Original Research Article

Community structure of intertidal macrofauna: spatial autocorrelation of two rocky coasts of Gujarat, India

ABSTRACT

The present study describes the community structure of intertidal macrofauna on two rocky coasts of the Kathiawar Peninsula, Gujarat State. The results show significant spatial autocorrelation between the two study sites, with the Mantel correlogram identifying contrasting patterns of species distribution across the coasts. The Veraval coast shows a strong positive correlation owing to its rocky coastal regions. The homogeneity of the intertidal habitats leads to a diverse and cohesive macrofaunal community. In contrast, the Adri coast displays a negative correlation, attributed to the heterogeneous habitats of its intertidal zones. The combination of sandy and rocky patches creates a range of microhabitats, resulting in distinct ecological regions within the coast. This environmental variability promotes a more distinct and less uniform distribution of species. The study underscores the importance of conducting further ecological research on diverse marine ecosystems, particularly in areas with varied habitat types.

Keywords: intertidal macrofauna;dominant phyla; spatial autocorrelation; Gujarat;India.

1. INTRODUCTION

Marine biodiversity is basically studied in coastal seas and around islands. Across all levels of biological organisation, about 60% of the human population resides in the coastal zone, which constitutes 18% of the surface of Earth [16]. All levels of biological organization, such as genes, species, and populations, as well as ecosystems, constitute marine biodiversity, which is the sum of highly interconnected ecosystemcharacteristics or components. Each level of diversity has distinct functional and structural characteristics [2]. Marine biodiversity plays a significant role in the global biodiversity landscape, particularly when it comes to deep diversity or essentially different forms of life that are distinguished not by individual species but by whole phyla.

Phyla represent essentially distinct forms of life because they constitute the second level of taxonomic categorization after kingdoms [9]. Macrofauna is crucial to many ecological processes, including food webs, pollution metabolism, nutrient cycling, secondary production, burial, and dispersal [11]. Ecological dominance is characterised as one or more species having a significant controlling influence over all other species based on their size, production, or associated activities [14]. Understanding the spatial distribution patterns may help to better comprehend the scale at which biological interactions, or ecological processes, take place. Assessing the spatial distribution of species and patterns of biodiversityis a fundamental aspect of ecology[15–6].The study of past and present organism spatial distributions is crucial to understanding all patterns of geographic variation in nature,from genes to entire communities and ecosystems. Biological diversity is influenced by factors that change across geographic gradients, such as area, isolation, latitude, depth, and elevation [7].Global collaboration, internet databases, and statistical tools have all grown in importance in recent years, advancing the field and enabling researchers to uncover marine macroecological patterns and ascertain the variables determining the breadth of a species geographic distribution. While there have been some efforts to utilise species distribution to define ecological units, the majority of research has concentrated on a particular group ofspecies or at the community level [8]. Geographic variation patterns in biological populations are being extensively utilised to characterise regional variation and infer conclusions about population structure using the method of spatial autocorrelation analysis [12-13-16].The spatial organization of biological populations and communities underscores the limitations of simple statistical techniques in ecological investigations. It explores methods for spatially organizing biological populations using techniques such as partial mantel tests, mantel correlogram, multivariate variograms, univariate approaches, and mapping ecological factors [5]. A basic method for spectral analysis of multispecies data from many species at different time scales or stratigraphic levels was introduced. Any ecological similarity measurement can be used with the Mantel correlogram-based technique [4]. The current study focused on the dominant phylum of the Veraval and Adri coasts, examining seasonal variations in ecological attributes such as density, abundance, and frequency. The results also indicated spatial autocorrelation at both sites using Mantel correlogram analysis.The dominant phylum often plays a significant role in the marine ecosystem, serving as an indicator of the overall health and stability of the marine environment. Understanding its ecological attributes can help identify any changes or disruptions in the ecosystem.The Mantel correlogram was used as the analytical method because it allows for a detailed examination of the spatial autocorrelation between data from the two sitesto identify patterns over time or space. Specifically, measuring autocorrelation allows for determining whether and how strongly a variable is correlated with itself at different time lags or spatial intervals. This is crucial in many fields, as it can reveal underlying trends and dependencies that might not be apparent from a simple analysis.

2. MATERIAL AND METHODS

The present study was conducted on two rocky shores of the Kathiawar Peninsula in Gujarat: the Veraval coast, spanning approximately 4 kilometers (20°54'35" N, 70°21'08" E), and the Adri coast, spanning 1.5 kilometers (20°96'07" N, 70°27'94" E) (Fig. 1). Sites were studied seasonally, from winter to post-monsoon, during low tide in the intertidal area.

