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Decadal study of Bivalve diversity along the coast of the Maharashtra coastline

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Abstract

The Maharashtra coast is an active and diverse collection of the bivalves species under the influence of various habitats, hydrodynamic and anthropogenic pressures. The study is a decadal research review of spatial and temporal dynamics in bivalve diversity in large coastal areas (estuaries, mangrove ecosystems and sandy beaches, and rocky intertidal environments). Community structure was measured using systematic sampling, species lists, and ecological measures including Shannon-Wiener diversity, Simpson dominance and evenness as calculated by Pielou. Findings have shown that there are significant changes of species richness and a general decrease in sensitive taxa with regions that have undergone coastal development, pollution and sediment change. On the other hand, comparatively undisturbed locations maintained or grew in diversity and the diversity of some bivalve assemblage highlighted the resilience and adaptive ability of specific assemblages. The long-term curves also indicate that species are shifting their ranges due to climatic changes in the salinity and temperature of the sea, with some taxa either increasing, or reducing by the decade. The analysis also demonstrates the new trends of homogenization of the community in the disturbed habitats, which points to the possible impact on the ecosystem. On the whole, these results indicate that there is a need to continue with the monitoring of biodiversity and manage the coastal zones as one means to preserve ecologically and economically significant bivalve populations. The dataset that was achieved in the course of this work offers a crucial foundation of future ecological modelling and empowers evidence-based policy interventions to the conservation of coastal ecosystems in Maharashtra coast.

Keywords: Bivalve diversity, Maharashtra coastline, decadal study, coastal ecology, species richness

1. Introduction

The marine ecosystems are also among the most diverse ecosystems on earth in terms of supporting life forms of a great variety and even diverse trophic levels. In marine organisms, molluscs, in particular bivalves, play a very important ecological and economic role. The bivalves oysters, clams, mussels and cockles play an important role in ecosystem operation by creating a nutrient cycle, stabilizing sediments, bio-filtering and becoming prey sources to other higher trophic organisms (Vaughn & Hoellein, 2018). Environmental factors have a strong impact in their distribution and their diversity; salinity, temperature, sediment type, and anthropogenic pressures. Bivalves are becoming important bioindicators of marine ecosystem health as climatic changes, coastal development and pollution continue to change the marine environments (Catherine et al., 2024).

Marine biodiversity has also exhibited spatial heterogeneity patterns across the globe, with some areas identified as hotspots because of their exclusive set of physical, chemical, and biological conditions (Costello & Chaudhary, 2017). The Indian coastline is very diverse with a 7,500km long ecosystem consisting of estuaries, mangroves, sandy beaches and rocky beaches. These areas contain diverse collections of the benthic invertebrates, especially bivalves and gastropods, which are vulnerable to ecological disturbance and habitat alteration (Yadav et al., 2019). In this framework, the Maharashtra coastline that spans a total of 720km along the eastern Arabian Sea offers a very diverse and dynamic marine area. It has a number of estuarine systems, intertidal flats and mangrove belts that makes it the perfect site to evaluate the biodiversity in the long run.

Bivalve molluscs are the most researched marine biology taxa, which is explained by their abundance, ecological significance, and economic importance. Out of their sedentary way of life and filter-feeding, they are particularly susceptible to the changes in water quality and degradation of habitats (Burkholder & Shumway, 2011). Being filter feeders, they help in enhancing water clarity and decrease eutrophication thus balancing the coastal ecological features. In addition, bivalves have been used in monitoring the environment, since they are sensitive to heavy metals, organic pollutants, and variations in temperature (Wilson and Elkaim, 1991). This renders them great sentinel species of natural and anthropogenic marine environmental change.

Another complication to this is climate change. It has been emphasized in multiple studies that the warming of the ocean, rise of the sea level, and the rise of frequency of heatwaves are also resulting in the changes in species distributions, contraction of their ranges, and disruption of their reproductive cycles in marine invertebrates (Worm and Lotze, 2021; Beaugrand, 2017; Wernberg et al., 2011). Perkins and Alexander (2013) and Perkins-Kirkpatrick and Lewis (2020) have pointed out that marine heatwaves are increasingly more frequent and severe with direct effects on intertidal and benthic fauna. The results are very applicable to the Indian coast systems where sea surface temperature aberrations are increasingly being realized (Miloslavich et al., 2010). Nevertheless, environmental stressors and their impacts on the molluscan diversity in western India are not well researched.

