea level pressure (hPa), rain amount (mm/ day), and dust mass (µg/ m³) were measured based on data from the Global Forecast System (GFS, NOAA), a weather forecast model (NCEP), and the Copernicus Atmosphere Monitoring Service (CAMS, ECMWF). The meteorological data were observed and reanalyzed daily at 0000, 0600, 1200, and 1800 (UTC) using the Viewfax program (Viewfax, a general Grib/ Fax viewer which can open and display grib weather data files, as well as most graphics formats).

3. Oceanographic data

The current directions were daily observed using ECMWF models, while the speed generated from the wind in shallow water was estimated following the method of **Ekman (1905)** based on the following equaition:

$$V = \frac{0.0127}{\sqrt{Sin\phi}} * W10 \quad (1)$$

Where:

V: current velocity (cm/ sec); Sin ϕ: Longitude of the region, and W10: Wind at 10 meters (m/ sec).

4. Assessment of U-238 concentrations in sediments, dust, biota, and seawater

18 samples were seasonally gathered from the studied area. Sediment samples were cleaned from extraneous materials, air- dried, homogenized, and kept in polyethylene containers until analyzed. Dust samples were collected from the surface of filter paper that was hanging on a building around MAPS area. Moreover, one gram of dust was treated as a sediment sample. Furthermore, one-gram per sample was digested with a mixture of hydrofluoric, nitric, and perchloric acids (3: 1: 1) overnight, then evaporated to near dryness to complete digestion. Following digestion, the leftover from each sample was diluted into 25ml of ultrapure water (Millipore Direct-Q System) and filtered using 40mm filter paper (Whatman, USA).

Biological samples were collected from the studied area, including three specimens representing *Leiognathus* sp. (fish), *Portunus sanguinolentus* (crab), and green algae. These samples were preserved in 70% ethanol and immediately transported to the laboratory. In the lab, the biological samples were washed, and the fleshy tissues were isolated. After drying for 8 hours, they were pulverized. Ten grams from each sample were digested with a mixture of nitric and perchloric acids (3:1) overnight. The mixture was evaporated until dry, dissolved in 2ml of HNO3, filtered, and diluted to 50ml with double-distilled water before analysis. Moreover, seawater samples were collected from the sub- tidal zone in front of MAPS coast at different spots using cleaned polyethylene and glass bottles (1- liter capacity), where the pH of the samples was adjusted to 3- 4.

The concentrations of U- 238 in all digested samples were determined utilizing an Agilent 7700 series ICP-MS system available at the Center for Study on the Bay of Bengal, Andhra University, Visakhapatnam, India. The optimal operating circumstances for ICP- MS analysis are provided by **Rao *et al.* (2017)**. The resulting concentrations are expressed in ppb. Before being rinsed with distilled water, all equipment was washed and autoclaved for 24hrs. in a 10% HNO3 solution. Triple digestions were performed on each sample. All biological, seawater, sediment, filter paper of dust samples, and equipment were carefully treated at any stage to avoid contamination from the surrounding environment as much as possible.

5. Biodiversity analysis

At the tidal zone of the sandy rocky area, three line intercept transects **(English *et al.*, 1997)** were applied to conduct the biological survey, and the number of living organisms was randomly counted in 1 x 1m^2 and 10 x 10cm^2 quadrats. The field survey was carried out by visual observations and photos analysis using tps program, and the monitored specimens were sorted and classified into major groups, such as cnidarians, algae, gastropods, crabs, crustaceans, and bivalves according to **Carpine (1987)**, **Delèpine *et al.* (1987), Gaillard (1987)**, **Holthuis (1987)** and **Poutiers (1987)**, respectively. To evaluate the diversity of the study area, various diversity indices were calculated, including species number per sample (S), abundance of individuals expressed as an average number of individuals/ m^2 (A), **Shannon and Weaver (1949)** index (H'), Simpson's Index (D), Inverse Simpson's Index (1/D), Species Richness (d) according to **Margalef (1951)**, and **Pielou's (1966)** Evenness index (J'). Additionally, the cover percentage of living and non-living components was estimated.

6. Statistical analysis

All statistical analysis were performed using SPSS program (V: 25) and microsoft excel program (2020). Meteorological data were visualized using wind rose plots for the meteorological data program (version 8.0.2), which gives a frequency distribution graph and wind rose with eight cardinal directions (N, NE, E, SE, S, SW, W, NW). Additionally, the current velocity was visualized by using the wind rose program. Diversity indices were calculated and Pearson’s correlation analysis was carried out to illustrate the associations between MOBR parameters. All findings are represented in tables and visualized in figuers as means ±SD.