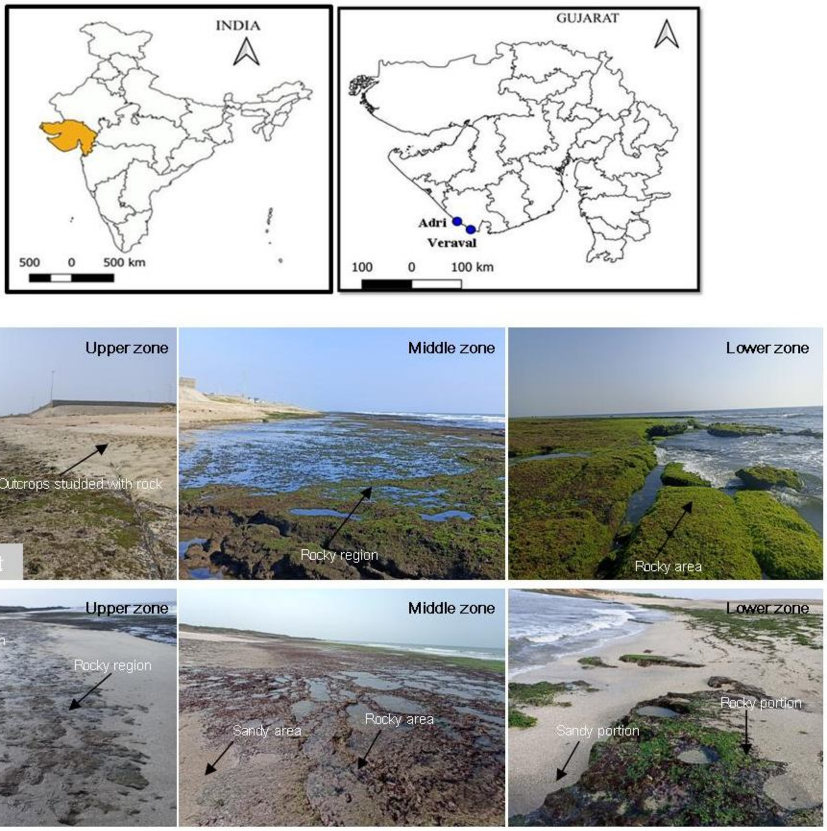


Fig. 1. Map of the study site: Veraval Coast, Adri Coast, Gujarat.

The intertidal macrofauna species have been assessed using the quadrat sampling method.A 0.25 m^2 quadrat frame was systematically placed at regular intervals using stratified random sampling to assess the macrofauna population in three intertidal zones (upper zone, middle zone, and lower zone) on both coasts. Data were recorded for three ecological attributes: density, abundance, and frequency. A total of 1,240 quadrats were laid throughout the study period, with two to four visits conducted each month at both study sites.

The identification of macrofaunal species was carried out using identification keys, reference books, journals, reports (Apte, 1998; Vachhrajani, 2015; Dixit et al., 2017; Sivadas and Carvalho, 2020; Sreeraj, 2020; Baroliya et al., 2023; Sabapara and Poriya, 2024, Purushothaman et al., 2022) and as well by using various e-portals likethe Global Biodiversity Information Facility (GBIF), the World Register ofMarine Species (WoRMS), the Biodiversity Heritage Library (BHL), the India Biodiversity Portal (IBP) and theZoological Survey of India (ZSI). The entire study was conducted in a non-destructive manner, ensuring that no organisms were disturbed, or if disturbed, only to the extent that no harm or mortality occurred. Some organisms, which were difficult to identify and challenging to distinguish, were collected and accurately identified after careful examination of their morphological features.

The coastal area of Veraval has a mostly rocky type of intertidal habitat and outcrops studded with rock. The upper, middle, and lower intertidal zones are predominantly rocky, while the supratidal zone is characterized by extensive rock cover interspersed with smaller areas of sandy patches (Fig. 1).
Adri coastal region featuring a blend of rocky and sandy intertidal environments, specifically, the supratidal zone is predominantly covered by sand, while the upper, middle, and lower intertidal zones each exhibit a rocky-sandy composition, reflecting distinct substrata of ecological zones along the coastal area (Fig. 1).

Spatial autocorrelation analysis of the rocky intertidal macrofauna species from the Veraval and Adri coasts in Gujarat, India, was performed using the Mantel correlogram technique in version 4.03 of the PAST software (https://past.en.lo4d.com/download).

3. RESULTS AND DISCUSSION

The present study conducted a comparative analysis of intertidal macrofauna along the Adri and Veraval coasts, revealing intriguing patterns in the distribution of dominant phyla. The data highlight eight distinct phyla, with observable variations in the number of species for each phylum between the two coasts: Porifera, Cnidaria, Platyhelminthes, Nemertea, Annelida, Arthropoda, Mollusca, and Echinodermata. Mollusca, with a notable total of 53 gastropod species, emerges as the most dominant phylum on the Veraval Coast.