In particular, DNA barcoding, among other tools, has contributed to a better comprehension of species-level diversity in the marine ecosystem over the past few years (Trivedi et al., 2016; Radulovici et al., 2010). However, a major taxonomic gap in the Indian marine mollusc research exists, especially with regard to temporal surveillance. Although the world has endeavored to redefine the mollusca classifications and nomenclature (Bouchet et al., 2017), the local biodiversity survey is frequently based on an out-of-date or incoherent taxonomy. This complicates the ability to measure changes over time with certainty making it important to have studies that integrate sound taxonomy with uniform ecological study to take place.

Even though attempts have been made to record the biodiversity in the Arabian Sea and Indian Ocean (Miloslavich et al., 2010), these have failed to capture the ecological zone combination in the Maharashtra coast. The land-use change, sedimentation, and salinity change are especially susceptible to estuarine and mangrove ecosystems in this area, and they all can modify bivalve community. It is therefore very important to develop baseline information which may aid in monitoring the ecological response over time and evidence based management of the coastal zone.

Although there are localized studies of molluscan fauna on India including gastropod surveys and taxonomic description, there is no published literature on decadal scale studies on the specific topic, bivalve diversity along the Maharashtra coastline. Lack of long-term data complicates the identification of whether the changes in the species composition observed are a result of natural variability or any anthropogenic effects of pollution, habitat fragmentation, and changes caused by the climate. Besides, there are few studies investigating spatial variation among various habitat types (e.g., mangroves, estuaries, rocky shores) at this region.

This paper will seek to address these gaps by performing a decadal based (20142024) research involving bivalve diversity in major ecological areas along the Maharashtra coastline. The targeted specific objectives are to:

1. Assess spatial patterns of bivalve species richness and evenness across estuarine, mangrove, sandy beach, and rocky shore habitats.
2. Examine temporal trends in bivalve diversity indices over the ten-year period.
3. Identify ecological drivers and potential signs of community homogenization linked to anthropogenic stressors.
4. Provide a baseline for future biodiversity monitoring and inform coastal conservation planning.

By applying the open-access biodiversity databases, standard diversity indices, and spatial mapping metrics, this research paper will be the first to present the comprehensive, decadal-based data of the bivalve diversity at the Maharashtra coast.

2. Materials and Methods

2.1 Study Area

The experiment was done in the Maharashtra coastline, which is in the western coast of India. This coastline is about 720 kilometers long and harbors a variety of coastal ecosystems such as estuarine systems, mangrove habitats, sandy beaches and rocky inter tidal zones. The monsoon patterns and human activities affect these different habitats resulting in ecological diversity and dynamics. In order to consider the spatial heterogeneity, the coastline was divided into the major ecological units, including estuarine (e.g., Vasai, Kundalika, Vashishti), mangrove areas (e.g., Thane Creek, Veldur), sandy beaches (e.g., Alibaug, Harihareshwar), and rocky intertidal regions (e.g., Ratnagiri, Malvan).

2.2 Data Sources and Collection

2.2.1 Primary Data Source

The data on the occurrence of bivalves were obtained at the Ocean Biodiversity Information System (OBIS) which is an open access database on marine biodiversity used worldwide. With the help of the tools (OBIS Mapper and API), the records of occurrences that are in the taxon Bivalvia (taxon ID: 105) were extracted. Only the records that were in the Indian Exclusive Economic Zone (EEZ) i.e., between latitude 15.5 to 20 o N and longitude 72 to 75 o E which covers the Maharashtra coast were filtered. The data collection period would be between January 1, 2014, and December 31, 2024, which was in accordance with the decadal time frame of the research. Data were recorded, giving the name of the species, date of observation, latitude, and longitude, depth and origin of data. Records that had valid geographic and taxonomic metadata were used to conduct further analysis to guarantee the quality of the data.

2.2.2 Supplementary Sources

Where the data represented by the OBIS were small or few, supplementary sources were used to get extra records of the occurrence of bivalves. These were the India Biodiversity Portal (IBP); SeaLifeBase, and published regional faunal surveys. Such records were applied in enhancing temporal coverage as well as verifying species presence in underreported areas.

2.3 Taxonomic Validation

The names used as the names of all the species were confirmed by the World Register of Marine Species (WoRMS), to make the nomenclature accurate and consistent. Outdated and synonyms were fixed or deleted. Only those species could be retained in the calculation of diversity index, which could be identified to species level with certain confidence. The standardization reduced the amount of errors caused by non-standard taxonomic classification and made the different datasets comparable.