RESULTS AND DISCUSSION

1. Meteorological and oceanographic data

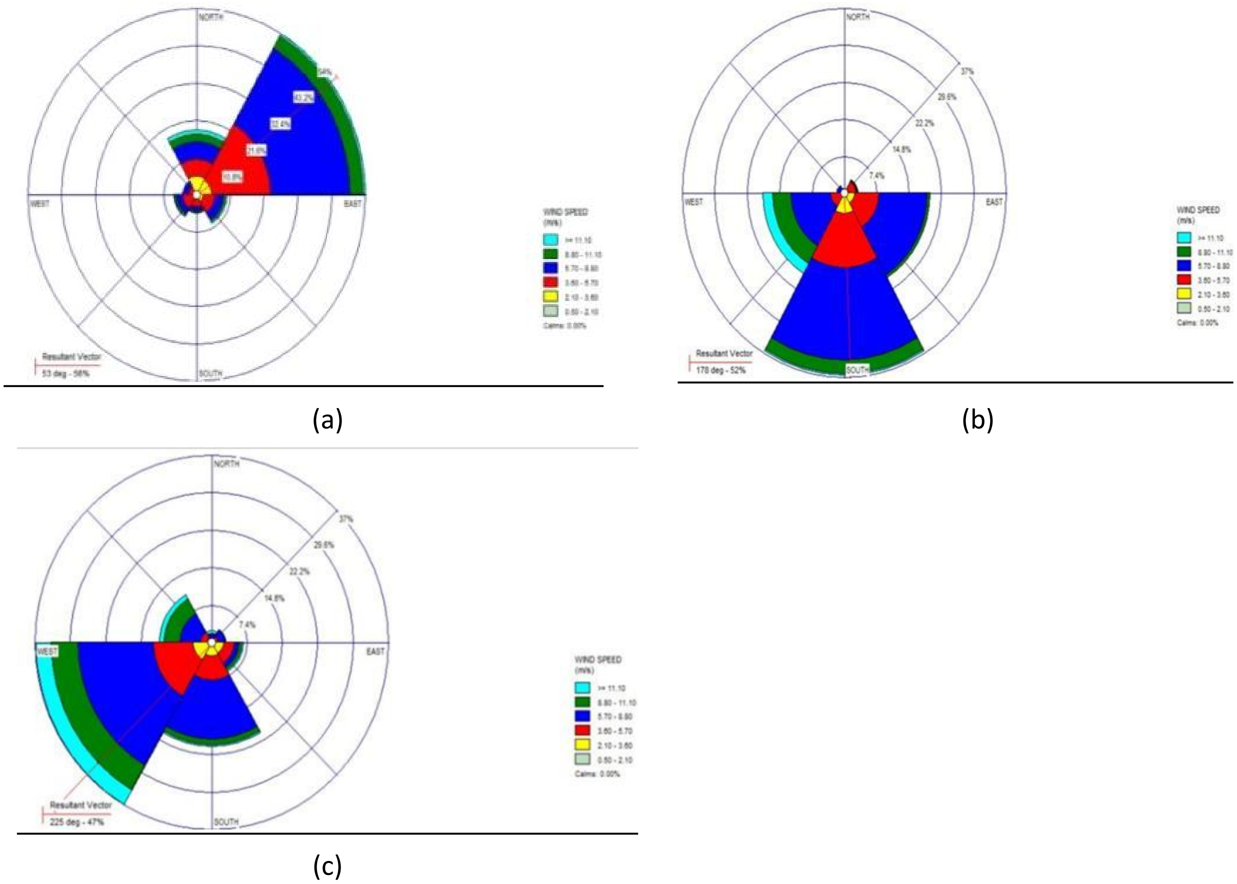


Fig. 2. Wind rose patterns around MAPS during (a) PoMon, (b) PrMon, and (c) Mon

The seasonal wind direction using wind rose and frequency distribution, as shown in Figs. (2, 3) were observed determining the wind in all directions in Mon and PreMon but in variable percentages. The predominant directions were NE, SE, and SW at PoMon, PrMon, and Mon seasons, respectively. The obtained data revealed that, in monsoon season, a total of 5.3% of the wind belonged to the extreme wind class ≥11.10m/ s (Fig. 3), while the lowest percentage (2.6%) was observed at PrMon. The wind class that varied between 8.80- 11.10m/ s have the same percentage (approximately 8%) at PrMon and PoMon, while the Mon recorded the high percentage (10.9%) of total wind during the study period. The calm wind in all seasons was non- significant. In this study, the climate is similar to many parts of the Indian Peninsula area and is influenced by the Indian monsoon (that in the tropical area roughly between 20°N and 20°S) and, more specifically, by its topography and geographical location.

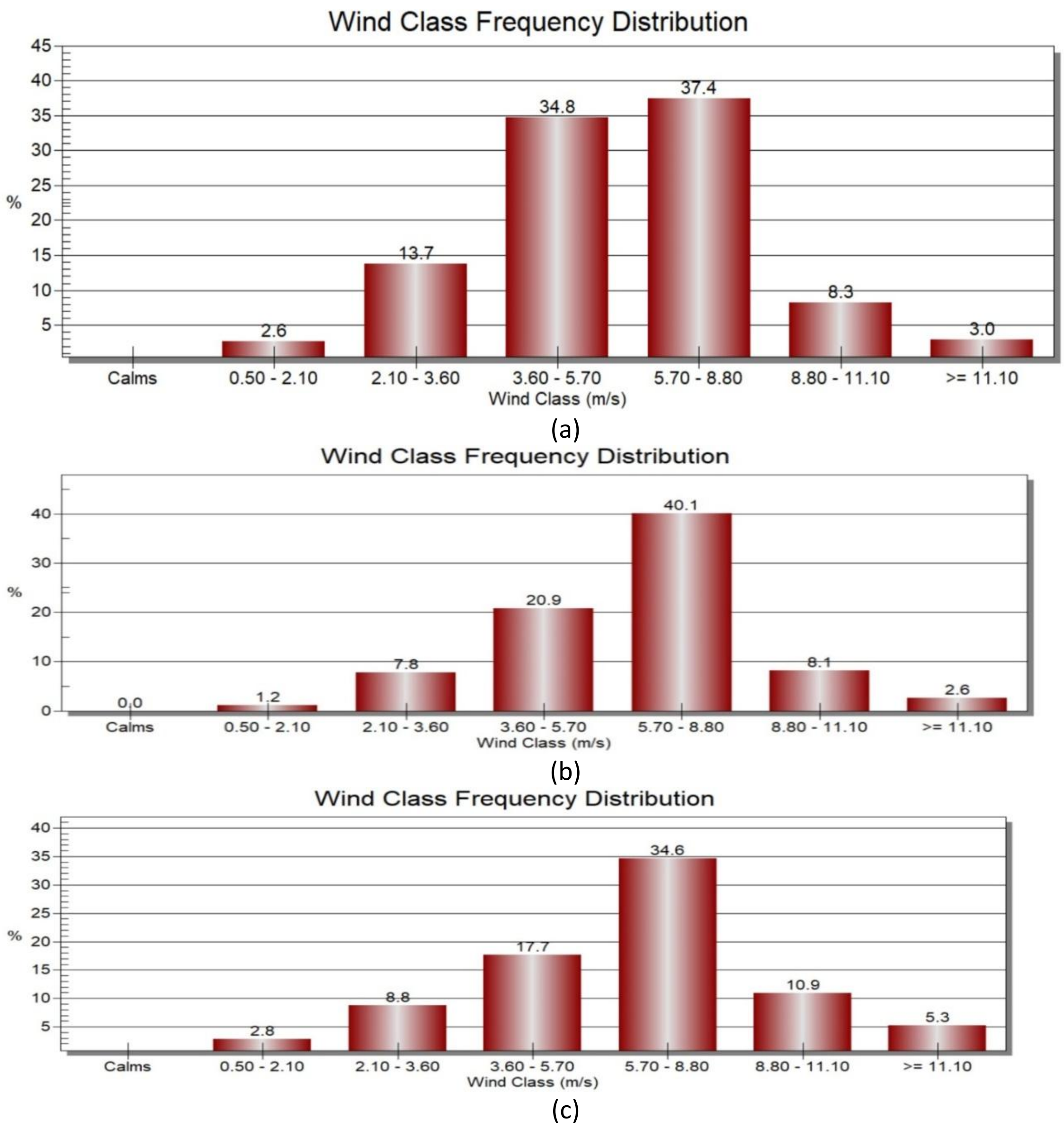


Fig. 3. Wind frequency distribution around MAPS during (a) PoMon, (b) PrMon, and (c) Mon

