Variation in the marine bivalve diversity with depth: A case study from benthic assemblages of Bay of Bengal

A Thesis

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by

Om Adarsh

Indian Institute of Science Education and Research Pune

Dr. Homi Bhabha Road,

Pashan, Pune 411008, INDIA.

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Supervisor: Dr. Devapriya Chattopadhyay

Certificate

This is to certify that this dissertation titled **Variation in the marine bivalve diversity with depth: A case study from benthic assemblages of Bay of Bengal** towards the partial fulfilment of the BS-MS dual degree programme at the Indian Institute of Science Education and Research, Pune represents study/work carried out by Om Adarsh at Indian Institute of Science Education and Research under the supervision of Dr. Devapriya Chattopadhyay, Associate Professor, Department of Earth and Climate Science, during the academic year 2022-2023.

Om Adarsh
Reg no-20181012

Dr. Devapriya Chattopadhyay

Committee:

Dr. Devapriya Chattopadhyay

Dr. Sudipta Sarkar

This thesis is dedicated to my parents and my brother for being a continuous source of support throughout the journey.

Declaration

I hereby declare that the matter embodied in the report **Variation in the marine bivalve diversity with depth: A case study from benthic assemblages of Bay of Bengal** are the results of the work carried out by me at the Department of Earth and Climate Science, Indian Institute of Science Education and Research, Pune, under the supervision of Dr. Devapriya Chattopadhyay and the same has not been submitted elsewhere for any other degree.

Om Adarsh
Reg no-20181012

Dr. Devapriya Chattopadhyay

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ABSTRACT

Mollusks are one of the most widely studied phyla used as paleoclimatic proxies. One of the primary drivers of terrestrial diversity is the latitudinal gradient. However, here we focus on marine mollusks to see how oceanographic determinants play a significant role in governing the diversity in addition to latitudes. The factors of diversity studied were species abundance, richness, and evenness, and the diversity index used for the study is reciprocal Simpson's diversity index. The oceanographic determinants which affect the diversity are temperature and salinity and the contents of nitrate, phosphate, and silicate. Here, we account for a detailed study of bivalves collected from three cruises in the western Bay of Bengal across twelve latitudinal bins ranging from 10-21 degrees north. Bivalves were collected from 45 stations, ranging from depths 24-738m below sea level. A total of 422 specimens were collected belonging to 21 families. The most abundant family was Veneridae.

Our study shows that the richness, evenness, and diversity index do not show any particular trend with depth across all the latitudinal bins.The maximum value of richness and Simpson's diversity index corresponds to mid-latitudinal bins in the Krishna Godavari delta where the organic content in the sediment is comparatively high. NMDS results showed random scattering among stations in different depth and latitudinal bins which suggests none of bins can be represented by a particular assemblage. Among oceanographic variables, there was some significant correlation of species evenness with temperature and phosphate content.

ACKNOWLEDGEMENT

I would like to thank Dr. Rajeev Saraswat and his lab members for helping me to get the samples required for the study of mollusks. I would also like to thank Dr. Devapriya Chattopadhyay and Phd members of lab KS Venugopal and Avinash Dahakey for continuous direction and help in my work.

INTRODUCTION

Marine biodiversity tends to increase with increasing temperature, energy availability, and environmental stability *(Fine, 2015; Jetz & Fine, 2012; Mittelbach et al., 2007)*. The energy here is related to primary productivity, and better primary productivity leads to a surge in population. In marine systems, while energy and temperature decrease with increasing depth, environmental stability increases *(Fine, 2015; Ramirez-Llodra et al., 2010; Valentine & Jablonski, 2015)*. Studying biodiversity along depth gradients helps us to disentangle the drivers of diversity, namely energy, temperature, and environmental stability.

Total marine species richness across the globe has been calculated according to depth *(Costello & Chaudhary, 2017)*, and it demonstrates a peak at 400-500m, with the next highest being 0-100m. A similar study on pelagic fishes also demonstrated higher species richness between 100 and 200 m than in the shallowest interval, 0–100 m *(Smith & Brown, 2002)*. Another study in the central Arctic Ocean on benthic macrofauna suggests the highest diversity values at a depth of 100-300m, and a parabolic trend of diversity across depth was observed *(Vedenin et al., 2018)*.

The variation in diversity with depth has also been studied in regional scales for several marine invertebrate groups. The invertebrate community comprising of decapods and stony corals of Clipperton Atoll in the tropical eastern Pacific showed a gradual increase in diversity till 200m and a steep fall after 200m *(Friedlander et al., 2019)*. Foraminiferal diversity of the Bay of Bengal (Indian Ocean) showed increasing abundance and diversity with increasing depth towards the edge of the photic zone *(Bhadra & Saraswat, 2021)*. This trend is contrary to trends observed earlier. The main reasons for the low abundance of the foraminifera in shallow depths have been attributed to the low salinity, high turbidity, and dilution by the high terrigenous flux from the land. A study was conducted on the bryozoan population in the North Atlantic, which showed the highest species richness at intermediate depths of 10-75m. However, no latitudinal pattern was observed for the diversity patterns *(Clarke & Lidgard, 2000)*.