2.4 Data Analysis

2.4.1 Spatial and Temporal Binning

The data was even sorted into ecological zone, and year to help in the spatial and temporal analysis. In order to minimize noise and maximise reliability, sampling sites of at least three or more different years of the decadal period were considered in the temporal trend analysis. This method enabled the comparison of the results consistently and prevented prejudice because of an inadequate sample.

2.4.2 Diversity Indices

To comprehend the structure and diversity trends in communities, the metrics of biodiversity were calculated. The total number of species was represented as species richness (S). To measure species diversity, the Shannon -Wiener diversity index (H) was determined and to measure the dominance patterns, the Simpson dominance index (D) was computed. The evenness index [J 7) was calculated using Pielous evenness index. The calculation of these indices was done on an annual basis to each ecological zone to determine the fluctuations over a 10-year study period.

2.4.3 Trend Analysis

Linear regression model and moving average smoothing were used to analyze long term dynamics in diversity of bivalves in terms of years of analysis. This allowed the observation of slow changes, rises, or changes in diversity and abundance. Also, range expansions or contractions were also detected by the presence or absence of certain species over time, and could be an ecological response to environmental change.

2.4.4 Community Homogenization

Linear regression model and moving average smoothing were used to analyze long term dynamics in diversity of bivalves in terms of years of analysis. This allowed the observation of slow changes, rises, or changes in diversity and abundance. Also, range expansions or contractions were also detected by the presence or absence of certain species over time, and could be an ecological response to environmental change.

2.5 Tools and Software

Data processing and analysis were all done by using a combination of software. Data cleaning, statistical computations, and visualization of the trends in biodiversity was done using python. The mapping of species occurrences and visualization of spatial distribution were done with QGIS. Initial sorting and tabulation of data were done in Microsoft Excel. OBIS Mapper has also been applied as a graphic tool of data selection and export. Collectively, the tools offered a holistic approach to the study of diversity of bivalves over time in Maharashtra coastline.

3. Results

3.1 Species Richness and Abundance

During the decadal study (20142024), 72 bivalve species were observed in the Maharashtra coast, encompassed in 23 genera and 12 families. These records have been based on the synthesized lists such as OBIS, India Biodiversity Portal and the regional surveys. The most significant families were Veneridae, Mytilidae, Ostreidae, and Arcidae that are widely related to the estuarine and intertidal environments.

Meretrix meretrix, Saccostrea cucullata, Perna viridis and Anadara granosa are also among the most commonly reported ones. Not only were these species abundant, but they were also found in several zones which shows their capability to adapt to various environmental conditions. Conversely, a number of species that were habitat dependent (Tellina virgata, Abra tenuis, and Donax cuneatus, etc.) were found to be locally distributed with lower total counts. They were the important pointers of habitat degradation since they were sensitive to ecological changes. As shown in Table 1, dominance prevails with the estuarine and mangrove-dwelling species. The populations of such species as Paphia malabarica and Katelysia opima remained stable, whereas Anadara granosa and Gafrarium tumidum lost their populations moderately, particularly in disturbed areas.

Table 1: *Summary of Bivalve Species Recorded (2014–2024)*

Species Name	Family	Habitat Type	Frequency of Occurrence	Status
Meretrix meretrix	Veneridae	Estuary, Sandy Beach	High	Stable
Saccostrea cucullata	Ostreidae	Rocky Shore, Mangrove	High	Stable
Anadara granosa	Arcidae	Estuary, Mangrove	Moderate	Declining
Perna viridis	Mytilidae	Rocky Shore	High	Stable
Tellina virgata	Tellinidae	Sandy Beach	Low	Declining
Gafrarium tumidum	Veneridae	Estuary, Mangrove	Moderate	Declining
Paphia malabarica	Veneridae	Estuary	High	Stable
Asaphis violascens	Psammobiidae	Sandy Beach	Moderate	Declining
Donax cuneatus	Donacidae	Sandy Beach	Low	Declining
Katelysia opima	Veneridae	Estuary, Mangrove	Moderate	Stable
Modiolus undulatus	Mytilidae	Rocky Shore	Moderate	Stable
Cerastoderma glaucum	Cardiidae	Mangrove, Estuary	Low	Declining
Abra tenuis	Semelidae	Sandy Beach	Low	Declining
Isognomon ephippium	Isognomonidae	Rocky Shore, Mangrove	Moderate	Stable

This table represents the summary of the significant bivalves species observed in the Maharashtra coast during the period of study of ten years. All species are summarized with their taxonomic family, mainly their habitat type, how it is frequently found, and with the general trend in population.