According to Halley's concept (Thermal concept), the differential heating effects of the land and the sea are considered the primary cause of that seasonal fluctuation, besides the Himalayas and Tibetan plateau which act as a physical barrier, as well as the effects of the westerly and tropical easterly jet stream (TEJ) **(Ramage, 1971; Holland *et al.*, 1998; Attri & Tyagi, 2010)**. Table (1) shows the seasonal averages of surface air temperature (T), sea level pressure (P), rain amount (Ra), and dust mass (Dm). Due to the proximity of the study area to the sea (Jeganathan, 2018), the obtained mean values are very close in all seasons, fluctuating between 27.1±2.7°C and 29.7±3°C. The maximum value (40°C) was recorded at PrMon as a result of dry south wind (Resultant Vector 176 deg - 54%), while the minimum was recorded at the PoMon.

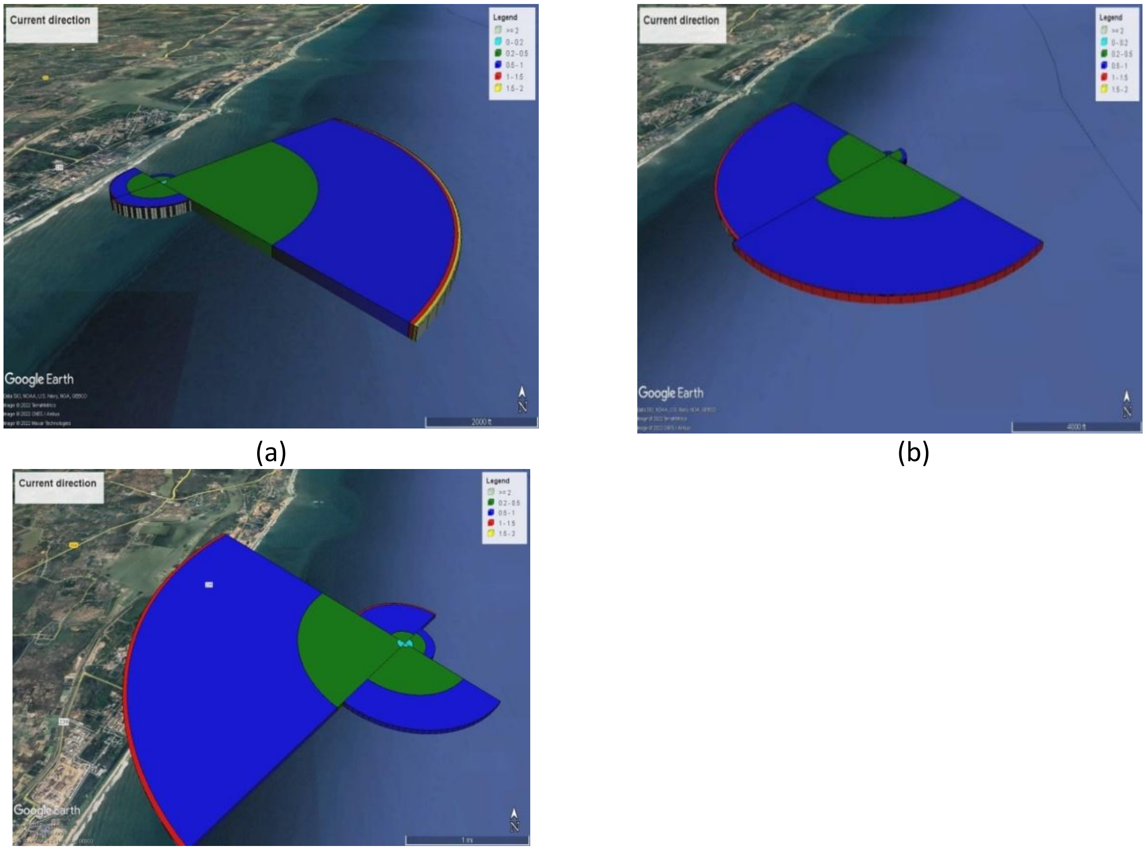


Fig. 4. Sea current velocity around MAPS during (a) PoMon, (b) PrMon, and (c) Mon

According to **Ramage (1971)**, the pressure pattern over the Indian region was affected by the combination of heat lows and equatorial troughs (or the ITCZ), forming a continuous low-pressure belt at the surface. This was reflected in the pressure values (P), which showed sharp seasonal fluctuations with mean values of 1010 hPa and 1005 hPa during PoMon and Mon, respectively. The minimum values were even lower, measuring 997 hPa, 1000 hPa, and 996 hPa during PoMon, PrMon, and Mon, respectively. These values were below the standard atmospheric pressure (1013 hPa), indicating the presence of a tropical storm **(Gray 1968, 1975; Goswami & Mohan, 2001)**.

The Rainfall in India varies greatly both spatially and temporally. **Attri and Tyagi (2010)** illustrate that the coastal regions of India are characterized by unvarying warmth and frequent rains. Chennai city has the heaviest rainfall in the district of Tamil Nadu **(Rajeevan, 2008)**. The present data showed sharp fluctuation between the maximum and minimum values (17- 0.2mm/ day). Moreover, fluctuation appeared in the standard deviation values which is close to or more than the mean values at all seasons. The dust in the study may come from many sources, such as stone crushing, soil, and other bulk materials resuspended by the wind **(Chow *et al.*, 1991)**.