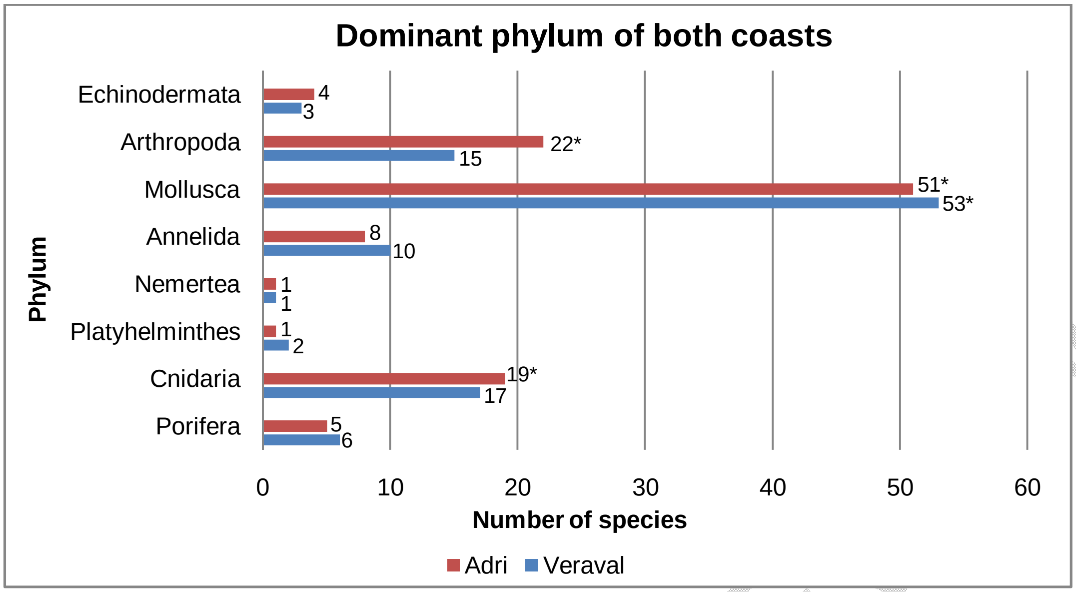


Fig. 2. Macrofauna species along the Veraval coast and Adri coast

The variation in species numbers, particularly the high count of mollusc species, suggests that the substrate type and optimal conditions along the Veraval coast are highly favorable to the mollusc population. Other contributing phyla included Cnidaria (17 species), Arthropoda (15 species), and Annelida (10 species), indicating that the intertidal habitat provides suitable conditions for this phylum as well.However, the other phyla like Porifera (6 species), Echinodermata (3 species), Platyhelminthes (2 species), and Nemertea (1 species) (Fig. 2) reveal that these organisms either have more specialised habitat needs or face competitive challenges on the studied coast.Conversely, the Adri coast presents a different pattern. Mollusca, the most dominant with 51 species, shows similarity compared to Veraval. This suggests that the microscale habitats and climatic conditions are ideal for sustaining mollusc species a constant throughout the seasons [3]. However, Arthropoda is a more prevalent phylum in Adri, with 22 species, suggesting that this coastal region provides optimal conditions for arthropods, possibly due to factors such as food availability, habitat diversity, and lower predation pressure. Cnidaria has 19 species, indicating a more suitable environment for these organisms. Other phyla observed were Annelida (8 species), Porifera (5 species), Echinodermata (4 species), Platyhelminthes (1 species), and Nemertea (1 species) (Fig. 2), highlighting their specific habitat requirements and favourable conditions.This consistency might imply that these phyla are less sensitive to the variations in coastal conditions between Veraval and Adri. On both coasts, Platyhelminthes and Nemertea have minimum species (Platyhelminthes: 2 in Veraval and 1 in Adri; Nemertea: 1 in both), indicating that these phyla are rare or have very specific characteristics that are not widely available in either coastal region.

The overall dominance of Mollusca on both coasts underscores the ecological importance of this phylum in coastal ecosystems. However, the higher prevalence of Arthropoda and Cnidaria in Adri highlights regional differences that could be attributed to ecological variations such as habitat structure and interspecies interactions. This data not only emphasizes the rich biodiversity along these coasts but also points to the complex interplay of environmental factors that shape the distribution of marine life. Understanding these patterns is crucial for marine conservation efforts, as it helps identify critical habitats and inform strategies to protect and conserve marine biodiversity.

The graph (Fig. 3) shows data on the frequency, density, and abundance of different marine phyla along the Veraval coast in the winter (W), summer (S), post-monsoon (PM), and monsoon (M) seasons.This data provides insights into the ecological dynamics of phyla and highlights the seasonal fluctuations in their presence. The data from the Veraval coast display an extensive representation of density, abundance, and frequency across different seasons, reflecting the intricate ecological dynamics of coastal ecosystems. This data reveals distinct patterns in the density, abundance, and frequency of marine phyla across seasons. The data shows that along the Veraval coast, Mollusca maximum density was reported in all seasons, especially high in winter, and minimum density was noted during the monsoon and post-monsoon.The maximum density of Arthropoda and Cnidaria was noted during the summer and winter, while the minimum density was reported in the monsoon and post-monsoon, respectively. The minimum density of Nemertea was reported in winter, and Annelida, Porifera, had the highest density reported in winter and the lowest density in other seasons. Platyhelminthes and Echinodermata had the highest density reported in the monsoon and post-monsoon and the lowest density in winter and summer (Fig. 3).Phylum Mollusca was the most dominant in all seasons compared to other phyla. The maximum abundance of Mollusca was reported in summer and post-monsoon, especially high in winter, and the minimum abundance was noted during the monsoon. The highest abundance of Cnidaria was noted post-monsoon and during the monsoon, and the lowest during summer. The maximum abundance of Arthropoda was recorded post-monsoon and in summer, while the lowest was reported in winter. The minimum abundance of Nemertea was reported in the winter, and Porifera was reported to have the highest abundance in winter and the lowest abundance in other seasons.The highest abundance of Annelida was noted in the summer and the lowest during the winter and the lowest abundance of Platyhelminthes was reported in all seasons and was not recorded in the post-monsoon period.The lowest abundance of Echinodermata was recorded across all other seasons, while the highest abundance was recorded during the monsoon (Fig. 3).

Mollusca maximum frequency was reported in winter and monsoon, and minimum frequency was noted during post-monsoon. The minimum frequency of Arthropoda was noted during the summer and the maximum frequency was reported in the winter and the monsoon.