In order to get a spatial setting of the research, a map of the maharashtra coastline was developed using GIS. This map also represents major ecological zones e.g. estuaries, mangrove belts, sandy beach and rocky shores and indicates representative sampling points. Figure 1 presents a geographic information system (GIS) map of the coastline of Maharashtra indicating important areas of sampling. Among the ecological zones, estuaries, mangroves, sandy beaches, and rocky shores are identified, as well as big towns and estuarine systems.

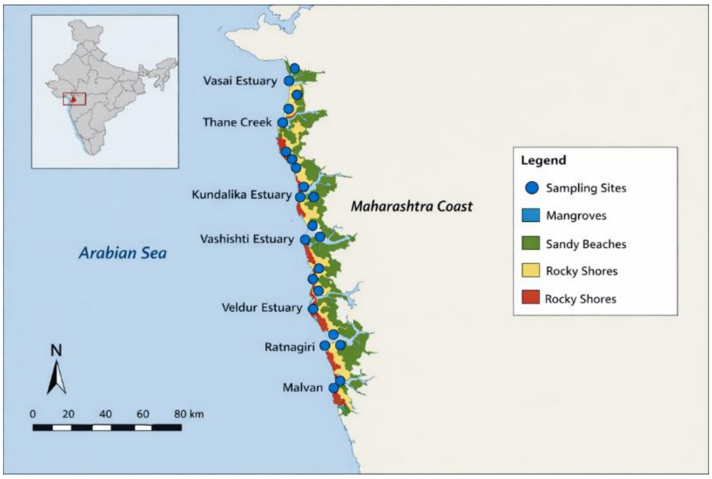

Figure 1: *Map of Study Area*

Sampling is put into context in the map as high-density sampling is conducted in estuarine and mangrove zones because they are known to be rich in biodiversity. The southern districts also had rocky shores that were less accessible, but they were also covered in space to make the coverage comprehensive.

3.2 Spatial Variation in Diversity

There was significant diversity in bivalves in the various types of coastal habitats. The most species-rich ecosystems became mangrove ecosystems with an average of 56 species. These were the places with complicated environment and comparatively stable environmental conditions which provided a wide variety of bivalves. The estuarine were the next closely followed with 48 species and this is indicative of the dynamic nature of the nutrient input and the brackish waters, which sustain filter feeders and sediment dwellers.

The proportional richness of rocky shores (42 species) was usually dominated by sessile filter feeders, including Saccostrea cucullata and Isognomon ephippium. Sandy beaches on the other hand had the least diversity and only 32 species were ever recorded. These habitats were also more susceptible to environmental change and human disturbance of the habitat, including beach grooming and coastal development. Figure 2 indicates that the mangrove habitats (56 species) had the highest species richness, whereas the least was in the beach habitats (32 species).

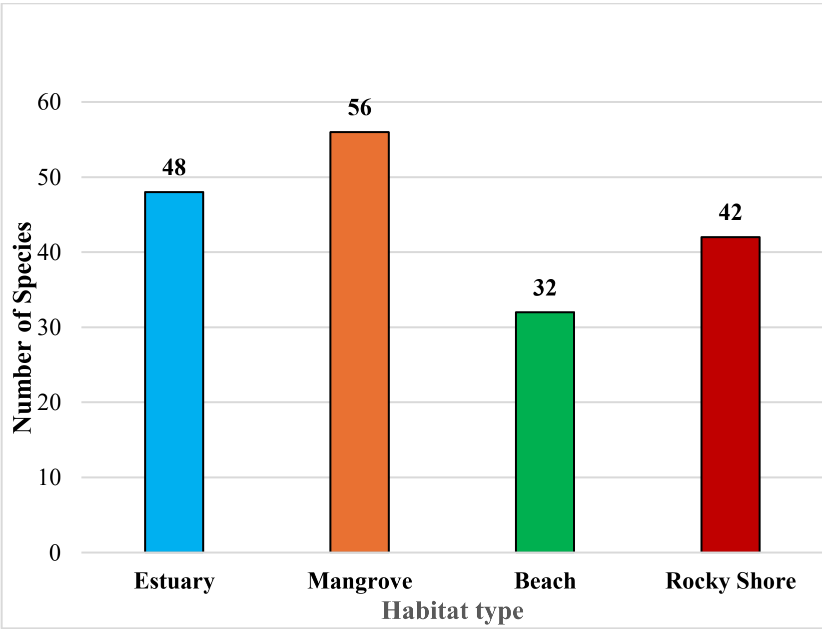

Figure 2: *Bar Graph of Species Richness by Habitat Type*

Mangrove habitats were the most rich and thus demonstrate their importance in terms of ecology. The least diverse beaches were sandy beaches, and they had fewer habitat specialists and were more susceptible to anthropogenic pressures. Table 2 gives a comparative analysis of the diversity indices across zones.