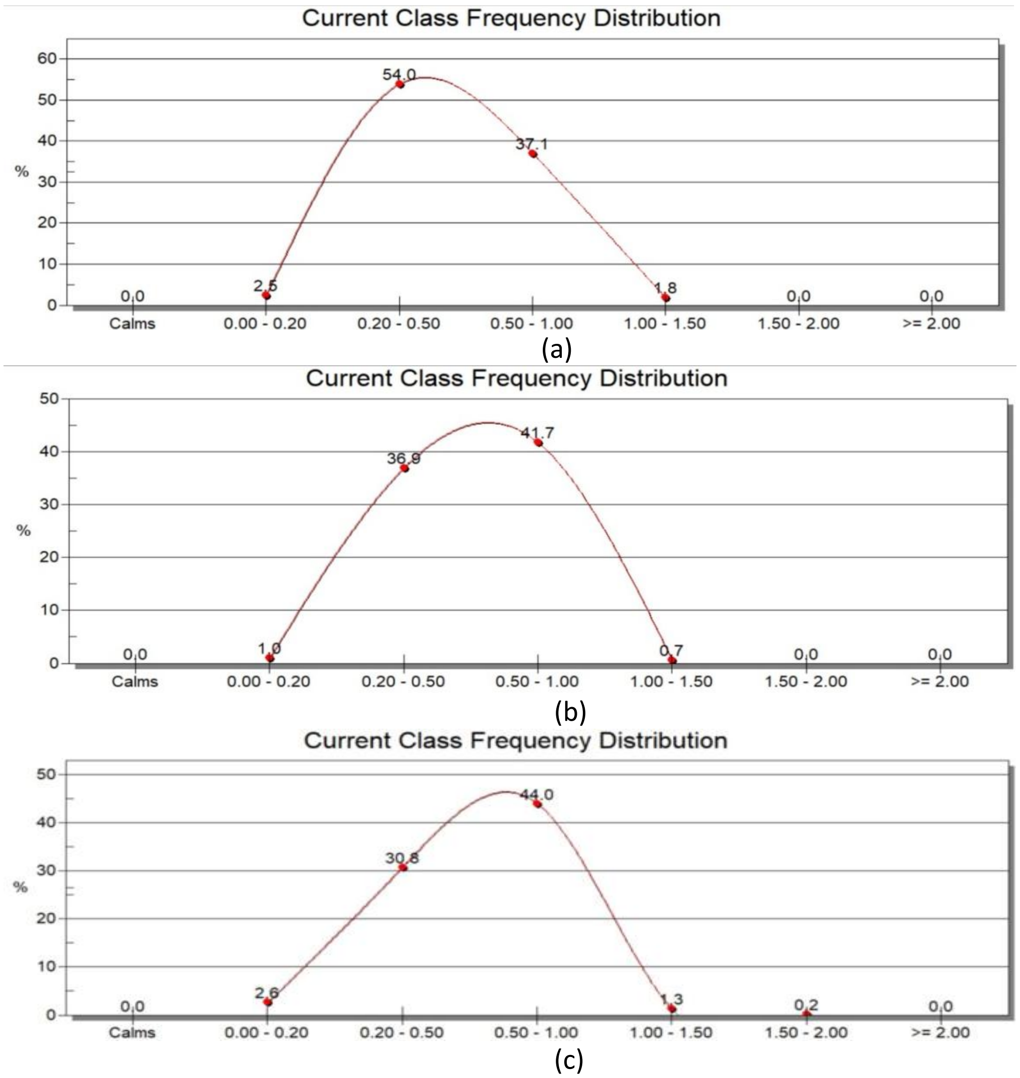


Fig. 5. Current frequency distribution around MAPS during (a) PoMon, (b) PrMon, and (c) Mon

The values of dust mass are correlated with wind direction, dryness, and rainfall. The lowest mean value (6.77µg/ m³) was recorded during PoMon, with the NE wind blowing from the Bay of Bengal. In contrast, the maximum values of 206,312µg/ m³ were recorded during PrMon and Mon, respectively, with the SE wind originating from the land and influenced by Aeolian processes (which occur wherever there is a supply of granular material and atmospheric winds of sufficient strength to move them) **(Kok *et al.*, 2012)**. The study revealed slight fluctuations in the current velocity (Figs. 4, 5). The current class varied between 0.50- 1cm/ sec, with a high ratio (44% and 41.7%) observed during Mon and PrMon, respectively. In contrast, during PoMon, 54% of the total wind belonged to the class 0.20- 0.50cm/ sec. The extreme current velocity (1.50- 2cm/ sec) was recorded during Mon with a total of 0.2%. The predominant current directions were identified based on the direction of the wind. During PrMon and Mon, the predominant directions were SE and SW, while during PoMon, it was NE. This pattern is a result of significant influence from the wind **(Ekman, 1905; Stommel, 1957; Murty *et al.* 1992; Green, 2004)**.

Table 1. Results of surface air temperature, sea level pressure, rain amount, and dust mass at MAPS

Parameter	Seasons	Mean±SD	Median	Minimum	Maximum
T (°C)	PoMon	27.1±2.7	27	10	34
	PrMon	29.7±3	29	20	40
	Mon	29.3±2.30	29	22	40
P (hpa)	PoMon	1010±3	1010	997	1015
	PrMon	1007±3	1007	1000	1014
	Mon	1005±3	1005	996	1012
Ra (mm/day)	PoMon	2.76±1.74	3	0	6
	PrMon	1.95±1.99	1	0	6
	Mon	3.11±3.16	2	0	17
Dm (µg/m³)	PoMon	6.77±7.87	4	1	64
	PrMon	37.47±40.16	19	1	206
	Mon	30.25±32.05	25	3	312

2. Assessment of U-238 concentrations

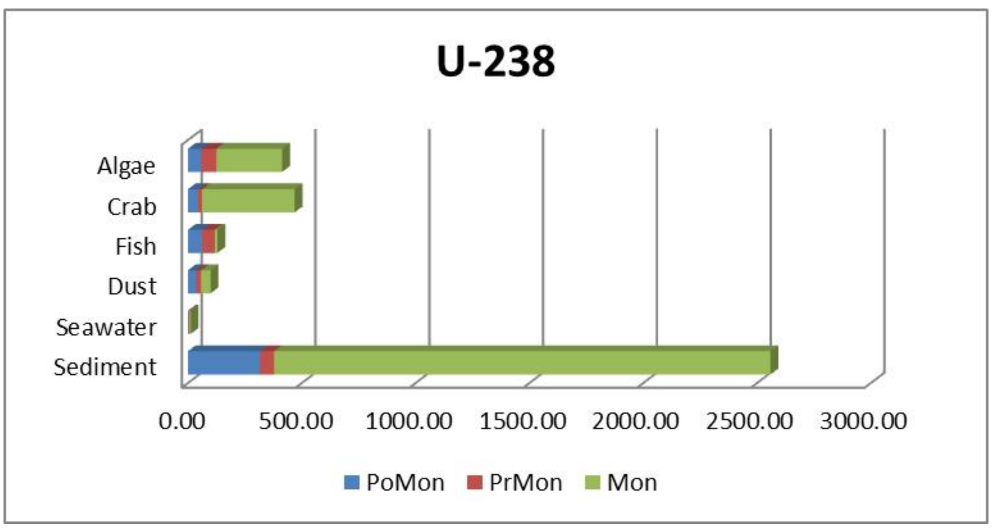


Fig. 6. Seasonal variations of U- 238/ ppb concentration around MAPS during PoMon, PrMon, and Mon