Calcareous organisms have been widely used for paleoclimatic studies. Mollusks are the second largest phylum of invertebrates. Their habitat range is quite diverse, ranging from mountaintops to terrestrial to deep sea vents. Their shells are quite durable, which makes them feasible to be studied. They are major calcareous organisms which play an important role in the overall carbonate cycle since their appearance in Cambrian *(Parkhaev, 2007; Sigwart & Sutton, 2007)*. Mollusks are generally used to assess marine biodiversity according to depth and latitudinal bins.

The variations of macrofaunal species composition with depth have been related to sediment type, temperature, currents, and topography *(Day & Pearcy, 1968; Rowe & Menzies, 1969; Rufino et al., 2008)*. Mollusk diversity on the east coast of India, bordering the Bay of Bengal, has been studied extensively with beach samples *(Chattopadhyay et al., 2021)*. One pattern suggested by previous deep-sea studies suggested a maximum abundance and biomass at depths 51-75m compared to further below; the highest diversity index was, however encountered at 30-50m. However, along with mollusks, other classes like polychaetes and decapods were also considered *(Ganesh & Raman, 2007)*. However, there was no quantitative difference shown between the diversity of shallow water and deep water environment in a particular latitudinal bin. There have been some attempts to study benthic species, and they dealt with latitudinal bins between 16 to 20 degrees north representing the northeast shelf and worked with benthic macrofauna, which showed the highest Shannon index value of 2.32 ± 0.01 between 30-50m, followed by 0.73 ±0.09 (>100m) and decreased further *(Ganesh & Raman, 2007; Mahapatro et al., 2021)*. A study on gastropods and bivalves in West Antarctica from the South Shetland Islands to the Bellingshausen Sea suggested no trend for the diversity of gastropods along the depth. However, in the same study for bivalves, the Shannon Index of diversity showed the highest values at 500m with decreasing trend till ~1200m *(Aldea et al., 2008)*. A study on bivalved mollusks from the Gulf of Mexico in the Perdido Fold Belt *(Suárez-Mozo et al., 2021)* demonstrated diversity change between the continental shelf and the bathyal zone. The results suggested similar gamma diversity across both the bathyal zone and continental shelf, with high α diversity and low β diversity in the continental shelf, whereas low α diversity and high β diversity in the bathyal zone. The highest values of diversity were encountered between 1209 to 1779m.

Ganga. Brahmaputra, Irrawaddy, Godavari, Krishna, Mahanadi, Brahmani, and Cauvery river systems contribute to the maximum sediment load of the Bay of Bengal, which is dominated by terrigenous sediments *(Mohanty et al., 2008)*. During the summer monsoon, the river discharge warms the surface waters by 2 °C in the nearshore areas but decreases its salinity by 0.5 psμ *(Bhadra & Saraswat, 2021)*. The salinity generally shows a dominant relationship with a latitude of <32.0 psμ in the northern bay, increasing to >33.2 psμ in the southwestern bay *(Zweng et al., 2019)*. During the winter monsoon, the river discharge from the Ganga-Brahmaputra decreases the sea surface temperature in the northern Bay of Bengal *(Shetye, 1993)*.

The area of focus of deep-sea studies has been divided into two major parts: i) Continental shelf and ii) Bathyal Zone. The first 200m is the photic zone till where sunlight reaches, and photosynthesis is possible, resulting in greater productivity; beyond that, till 4000m, the bathyal zone; beyond that, the abyssal zone till 6000m, and further below is the hadal zone. We used to drill holes as a predation proxy to check if predation is concentrated in any particular depth or latitudinal bin. In this work, we will focus on the samples collected across a depth gradient of 20-2574m, with most of the specimens concentrated in the first 0-200m.We use drill holes as a predation proxy to study the biotic interaction.

The main objectives of our study are :-

i) Does the diversity change with depth and how does it change?

ii) How does the biotic interaction change with depth?

iii) How environmental parameters contribute in variation of community structure?