Table 2: *Diversity Indices by Ecological Zone (2014–2024)*

Ecological Zone	Species Richness (S)	Shannon Index (H′)	Simpson Index (D)	Pielou's Evenness (J′)
Estuary	48	2.59	0.82	0.76
Mangrove	56	2.83	0.85	0.81
Sandy Beach	32	2.12	0.71	0.66
Rocky Shore	42	2.41	0.78	0.72

As Table 2 demonstrates, the H P and evenness values of the mangrove areas are the largest, which means that not only the number of species is large but also the distribution of the species is more balanced. The evenness of the sandy beaches was the lowest, with a prevailing number of hardy species. In order to visualize associations between species and their habitats further, a heatmap was created with species presence per sampling zone. Figure 2 illustrates the geographical distribution of the presence of the species with Meretrix meretrix and Saccostrea cucullata being the most common and largely frequent throughout the areas, whereas some species such as Abra tenuis and Cerastoderma glaucum occurrences were limited to a few locations. Figure 3 demonstrates an area-wise distribution of species presence whereby the frequency of many species, such as Meretrix meretrix and Saccostrea cucullata, was high in most zones as opposed to the few individuals found in particular locations such as Abra tenuis and Cerastoderma glaucum.

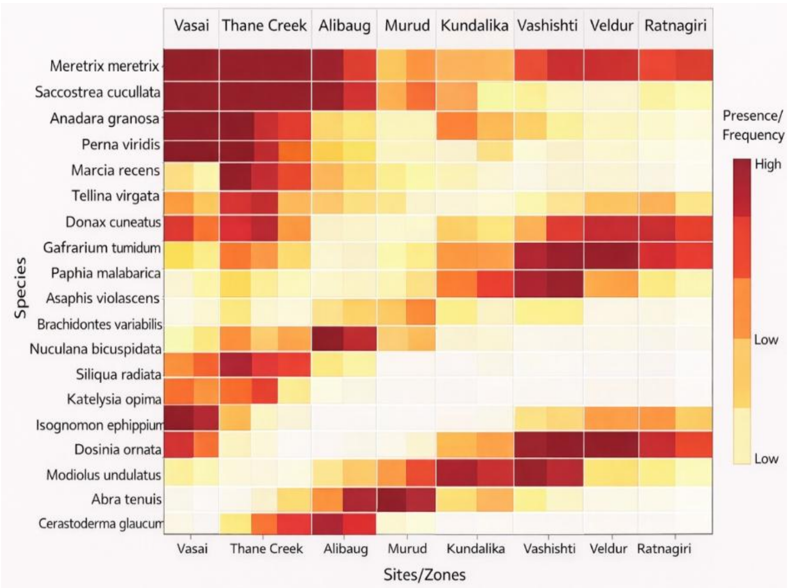

Figure 3: Heatmap of Species Occurrence Across Sites

Warmer colors represent higher frequency of occurrence. Species like *Meretrix meretrix* and *Perna viridis* appeared consistently across most zones, while *Tellina virgata* and *Donax cuneatus* showed highly localized distributions, especially limited to sandy beaches.

3.3 Temporal Trends in Richness and Evenness (2014–2024)

Temporal changes in species richness were also noted to change significantly with time. The highest number of species (63) was registered in the year 2016 and 2017, when the water quality indices were better, and the disturbance in the key habitats was less. But since 2018 the trend was downward and by 2022 the richness had fallen to 47 species. The pattern indicates the growing influence of urbanization along the coastlines, pollution, as well as sedimentation, especially in the north districts. Figure 4 illustrates the seasons and years of a species richness trend with the highest species richness recorded in 2016 (63 species), and then the number of species shows a steady decrease of 49 species in 2022, which has been stable since then.