The data in Fig. (6) show the seasonal variation of the concentration of U- 238 at the part of the lithosphere (sediment), atmosphere (dust), hydrosphere (seawater), and biosphere (marine organism). On one hand, the highest values of U- 238 were recorded in the sediment, dust, crab, and green algae during the Mon season at the time of this study, whereas the value in fish was the lowest during the same season. However, the values of U- 238 in seawater didn't show a large gap at the different seasons. The seasonal fluctuation of concentrations among those spheres, particularly during Mon, may be related to the coastal morphology and processes [longshore/ cross- shore movement and sea current direction (SE/ SW)] **(Aubrey, 1979; Saravanan & Chandrasekar, 2010; El-Taher *et al.,* 2018; Shetty *et al.,* 2022)**. Besides, the concentrations of the organisms are highly affected owing to their bioaccumulation behavior and movability, such as sessile, sedentary, or mobile organisms **(Ansell & Trevallion, 1969; Henner, 2008; Stewart *et al.,* 2008; Hussain *et al.,* 2010; El-Komi, 2011; Satpathy *et al.,* 2019).** While, uranium concentration is primarily determined by the geology of the region and differs from site to site according to **WHO (1998).** This study may provide evidence showing that those U- 238 concentrations varied seasonally and temporally at any sphere, such as water bodies, air masses, and biological species.

3. Biological data

3.1 Cover percentages for living and non-living components

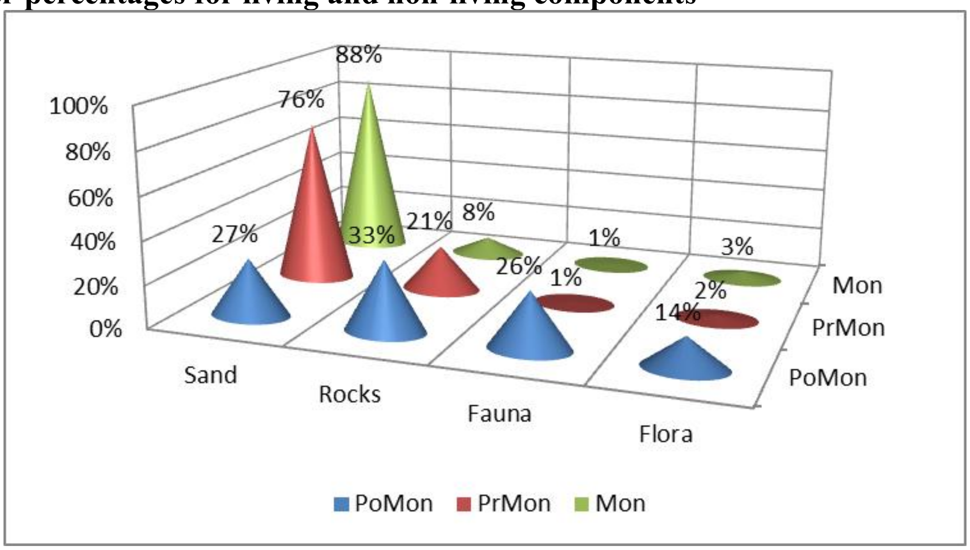


Fig. 7. Seasonal variations in the cover percentage of living and non- living components around MAPS during PoMon, PrMon, and Mon

Data in Fig. (7) illustrate the seasonal cover percentages for living and non- living components in the study areas. The living components consist mainly of fauna and flora in this investigation, while the non- living is sand and rocks. The observations revealed a pivotal point for this study during the PrMon and Mon seasons. The study area was predominately covered by high sand ratios, covering 76 and 88% of the study area, respectively. On the other side, there were non- significant fluctuations of living and non-living components at PoMon with a maximum percentage rock (33%), followed by sand (27%) and fauna (26%). According to **Balaji (1988)**, the pre- monsoon season is considered the main growth span for most of the benthos; despite this fact, the pivotal ratio of sand decreased the ratio of fauna and flora from 26 and 14 to 1 and 3% at post-monsoon and monsoon, respectively. The domination of sand is a result of the effects of meteorological and oceanographic factors, particularly by waves, seawater current movement from SE and SW coordinate, and the storm weather adds to this dominance **(Aubrey, 1979; Aubrey & Ross, 1985; Dubois, 1988; Saravanan & Chandrasekar, 2010; Shetty *et al.,* 2022)**.

3.2 Faunal composition

A slight variation was noticed in the structure of the bottom fauna throughout the study (Fig. 8). Only a total of 26 taxa were identified. They belong to 7 genera with 1583 individuals; namely, Decapoda, Gastropoda, Bivalvia, Echinodermata, Anthozoa, Annelida, and Actinopterygii. Fig. (10) reveals that all groups represented at the PoMon but some absence is at PrMon and Mon. Gastropods exhibited seasonal dominance with a semi-instantaneous percentage, followed by decapods and bivalves despite the significance of the seasonal decrease in abundance, particularly during the pre-monsoon and monsoon periods.

Regarding fish species, decapods (in sandy rocky habitat) and actinopterygii (in seawater habitat) showed a significant increase during different seasons. This aligns with previous studies by **Dhar and Rakhecha (1983), Ansari *et al.* (2003)** and **Satpathy *et al.* (2010)**, indicating that the coastal biodiversity in tropical regions, particularly in Tamil Nadu, India, is influenced by hydrological variables resulting from seasonal variations in climatic conditions. The results provided a more precise explanation for the seasonal biodiversity, revealing that the sand- to-rock ratio affected the abundance and absence of some groups during the pre- monsoon and monsoon seasons (Fig. 9). A significant variation in the structure of littoral fauna was observed throughout the study period. The number of identified species decreased from 24 species (945 ±75 individuals/ m2) at PoMon to 16 species (266 ±17 individuals/ m2) at Mon. However, the values of the Shannon-Weaver index (H), Simpsons index (S), evenness index (J), as well as species richness (SR) (Fig. 10) show slight seasonal variation while remaining within the normal range. This implies a positive aspect of the community structure and distribution pattern in the area surrounding MAPS, as indicated by previous studies **(Hussain *et al*., 2010; El-Komi, 2011; IGCAR, 2020)**. The sharp variation of the number of species and abundance may be highly affected by the seasonal changes of cover percentage between sand and rocks in the study area, which is made by winds, waves, and surface currents (Fig. 9) since meteorological and oceanographically factors act as a driving force for the transportation and deposition of sands from the sea to beaches. Changes in the Cardinal directions of those factors have a significant impact on the study areas beach profile's shape, making it not identical at all seasons. This is due to the large number of sands that are transported into the nearshore by longshore and cross- shore movement; some of these processes occur over millennia; others are recent and may be cyclic **(Saravanan & Chandrasekar, 2010; Kannan *et al.,* 2014; Veerasingam *et al.,* 2016)**. **El-Komi (2011)** and **Green (2014)** provided illustrations of how this is true, showing that the ability of any species to survive in any given environment depends on how well- adapted it is to the various environmental factors presented in the coastal sedimentary areas.