MATERIALS AND METHODS

Sampling location

Samples were collected from a total of 147 stations in the Bay of Bengal along the eastern coast of India over the course of three cruises namely SK308, SSK35 AND SSD067 across latitudes ranging from 10 to 21 degrees north. The sampling locations were divided into three portions namely north, central and south Bay of Bengal. The South portion comprises of latitudinal bins in range 10-14N, central portion comprising 14-18N and northern portion comprising 18-21N (Fig 1). The surface samples include 60 multicore top samples (Ocean Scientific International Limited) Maxi Multi-corer, with core-tubes of 100 mm inner diameter) collected during ORV *Sagar Kanya* cruise (SK308) in January 2014, 39 spade core top samples collected during RV *Sindhu Sankalp* cruise (SSK35) in June 2012, 56 multicore top samples were collected during *Sindhu Sadhana cruise* in 2019 (SSD067) and 11 grab samples were collected during *Sindhu Sadhana cruise* (SSD067). The samples collected ranged from depth of 20m – 2574m. The details of the sample collection is described in (Bhadra & Saraswat, 2021).

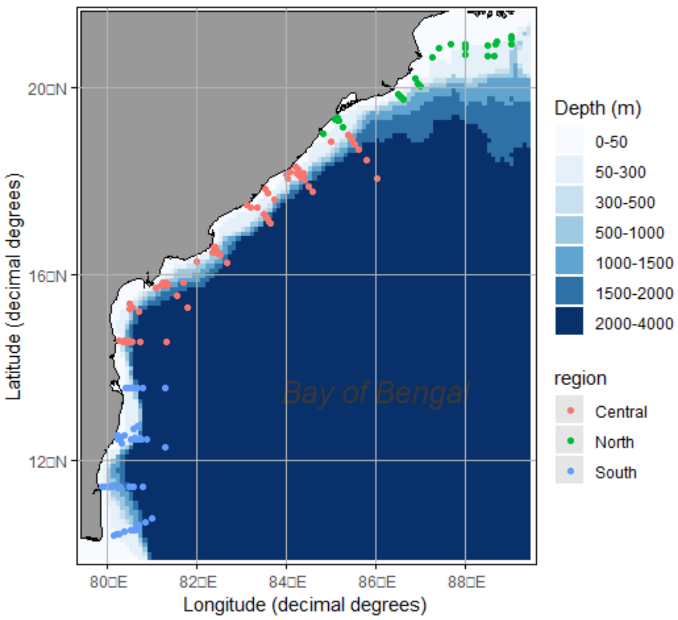

Fig 1. Contour map of India showing depth below sea level. Points in green depicts the stations from which samples were collected in the 3 cruises by NIO Goa.The area of study is divided into northern, central and southern regions.

Sampling and sample identification

The top 0-1 cm of all the samples was processed using the standard procedure *(Naik et al., 2014)*. In SSD067, at 10 stations grab sampling was also done for collecting the samples. A small portion of the sample was collected in labelled and weighed petri dishes and freeze dried. The dried samples were weighed and sieved with a 63µm mesh. The material which remained on the mesh is the coarse fraction and this was further transferred to beakers and dried overnight. A part of the coarse fraction was then sieved at 125µm mesh. A weighed portion of the >125µm fraction was then used for picking bivalves and gastropods. The range of weight of >125µm fraction used for picking ranged from 0.01-5.567 grams. Only the bivalve specimens are used for this study. For every single bivalve specimen, we took the internal and external image of a valve using a ZEISS Stereo Discovery. V20 microscope. The size of the bivalves varied from approximately 125 µm to 5000 µm.

We identified the valves based on important morphological features using the published monographs (*Subba Rao, N. V. (2017). Indian Seashells (Part-2): Bivalvia, Rec. zool. Surv. India. Occ. Paper, (375), 1-568*).along with online databases such as WoRMS (https://www.marinespecies.org/). Some of the shells were broken and were difficult to be identified so were not used for further analysis. At first we classified the bivalves into families and then later based on similar morphological features like shape, rib patterns and dentitions we classified them into groups of morphospecies represented by MS (ex-MS_021). We also documented the valves having drill holes as we use drill holes as a predation proxy.