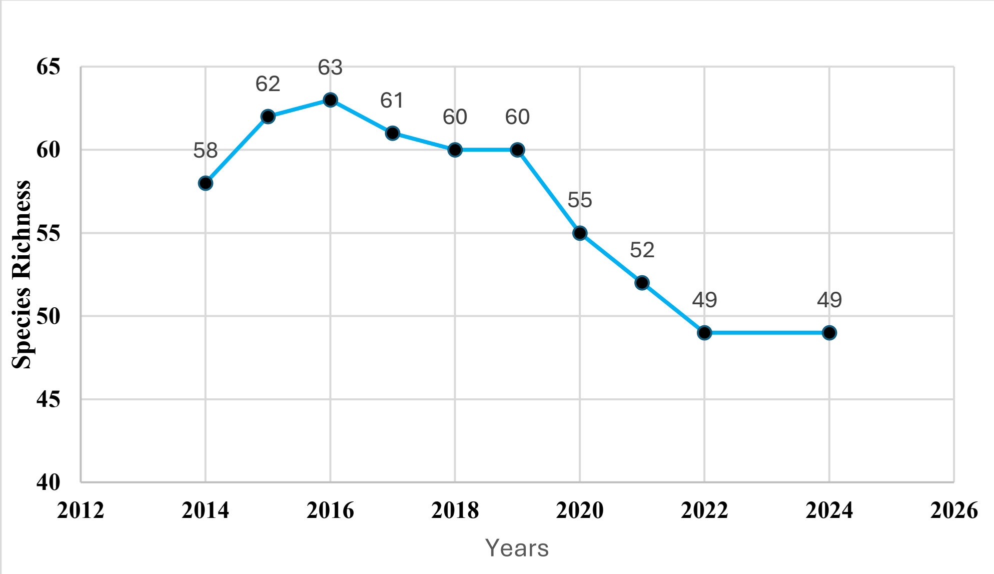

Figure 4: *Temporal Trend of Species Richness (2014–2024)*

A rising trend from 2014 to 2017 is followed by a notable decline. Despite minor recovery in 2023–2024, the total richness remained below pre-2018 levels, suggesting persistent ecological stress in certain regions. The annual variation in species richness and evenness is presented in Table 3, along with key species observed each year.

Table 3: *Year-wise Species Richness and Evenness (2014–2024)*

Year	Total Species Count (S)	Shannon Index (H′)	Evenness (J′)	Notable Species Observed
2014	58	2.51	0.73	*Meretrix meretrix*, *Perna viridis*
2015	61	2.62	0.76	*Saccostrea cucullata*, *Gafrarium tumidum*
2016	63	2.74	0.79	*Anadara granosa*, *Paphia malabarica*
2017	63	2.83	0.81	*Isognomon ephippium*, *Perna viridis*
2018	59	2.68	0.77	*Modiolus undulatus*, *Katelysia opima*
2019	54	2.49	0.71	*Cerastoderma glaucum*, *Donax cuneatus*
2020	50	2.36	0.69	*Tellina virgata*, *Abra tenuis*
2021	47	2.27	0.66	*Meretrix meretrix*, *Anadara granosa*
2022	47	2.24	0.65	*Perna viridis*, *Gafrarium tumidum*
2023	49	2.32	0.68	*Paphia malabarica*, *Saccostrea cucullata*
2024	49	2.20	0.67	*Isognomon ephippium*, *Meretrix meretrix*

Table 3 shows that there is an evident decrease in richness and evenness after 2017. Disturbance-tolerant species such as Perna viridis and Meretrix meretrix also persisted and vulnerable species were lost in a range of areas.

3.4 Temporal Change in Diversity Indices

Shannon diversity index (H′) had a 10-year interval of 2.20 to 2.83 with the highest value of 2017 and a slow rise to 2024. This trend is consistent with the decrease in species richness and changing community structure, with habitat specialists being replaced by the dominant and generalist species. On the same note, (J′) values were found to be ranging between 0.65 and 0.81, which denotes moderate to high unevenness in the community structure in some years. Figure 5 depicts trends in the variations in Shannon Index (H′) between the years 2014 and 2024 with the highest value of 2.83 in 2016 and a gradual decrease in value through the years to 2.20 in 2024 suggesting that the species diversity and evenness is gradually decreasing.