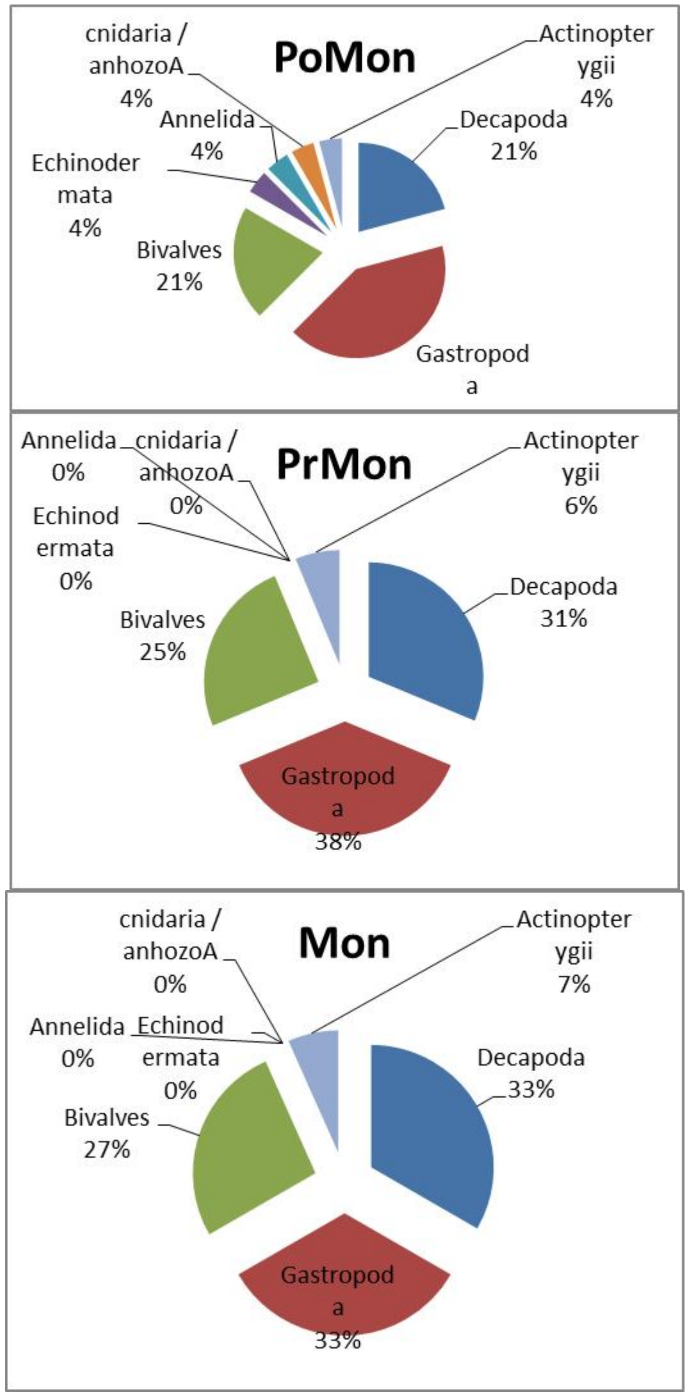
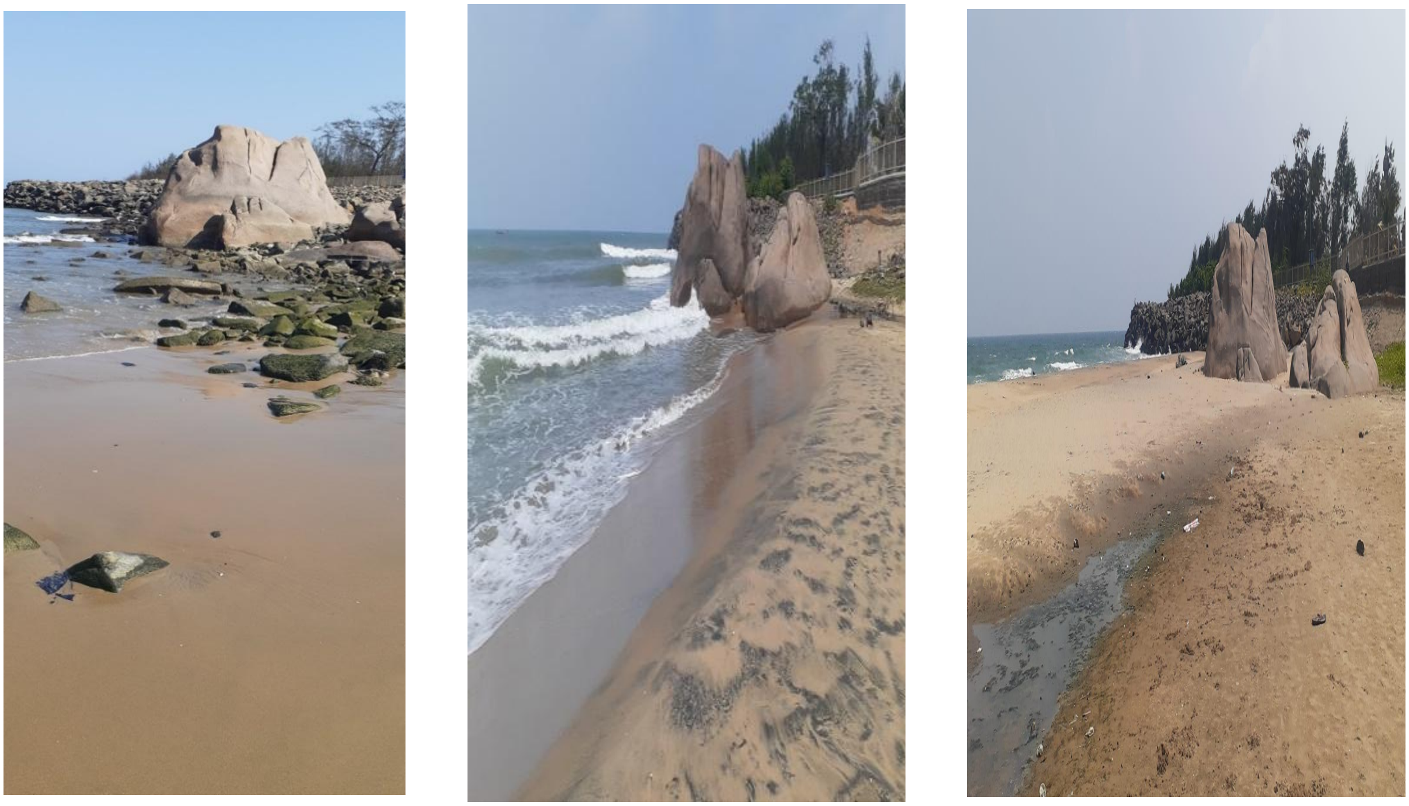