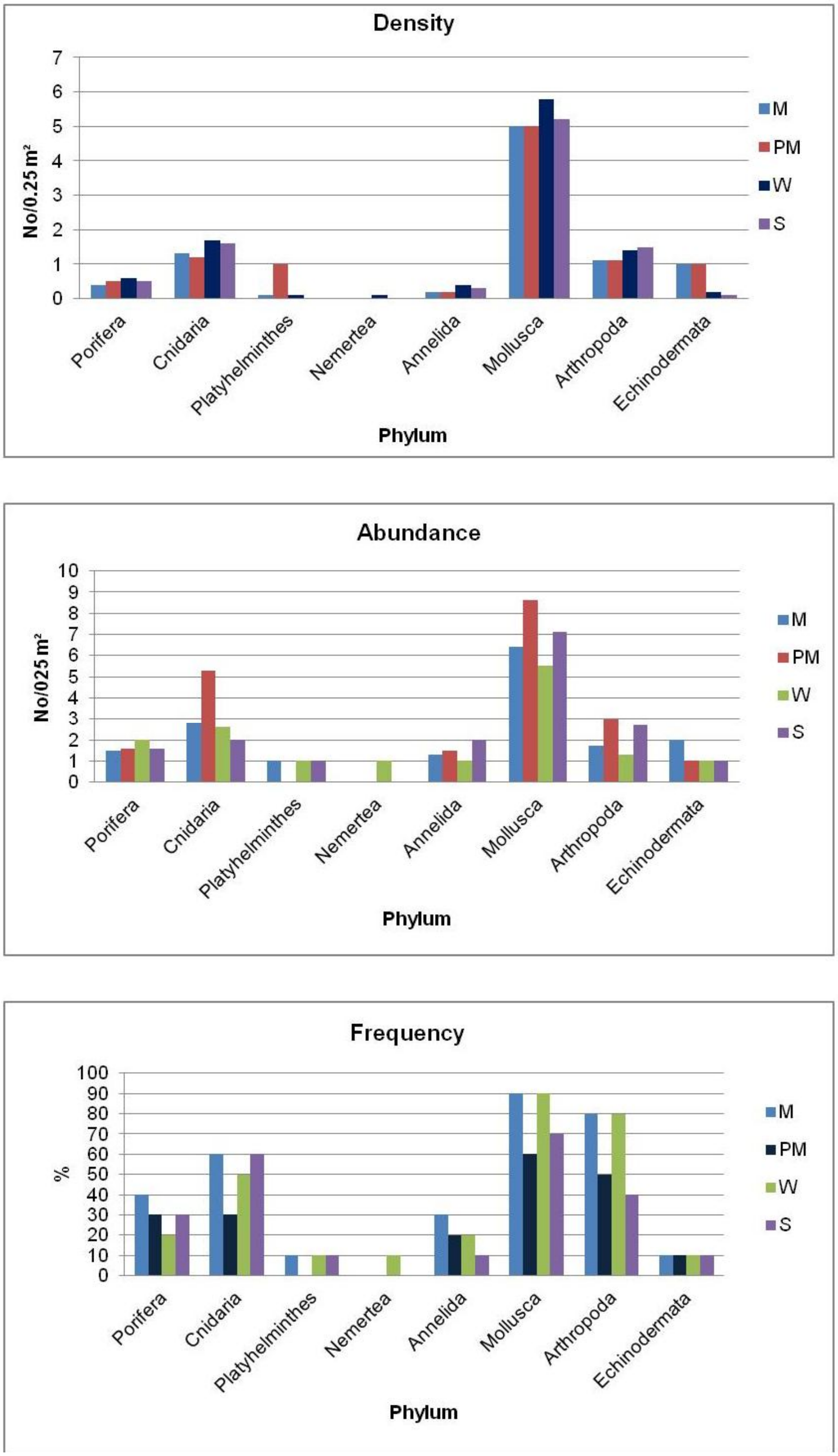
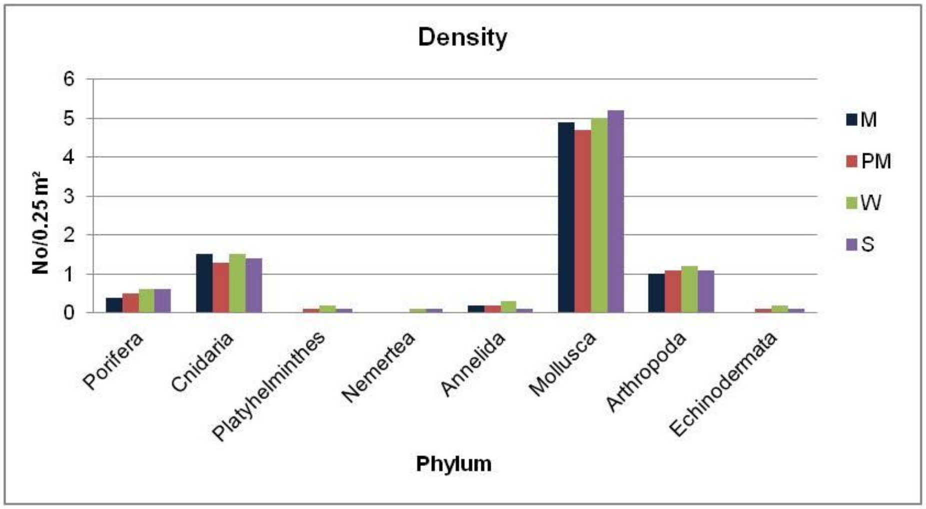
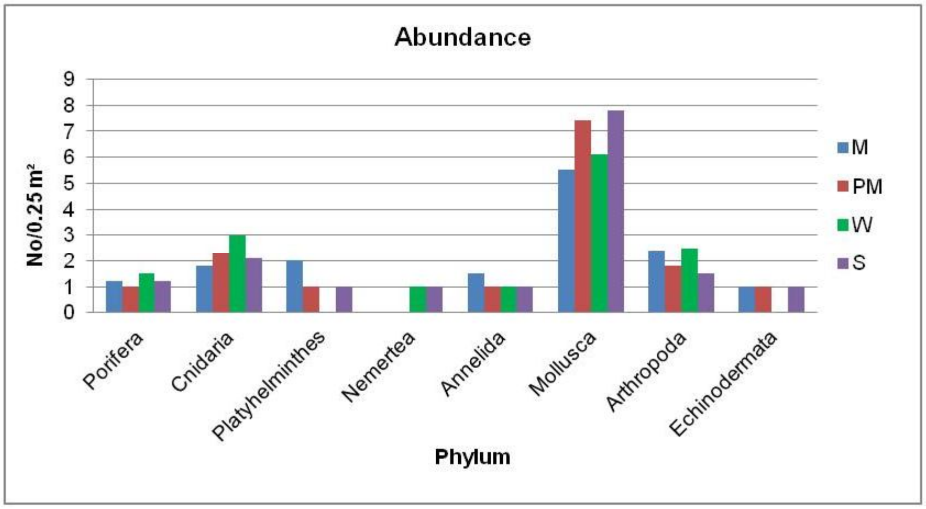