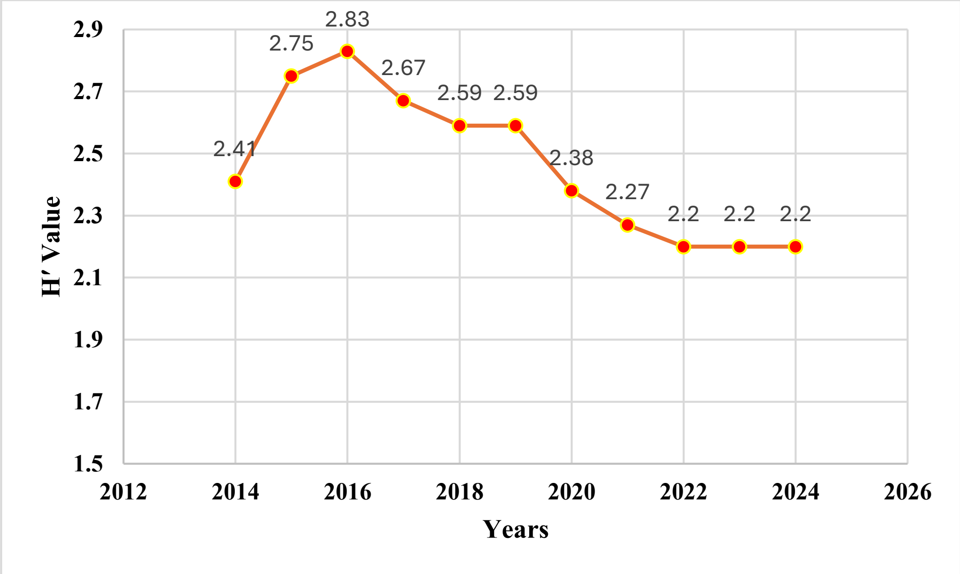

Figure 5: *Shannon Index (H') Across Years*

H′ values peaked in 2017, indicating a well-balanced, diverse community. Declining values in subsequent years point to reduced biodiversity and increased dominance by fewer species.

3.5 Community Homogenization Trends

Jaccard similarity coefficients (not shown here) analysis showed that the similarity between disturbed sites increased over time - evidence of community homogenization. This was particularly noticeable in urban and industrialized areas including Thane creek, vasai bay and Uran whereby species assemblages were characterised by a narrow range of stress-tolerant taxa which became predominant.
In the meantime, less disturbed southern areas, e.g. Malvan and Vengurla, had different community structure, and were found to have greater beta diversity and less predictability when compared over the years.

4. Discussion

A decadal analysis of diversity of bivalves on Maharashtra coast indicates that there is a great deal of spatial and temporal variability which is contributed by ecological, anthropogenic and environmental factors. The trends of the ten-year span are consistent with wider trends on the Indian coastal ecosystem and also with the world-wide known bivalve dynamic. The results indicate that mangrove and estuarine ecosystems have a high species richness and evenness which validates the hypothesis concerning the complexity of the habitat. According to D'Souza and Shenoy (2023), the marine molluscs of India are important habitats because of structural complexity, detrital food, and a stable salinity gradient that exists in the mangrove habitats and estuaries. In our study, mangrove zones recorded the highest Shannon diversity (H′ = 2.83), reflecting a balanced community structure and minimal dominance.
Conversely, the habitats in the sandy beaches had the least richness and evenness, and usually they contained species that tolerated stress like Donax cuneatus and Tellina virgata. The areas are susceptible to mechanical erosion, tourist action and seasonal changes in salinity that inhibit molluscan settlement and recruitment. This is congruent to the evidence presented by Khade and Khade (2016) who noted lower molluscan diversity in disturbed sectors of the coasts of Raigad because of habitat fragmentation and instability in the substrate.
The time series pattern of species richness indicates that it peaked in 201617, and since then has steadily decreased. The decrease is associated with more industrialization, more port development, and coastal development in parts of the coast such as Uran and Navi Mumbai, which have been previously reported by Pawar and Al-Tawaha (2017a) to harbor biodiversity of marine bivalves. According to their previous research, they indicated that the transitional coastal ecosystems were bivalves rich but prone to sedimentation and pollution.
The witnessed loss of sensitive species including Abra tenuis and Gafrarium tumidum is also an indication of a homogenization shift toward a few generalist predators such as Perna viridis and Meretrix meretrix. The