Fig. 8. Percentage of faunal composition around MAPS during PoMon, PrMon, and Mon



PoMon PrMon Mon

Fig. 9. Photographs showing the rocky sandy shore around MAPS during PoMon, PrMon, and Mon

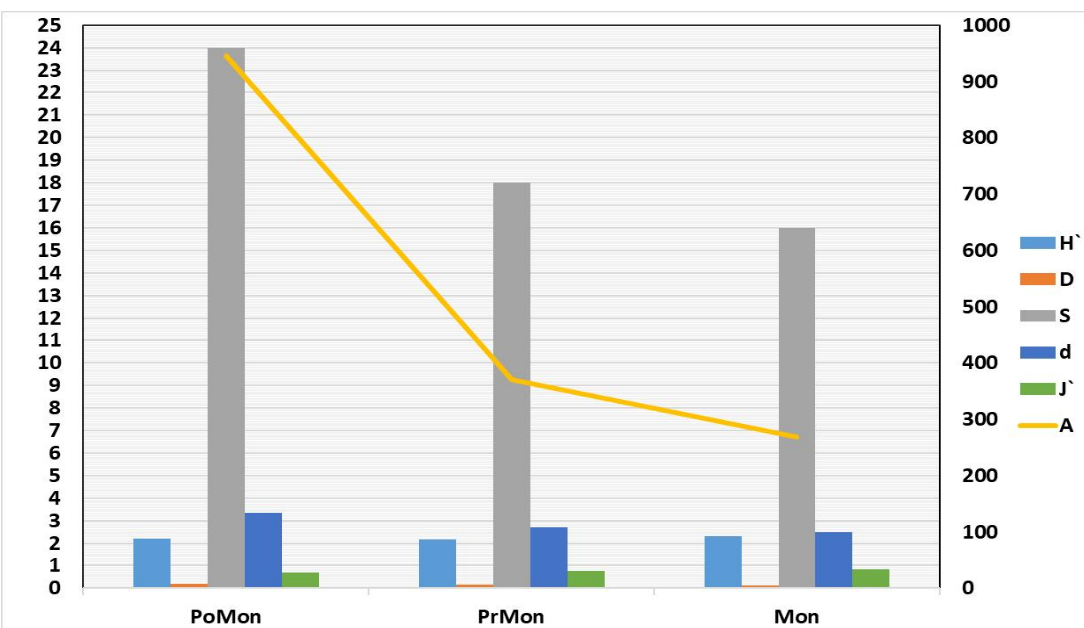


Fig. 10. Results of diversity indexes around MAPS during PoMo, PrMon, and Mon

This finding coincides with those of **Balaji (1988)**, **Dubois (1988)**, **Ansari *et al.* (2003)**, **Shahul *et al.* (2005)**, **Shahul *et al.* (2007)**, **Hussain *et al.* (2010)**, **Satpathy *et al.* (2019)** and **IGCAR (2020)**, about wellness and seasonal biodiversity of the marine ecosystem close to MAPS. However, it happens to contradict the justification for that seasonal fluctuation, whereas rainfall, organisms competition, salinity, turbidity, thermal discharge, etc. are considered the main factors in the biodiversity in some parts of the Kalpakam Coast. However, the most surprising finding in the results highlights the significant influence of temperature, pressure, wind, and sea current direction, among other environmental factors, in driving the seasonal changes in the cover percentage. For instance, the prevalence of 88% sand at Mon (Fig. 9) could be a major contributing factor to the fluctuations in biodiversity in this specific area, particularly the sandy rocky portion **(Dubois, 1988)**.

4. Correlation relationships among MOBR parameters

In Table 2, the correlation analysis reveals the intricate relationships between 24 parameters across the meteorological, oceanographic, biological, and radioactive data categories (MOBR). This investigation encompassed 276 data points for Pearson's correlation analysis (*r*). Notably, 104 of these values displayed positive and significant correlations ($r \geq 0.50$), indicating a strong positive relationship between these parameters. Conversely, 99 values exhibited negative and significant correlations ($r \geq -0.50$), denoting a robust negative relationship. Additionally, 73 values showed no significant correlations, suggesting a lack of association between these specific parameters. Indeed, the extensive data analysis conducted in this study provides compelling evidence regarding the intricate relationships and inverse correlations among various MOBR parameters. This comprehensive analysis reaffirms established scientific principles concerning the interconnections between abiotic and biotic factors, highlighting the mutual influences they exert on each other **(Green, 2014)**. Specifically, the study elucidates the cascading effects of parameters such as sea level pressure (P) on factors like surface air temperature (T) and their role in wind formation, as documented in previous research **(Gray, 1968)**. The study also delves into the intricate control mechanisms involving wind (M) and its impact on wave formation and current velocity (O). These interactions further influence the cover percentage of living and non-living entities, biodiversity (B), and even the seasonal behavior of U- 238 across different environmental spheres (R). This holistic understanding of the interconnectedness of these parameters contributes significantly to the broader scientific understanding of ecosystem dynamics.