Fig. 3. Seasonal variations in the density, abundance, and frequency of the number of macrofaunal species of different phyla studied along the Veraval coast





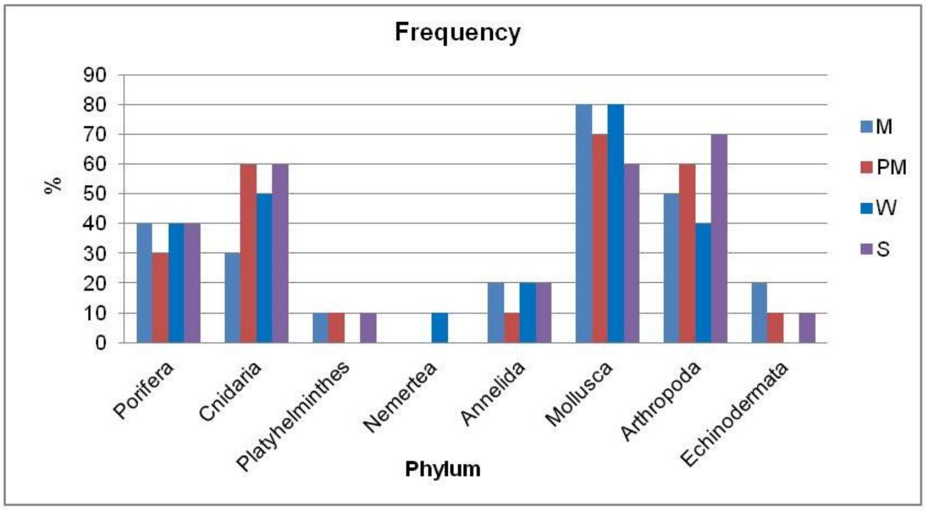


Fig. 4. Seasonal variations in the density, abundance, and frequency of the number of macrofaunal species of different phyla studied along the Adri coast

The maximum frequency of Cnidaria was noted during the summer and monsoon, while the minimum frequency was reported post-monsoon, respectively. The minimum frequency of Nemertea was reported in winter, and Annelida had the highest frequency reported in the monsoon and the lowest frequency in the summer. Porifera has the highest reported frequency in the monsoon and the lowest frequency in the winter, while both Platyhelminthes and Echinodermata have low frequencies in all seasons (Fig. 3).

Overall, the data from the Veraval coast illustrates varying ecological preferences and adaptations among different marine phyla, reflecting the complex dynamics of coastal ecosystems. The data emphasises the diverse ecological preferences and adaptations among marine phyla in coastal ecosystems. Understanding these patterns is critical, as the data reveal the way distinct species react to environmental changes along the Veraval coast.

The data from the Adri coast reveals distinct patterns in the density, abundance, and frequency of marine phyla across different seasons. The minimum density of Mollusca was noted during the post-monsoon and the maximum density was reported in all seasons, especially high in the summer. The maximum density of Arthropoda and Cnidaria was noted during the winter, while the minimum density was reported in the monsoon and post monsoon, respectively.

The minimum density of Nemertea was reported in winter and summer, which was nearly reported absent all seasons.The highest density of Annelida and Porifera was recorded in winter and the lowest density was reported in other seasons. For Platyhelminthes and Echinodermata, the highest density was reported in winter, and the lowest density was recorded during summer and post-monsoon (Fig. 4).