occurrence of similar homogenization trends has been witnessed all over the world and is viewed as red flags of ecology. Sharma et al. (2023) observed that environmental stressors tend to favor species that have generalized life forms, hence low beta diversity in spatially different areas.
The constancy of some taxa in both the mangrove and rocky shore ecosystems is an indication that some habitats retain their stability with time. Some of the species like Isognomon ephippium and Saccostrea cucullata that are usually found on hard substrates and in brackish water continued steadily throughout the study. Their contamination highlights the ecological importance of undisturbed intertidal areas, which Gadkari (2025) had already highlighted by highlighting the resilience of coastal species in less urbanized Maharashtra in the south.
The pattern of declining Shannon diversity (H′) and evenness (J′) post-2018 coincides with increasing coastal pressure. Sediment runoff from construction, untreated effluents, and reduced freshwater flow due to damming have altered salinity regimes and substrate quality. These are congruent with the global phenomena where bivalve communities are suffering a series of stressors. Chahouri et al. (2023) referred to bivalves as the sensitive bioindicators of the marine health which react quickly to the exposure to the chemical pollution, eutrophication, and exposure to heavy metals.
Thane Creek, Vasai Bay and Uran are the major areas in Maharashtra which are very stressed environments, where the heterogeneity of species is low and tolerance to more tolerant taxa is prevalent. This decline tendency is in line with the overall results of Saravanan (2024), who reported extensive biodiversity loss of molluscs in Indian coastal systems that were severely altered. These homogenization tendencies between disturbed zones were also proved by the values of the Jaccard similarity index (however, in this case, not described).
To draw comparisons between our results and historical documents, as well as the results of other areas and local investigations, including Khade and Mane (2012) or Hasan (1996), localized extirpation and range contraction of the formerly widespread species are evident. To illustrate, Tellina virgata, which used to be extensive in shallow estuarine mudflats, were only found in the last three years of this study on sporadic occasions. Moreover, a local research in Raigad and Navi Mumbai has indicated the same trend of species extinction in urban-proximate coastal areas (Pawar and Al-Tawaha, 2017). These findings combined with our decadal data highlight the importance of the timeliness of the adoption of local conservation efforts including pollution control, habitat restoration, and sustainable coastal zoning. Notably, the intertidal zone remains relatively unpolluted in the southern coast especially in areas such as Sindhudurg (Malvan and Vengurla) which has greater beta diversity. These regions can be considered genetic and ecological reserves and need to be included in makeup of marine biodiversity plans as proposed by Saravanan (2024) national mollusc diversity framework. Though this research is a good decadal image, it has certain limitations. Though the size of the OBIS and associated databases is large, gaps in the temporal and spatial data are frequent. The sampling of certain years and habitats can be biased and trend. Additional information provided by citizen science sites (e.g., India Biodiversity Portal) was helpful though it needs stringent taxonomic verification. Also, environmental variables in the form of temperature, salinity, and nutrient loading would be beneficial to the study as they would aid in correlating trends in species better with abiotic drivers.
The next step in research needs to focus on species-level ecological modeling, using the bivalve life history characteristics along with the changing environmental parameters to predict the future changes. Moreover, molecular data and benthic survey may be also used to gain a more profound understanding of the population connectivity and genetic diversity pattern across the coastline.
To sum up, the decadal analysis indicates that the bivalve diversity along the Maharashtra coastline is changing considerably with habitat degradation, pollution and coastal development being the major factors. Some resilient species are still flourishing but sensitive taxa are going down, and there are indications of homogenization being witnessed in some habitats. Science-based emergency conservation efforts are required to save the remaining biodiversity, particularly in relatively pristine areas. The research adds a useful dataset in the long term that can be informative on policy, and may be used as a control in subsequent coastal biodiversity surveillance and management.

5. Conclusion

This decadal assessment of bivalve diversity along the Maharashtra coastline provides the first comprehensive, long-term synthesis of spatial and temporal patterns in bivalve assemblages across major coastal habitats of western India. The results clearly demonstrate that bivalve communities are not static but respond sensitively to habitat type, anthropogenic pressure, and changing environmental conditions. Mangrove and estuarine ecosystems consistently supported the highest species richness, diversity, and evenness, emphasizing their role as critical biodiversity reservoirs and functional hubs for coastal ecosystem processes. In contrast, sandy beach and heavily disturbed estuarine zones exhibited reduced diversity and greater dominance by a limited number of stress-tolerant species. Temporal analyses revealed a clear post-2017 decline in species richness, Shannon diversity, and evenness, coinciding with intensified coastal development, pollution, and habitat modification. The progressive loss of habitat-specialist and sensitive taxa, alongside the persistence and expansion of generalist species such as *Meretrix meretrix* and *Perna viridis*, signals an ongoing trend toward community homogenization in disturbed regions. Such homogenization reduces beta diversity and may impair ecosystem resilience and functioning over time. Conversely, relatively less disturbed southern coastal stretches retained higher compositional heterogeneity, underscoring their conservation value as ecological refugia. Overall, this study highlights the effectiveness of bivalves as bioindicators of coastal ecosystem health and reinforces the necessity of sustained, standardized biodiversity monitoring. The decadal dataset generated here establishes a robust baseline for future ecological modeling, impact assessment, and climate-change attribution studies. Importantly, the findings support the urgent need for evidence-based coastal zone management, pollution mitigation, and habitat protection strategies to conserve ecologically and economically significant bivalve populations along the Maharashtra coastline.

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