The observed strong negative correlation between the sand percentage and several key parameters is indeed a significant finding. This correlation indicates a robust relationship between the dominance of sandy areas and the decrease in rocks, fauna, flora, diversity indices (D, S, A, and d), as these parameters typically exhibit a positive correlation with rocky terrains and diverse habitats. On the other hand, the sand percentage shows a strong positive correlation with evenness index (J) and a significant correlation with Shannon index (H). This important correlation suggests a substantial decrease in the numbers of individuals and species in the study area while maintaining the overall stability of biodiversity. This finding underscores the ecological nuances within the sandy areas and their impact on the composition and diversity of the local ecosystem, shedding light on the delicate balance between habitat types and their associated biodiversity patterns. The sand ratio with

U- 238 concentrations also showed a remarkable correlation (+/ -) particularly with USe, USW, UC, and UA. However, there is no significant correlation with UD as a result of the dominance of sand in the area of study.

Table 2. Correlation relationships among MOBR parameters

MOBR	H`	D	S	A	d	J`	U Se	U Sw	U D	U F	U C	UA	W S	W D	P	T	Dm	R a	C S	C D	Sand	Rocks	Fauna	Flora
H`	1.00																							
D	-0.76	1.00																						
S	-0.54	0.96	1.00																					
A	-0.46	0.93	0.99	1.00																				
d	-0.53	0.96	1.00	1.00	1.00																			
J`	0.82	-0.99	-0.92	-0.88	-0.92	1.00																		
U Se	1.00	-0.81	-0.61	-0.53	-0.60	0.87	1.00																	
U Sw	0.23	-0.81	-0.94	-0.97	-0.95	0.74	0.31	1.00																
UD	0.80	-0.22	0.06	0.16	0.08	0.32	0.75	-0.39	1.00															
U F	-0.96	0.91	0.76	0.69	0.76	-0.95	-0.98	-0.50	-0.60	1.00														
U C	0.99	-0.84	-0.65	-0.57	-0.64	0.89	1.00	0.36	0.72	-0.99	1.00													
U A	0.98	-0.88	-0.72	-0.64	-0.71	0.93	0.99	0.44	0.65	-1.00	1.00	1.00												
W S	0.80	-1.00	-0.94	-0.90	-0.93	1.00	0.84	0.77	0.28	-0.94	0.87	0.91	1.00											
W D	0.59	-0.98	-1.00	-0.99	-1.00	0.94	0.65	0.92	0.00	-0.80	0.69	0.75	0.96	1.00										
P	-0.02	0.67	0.85	0.90	0.86	-0.58	-0.10	-0.98	0.58	0.31	-0.15	-0.24	-0.62	-0.82	1.00									
T	0.22	-0.81	-0.94	-0.97	-0.94	0.74	0.30	1.00	-0.40	-0.49	0.35	0.43	0.76	0.92	-0.98	1.00								
Dm	0.11	-0.73	-0.89	-0.93	-0.90	0.65	0.18	0.99	-0.51	-0.39	0.24	0.32	0.68	0.86	-1.00	0.99	1.00							
R a	0.85	-0.30	-0.02	0.08	-0.01	0.40	0.81	-0.32	1.00	-0.66	0.77	0.71	0.36	0.08	0.51	-0.33	-0.43	1.00						
C S	0.67	-0.99	-0.99	-0.97	-0.99	0.97	0.72	0.88	0.09	-0.85	0.76	0.81	0.98	1.00	-0.76	0.87	0.81	0.17	1.00					
C D	0.19	-0.78	-0.93	-0.96	-0.93	0.71	0.26	1.00	-0.44	-0.46	0.32	0.40	0.74	0.90	-0.99	1.00	1.00	-0.36	0.86	1.00				
Sand	0.49	-0.94	-1.00	-1.00	-1.00	0.90	0.56	0.96	-0.12	-0.72	0.60	0.67	0.92	0.99	-0.88	0.96	0.92	-0.04	0.98	0.95	1.00			
Rocks	-0.77	1.00	0.95	0.92	0.95	-1.00	-0.82	-0.80	-0.24	0.92	-0.85	-0.89	-1.00	-0.97	0.65	-0.79	-0.71	-0.32	-0.99	-0.77	-0.93	1.00		
Fauna	-0.33	0.87	0.97	0.99	0.97	-0.81	-0.40	-0.99	0.30	0.59	-0.45	-0.53	-0.83	-0.96	0.95	-0.99	-0.97	0.22	-0.92	-0.99	-0.98	0.85	1.00	
Flora	-0.23	0.81	0.94	0.97	0.94	-0.74	-0.30	-1.00	0.40	0.50	-0.35	-0.43	-0.77	-0.92	0.98	-1.00	-0.99	0.32	-0.88	-1.00	-0.96	0.79	0.99	1.00

- (Correlation is significant at the level of *P*< 0.01 and 0.05 (2-tailed))

H`= Shannon- Weaver index, D= Simpson's Index, S= Species number per sample, A= Abundance of individuals that expressed as an average number of individuals/ $m^2$, d= Species Richness Margalef, J`= Pielou`s Evenness index, U Se= U- 238 concentration in sediment, U Sw= U- 238 concentration in seawater, U D= U- 238 concentration in the dust, U F= U- 238 concentration in fish, U C= U-238 concentration in crab, U A= U- 238 concentration in algae, W S= Wind speed, W D= Wind direction, C S=Current speed, C D= Current direction, Sand = Cover percentage of sand, Rocks = Cover percentage of rocks, Fauna = Cover percentage of fauna, Flora = Cover percentage of flora.

CONCLUSION

The current study is regarded as the first attempt to draw conclusions from the mutual influences of meteorological, oceanographic, biological, and radioactive characteristics on the marine environment (MOBR). The study indicates that the biodiversity in the MAPS region was directly affected by the seasonal high ratio of sand covering, which was sedimented as a result of meteorological and oceanographic changes based on an analysis of 24 parameters/ values pertaining to four categories of MOBR. These alterations also had an impact on U- 238 levels in the MAPS region's atmosphere, hydrosphere, lithosphere, and biosphere. After a comprehensive analysis, we are now able to clearly understand what is behind MOBR.

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AUTHORS CONTRIBUTIONS

AL-Sharif: did conceptualization, methodology, investigation, and writing the original draft. Osman, El-Taher, and El Bessa: reviewed and validated the biological, radiological, and meteorological parts respectively. Manjulatha: reviewed and supervision. All the authors contributed to the manuscript and approved the submitted version.

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