The highest abundance of Mollusca was reported in summer and the lowest abundance was noted during the winter. The maximum abundance of Cnidaria was noted during the winter and the minimum abundance occurred during the monsoon. The maximum abundance of Arthropoda was recorded post-monsoon and in winter, while the lowest was reported in summer. The minimum abundance of Nemertea was reported in the winter and summer, as it is nearly reported absent in other seasons. Porifera had the highest abundance reported in winter and the lowest abundance in post-monsoon. The highest abundance of Annelida was noted in the monsoon and the lowest during all seasons. Platyhelminthes had the highest abundance during the monsoon and the lowest abundance during all seasons. The minimum abundance of Echinodermata was noted in all other seasons (Fig. 4).Mollusca range frequency was highest in the winter and monsoon and lowest in the post-monsoon. The maximum frequency of Arthropoda was reported in the summer, the minimum frequency was noted during the winter, while the high frequency of Cnidaria was noted during the summer and post-monsoon, and the low frequency was reported during the monsoon, respectively. The minimum frequency of Nemertea was reported in the winter, which was noted to be nearly absent in other seasons. Annelida had the highest frequency reported in the winter, summer, and monsoon and the lowest frequency in the post-monsoon.Porifera had the maximum frequency reported in the winter, summer, and monsoon and the minimum frequency in the post-monsoon.The low frequency of Platyhelminthes was noted in the summer, monsoon, and post-monsoon, whereas a high frequency of Echinodermata was recorded during the monsoon and a low frequency in other seasons (Fig. 4).

These patterns highlight the diverse ecological dynamics and varying ecological communities occupied by marine phyla on the Adri coast, which are influenced by seasonal changes and specific habitat requirements. A comparison of marine phyla data between the Veraval coast and Adri coast reveals significant differences in the distribution patterns of various phyla across seasons.Mollusc species that inhabits a variety of microhabitats, including beneath rocks, on rock surfaces, and under boulders, as well as in tide pools, puddles, and crevices. Its density, abundance, and frequency values are consistently higher on both coasts. In contrast, Cnidaria displays significant fluctuations in density and abundance, with varying frequencies across seasons on both coasts, indicating adaptive responses to habitat and environmental changes.Porifera displays moderate values across seasons on both coasts, reflecting its stable but adaptable presence.Platyhelminthes and Nemertea show minimal presence and variability across seasons, with occasional peaks in abundance observed on both coasts. Annelida demonstrates moderate values in density and abundance, with stable frequencies on both coasts, indicative of its resilient adaptation to coastal environments. Arthropoda exhibits moderate to high values in density and abundance, with variable frequencies across seasons, reflecting its adaptable nature to changing environmental conditions. The consistently low number of Echinodermata on coastlines suggests a specific, suitable habitat and environment.

The Mantel correlogram results revealed differing correlations between the two coasts. On the Veraval coast, the correlogram indicates a significant positive correlation.

Positive Correlation: A positive Mantel correlation at a specific distance phylum indicates that sites within that distance are more similar in species composition than expected by chance. This could suggest the presence of dispersal limitations or other factors affecting distribution within that range.

The Adri coast, on the other hand, shows a negative correlation.

Negative Correlation: A negative Mantel correlation indicates that sites within that distance phylum are more dissimilar than expected by chance, which might be due to competitive interactions or environmental heterogeneity.

3.1. The spatial autocorrelation – Mantel correlogram

Spatial structures, such as patches or gradients, are crucial in ecological theories and population sampling. Spatial heterogeneity is the consequence of living things aggregating into uniform and random distributions in nature. The components of an ecosystem are more likely to be impacted by the same producing process, highlighting the importance of spatial heterogeneity in ecological systems [5].

The Mantel correlogram is an advanced method for calculating correlograms from multivariate data. Its efficiency was nearly equivalent to that of univariate methods. The statistical significance in multivariate contexts was intrinsically similar, as the multivariate variogram test developed within the framework of multiscale ordination was essentially a Mantel correlogram. The Mantel correlogram accurately identified spatial correlations at rates comparable to those of permutation tests for variance statistics in multivariate variograms. Consequently, the Mantel correlogram proved to be a valuable addition to the analytical resources available to ecologists [1].An ecological and biogeographic method for analysing the spatial autocorrelation of two data sets is the mantel correlogram. It assesses whether the similarity in one set of data corresponds to the spatial distance between locations where the data was collected. This can help identify patterns of spatial clustering or dispersion. The actual interpretation of the correlogram will depend on the specific patterns. The mantel correlogram chart illustrates the relationship between the ecological attributes of phyla and their positions in a distance matrix. Density data related to these attributes and distances has been evaluated using the quadrat method of stratified random sampling.

The Mantel correlogram highlights how spatial autocorrelation differs across places when applied to area species, such as the Adri and Veraval coastlines. By analysing the geographical correlations between many variables, the Mantel correlogram may highlight unique spatial patterns and community structures in specific regions. The Mantel correlogram includes many variables, providing a more detailed understanding of spatial interactions than ordinary correlograms, which often concentrate on univariate data. This multivariate method helps in determining if the spatial correlations between various variables are consistent across various geographic regions.

Autocorrelation in a generic correlogram is evaluated on the basis of one variable and frequently stated as an indicator of distance. Conversely, the Mantel correlogram computes the correlation between geographical data distances and multivariate data distances. Understanding the spatial structure of complex, multidimensional datasets may be accomplished with the help of this method.

Spatial autocorrelation measures the level to which a variable at one location is correlated with the same variable at neighbouring locations. It assesses the similarity between values of a single variable across space. On the Veraval coast, the rock-dominated substrate may provide a more uniform habitat, leading to higher similarity in macrofauna communities at close distances. The relatively stable rock habitat could reduce environmental variability and barriers to dispersal, resulting in greater homogeneity in macrofauna community composition, highlighting positive correlation. The combination of sandy and rocky substrates creates a more heterogeneous environment at Adri coast. This variability in substrate types could lead to more diverse and less predictable macrofauna communities within the same distance, resulting in a negative correlation. Differences in substrate types can affect habitat suitability and availability, which is influencing the distribution and abundance of macrofauna species.

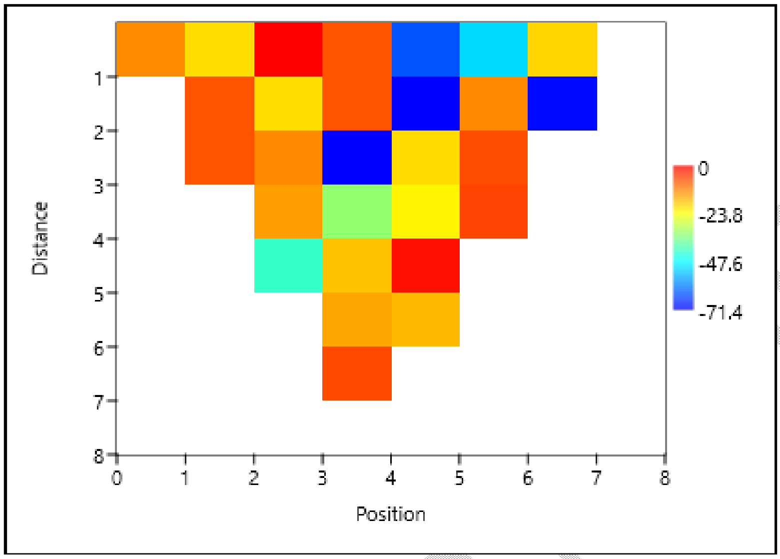


Fig. 5. Veraval site

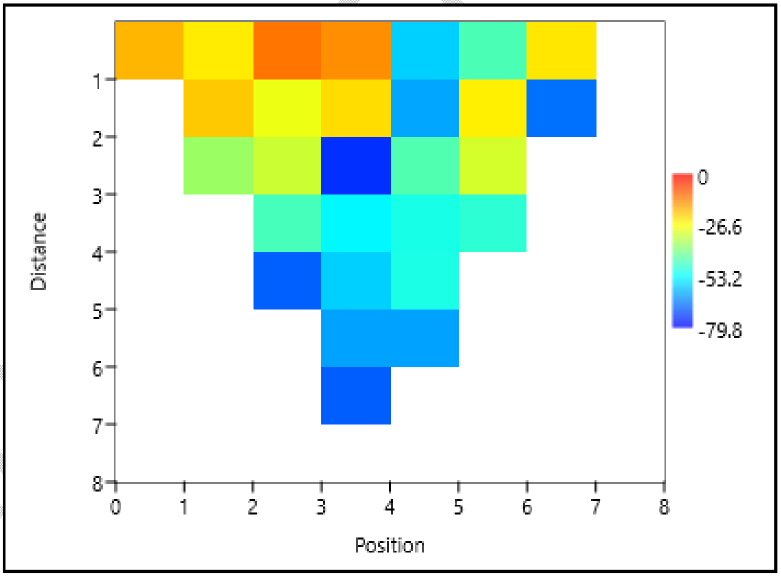


Fig. 6. Adri site

The X-axis represents the distance classes or intervals over which the spatial autocorrelation is being measured. These distances are typically divided into squares or ranges, and each square represents a specific range of distances between pairs of locations.

The Y-axis shows the Mantel correlation coefficient, which quantifies the strength and direction of the relationship between the distances in the data. This coefficient ranges from -1 to 1. A value close to 1 indicates a strong positive spatial correlation (i.e., similar values are found closer together), while a value close to -1 indicates a strong negative spatial correlation (i.e., dissimilar values are observed closer together). A value around 0 suggests little to no spatial correlation.

The colorant legend helps in interpreting the plot by providing information on how different colors correspond to various values or ranges of the Mantel correlation coefficient. For instance, different colors represents different levels of correlation strength, with a gradient indicating how strong the correlation is at various distances.

Specified values in the Mantel correlogram are usually shown as data points or lines plotted on the graph. These values correspond to the Mantel correlation coefficients for each distance class. Each point on the plot represents the correlation coefficient for a particular distance interval, and the overall pattern of these points can indicate how spatial autocorrelation changes with distance.The Mantel correlogram identified distribution patterns of species similarity based on distance and the colour-coded correlations.

Correlogram (Fig. 5) for the Veraval coast: On the Veraval coast, the Mantel correlogram analysis illustrates the level of autocorrelation between species distributions across the intertidal zones (upper, middle, and lower). The colours in the correlogram reflect different patterns or relationships between the spatial distributions of various phyla, with red, blue, orange, and green highlighting these variations. Red generally indicates positive autocorrelation, meaning that species within a given phylum were distributed similarly across zones and their distribution pattern remains consistent between distances and zones.

In this Mantel correlogram analysis, red is the dominant colour, suggesting that certain phyla, possibly those that are highly adaptable, such as Porifera, Cnidaria, and Mollusca, exhibit similar distribution patterns across all zones (upper, middle, and lower) along the Veraval coast, with a positive correlation. The predominance of red implies that these species may be widely distributed across different zones without showing significant variation in their spatial patterns. This pattern could be attributed to environmental factors. Phyla that are adaptable to various environmental conditions, like Mollusca, Echinodermata, and Cnidaria, often thrive across different zones due to their ability to tolerate variations in water availability, salinity, and substrate types. This adaptability leads to more consistent distributions across zones. Similarly, for other phyla, such as Porifera and Arthropoda and Annelida, Platyhelminthes, and Nemertea, the availability of moisture and water in the middle and lower zones may create more consistent habitat conditions, resulting in positive autocorrelation and a stronger presence of red in the correlogram. The middle and lower intertidal zones, which are more frequently submerged by tides, provide a stable environment for species that rely on consistent water access.

The dominant species in these zones may suggest that they are less restricted to specific zones and exhibit uniform distribution across the intertidal zones. If competitive pressures are lower, species may spread more evenly, avoiding sharp boundaries between zones. In this chart, the phyla shown in red in the correlogram may not be as sensitive to competition or resource limitations, providing all species to maintain similar distributions across all zones. Other colours in the correlogram, such as blue, orange, and green, represent different types of spatial relationships. Blue typically indicates negative autocorrelation, where species distributions vary significantly between zones and phylum may be present in one zone but absent in another. Orange may represent intermediate patterns of negative autocorrelation, while light green often indicates a random distribution where no clear spatial pattern or relationship exists between zones. Given that red dominates this Mantel correlogram, it is likely that the phyla represented by this colour (possibly Porifera, Cnidaria, Arthropoda, and Mollusca) are well-adapted to a broad range of environmental conditions across the three zones. These species may be dominant and thrive in a variety of habitat types, thereby exhibiting similar distribution patterns with positive autocorrelation. Habitat conditions such as moisture retention, substrate availability, and tidal influence likely favourable environments for these phyla and macrofauna species to survive to dominate the intertidal zones.

Correlogram (Fig. 6) for Adri coast: On the other hand, along the Adri coast, blue, light green, and yellow are more dominant, reflecting stronger negative autocorrelation and this suggests significant differences in the distribution of the phyla between zones. Blue and yellow in the correlogram represent negative autocorrelation, meaning the distribution patterns of the phyla across the zones are dissimilar. This could occur when species are restricted to certain zones, showing strong habitat preferences that prevent them from being evenly distributed across the upper, middle, and lower zones. The prevalence of these colours suggests that the species of the analysed phyla exhibit zonal differentiation, where their distribution is more concentrated in certain zones rather than being spread evenly.

The coastal habitat of Adri, being a mix of rocky and sandy substrates, likely plays a major role in the differences in species distribution. Rocky habitats and Sandy habitats, more commonly associated with those found in the middle and lower intertidal zones and upper zones, tend to support phyla like Arthropoda and potentially some Nemertea, Annelida, and Platyhelminthes, which are more adaptable to fluctuating environments. This mix of rocky and sandy often provides complex structures that can support a greater diversity of species like Porifera, Cnidaria, Mollusca, and Echinodermata, which may prefer more stable substrates. Blue and yellow dominance might indicate that species found in rocky substrates, such as Porifera and Cnidaria, are more confined to the middle or lower zones, leading to dissimilarity in distribution compared to the sandy upper zones. The negative autocorrelation suggests that phyla in the middle or lower zones are not present in the upper zones, possibly due to substrate type or tidal influences, which create distinct ecological microhabitat. The observed negative autocorrelation (blue, light green, and yellow dominance) likely arises because these phyla have specific habitat preferences tied to substrate type (rocky and. sandy) and tidal influences (moisture availability, exposure to waves). Rocky zones support more structured and stable communities, while sandy areas tend to be more dynamic, leading to distinct species distributions across the upper, middle, and lower zones. Each phylum's distribution is shaped by these environmental factors, resulting in the different colour distinct patterns seen in the Mantel correlogram.

Turbo intercostalis *Astralium semicostatum* *Perronia verruculata* *Gyrenium natator*

Cerithium caeruleum *Mauritia arabica* *Conus figulinus* *Purpura panama*

Fig. 7. Phylum Mollusca: Common intertidal gastropod species

4. CONCLUSION

The present study focused on the dominant phyla along the rocky intertidal zones of the Veraval and Adri coasts of the Kathiawar Peninsula, Gujarat. Phylum mollusca was the most dominant phylum on both coasts due to favourablemicrohabitas. The substratum and intertidal zones along both coasts provide favourable habitats that support a rich diversity of macrofauna species. Seasonal variations significantly affect macrofauna distribution, creating distinct ecological attributes between the two coasts. These variations cause shifts in species density, abundance, and frequency, resulting in unique macrofaunal distribution patterns on both coasts that reflect the impact of seasonal changes. The Veraval coast is mostly rocky, while the Adri coast includes both rocky and sandy intertidal zones. Mantel autocorrelation analysis highlights that as distance increases, the correlation may weaken, indicating that macrofauna community compositions become more variable as environmental factors, such as tidal exposure or substrate composition, change across larger spatial scales. As the distance decreases, environmental factors tend to be more consistent, leading to more similar macrofauna communities. The habitat difference leads to varied species distributions, resulting in spatial autocorrelation. Although these coastal regions are geographically close and distinguished by unique intertidal habitats and zonation patterns, both coasts display distinct coast characteristics, species richness, and diversity.

Disclaimer (Artificial intelligence)
Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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