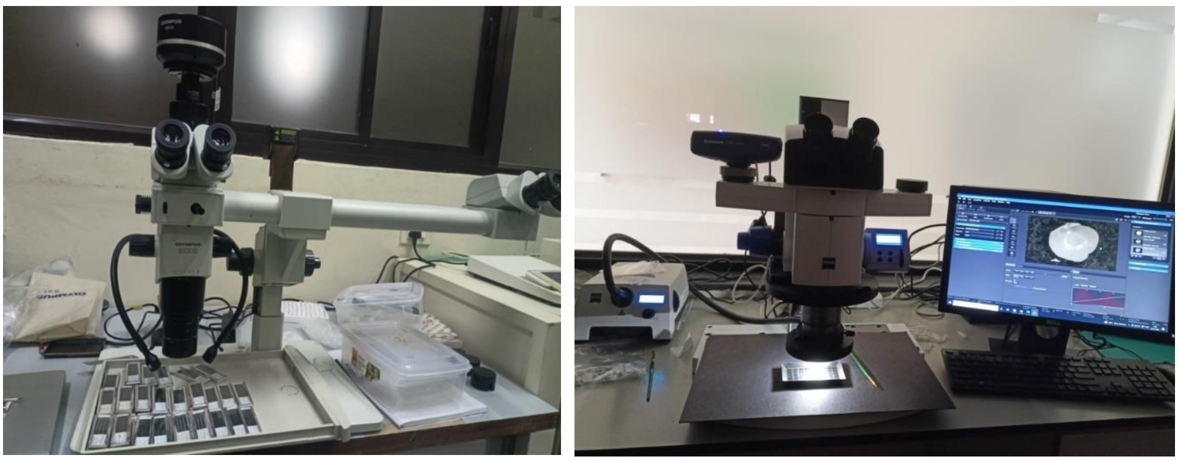

Fig 2. Firstly >125µm fraction was used to pick bivalves and gastropods and later bivalves were documented and identified. In the first figure the slides present on the plate contain >125µm fraction after foraminifera were picked, the same was used to pick bivalves and gastropods later to collect my

and in the second figure the microscope is shown which was later used to document the pictures of bivalves.

Documenting community structure

We calculated abundance, richness, diversity and evenness of the bivalve collection. Abundance represents the total number of specimens. Richness is calculated as the total number of different morphospecies found. We used Simpson reciprocal index (1/D) *(Morris et al., 2014)* to evaluate the diversity of a community using the following expression:

$1/D = 1/\sum(n / N)^2$

n = Total valves of a particular morphospecies (As the total no of same morphospecies in a particular location was at maximum 12 and at most stations 1, there is really less chance of two single valves belonging to the same specimen, so we have assumed all single valves to be a single species)

N = Total number of organisms of all species (Abundance)

Higher value of 1/D, greater is the diversity. The least value possible is 1 which would indicate the community comprising only one species.

Evenness indicates how evenly the species are spread out in the community and we calculated using the following expression

Simpson index of Evenness = (Simpson reciprocal Index / Richness) (Nagendra, 2002)

Oceanographic variables

The sea surface temperature, salinity, silicate, nitrate and phosphate content were calculated across four seasons and their average was calculated. For calculation of the above factors three stations were considered for each sector namely MC71 for northern Bay of Bengal (19-21degrees North), MC58 for central Bay of Bengal (15-18degrees North) and MC03 for southern Bay of Bengal (10-14degrees North) as shown in figure 1 *(Bhadra & Saraswat, 2021)*.

Statistical analyses

Correlation – We used Pearson Product-moment correlation to check the linear dependence between two variables and the value is indicated by R. R can range from -1 to +1. A value of -1 suggests a strong negative correlation between two variables, and a value of +1 shows strong negative correlation between two variables. Value of $|R|<0.3$ suggests a weak correlation and $|R|>0.7$ suggests a strong correlation. The p value used in graphs shows statistical significance, only if $p < 0.05$, we consider the variables to be significantly related.

Rarefaction – In order to avoid sampling biases, and avoid the biases caused to difference in weight of the picked samples, we used rarefaction to compute the species richness according to no of individuals picked at the stations *(Simberloff, 1972)*. I used R programming to code for random sampling and plot a rarefaction curve and then plotted a curve falling within 95% confidence interval of the original curve and after doing such I plotted the abundance number at difference stations, latitudinal bins and depth to check if richness was affected by number of specimens.

NMDS – NMDS (Non metric multi dimensional scaling) is a measure of checking dissimilarities between individual cases. For any number of dimensions, it gives a 2D scatter plot provided the data is in form a distance matrix (Kruskal, 1964). In our work we use nmds based on presence absence data to check if there is any clustering between stations in same latitudinal bins and depth.

RESULTS

We documented a total of 511 bivalves out of which 423 could be identified as the broken shells were hard to be identified. The specimens represent 94 morphospecies of 21 families. The most abundant family was Veneridae (21.5%), followed by Nuculidae (12.5%) and Glycemerididae (12.5%). Some of the shells were pink in colour as they were dyed by Rose Bengal (Fig 3) which acts as an indicator of whether the particular specimen was alive or dead at the time of collection. 56 of the 423 had drill hole as predation mark (Fig 3). Cardidae had the highest percentage of predation (~25% of total cardidae found). The diameter of the shell ranged from a few 100µm to approximately 5000µm at largest.

Fig 3:- The top two images belong to the most dominant family(Family – Veneridae). At the bottom the left image shows a specimen which shows pink coloration due to Rose Bengal dye (Family – Nuculidae). The right image show a specimen having a drill hole as a predation mark (Family- Arcidae)

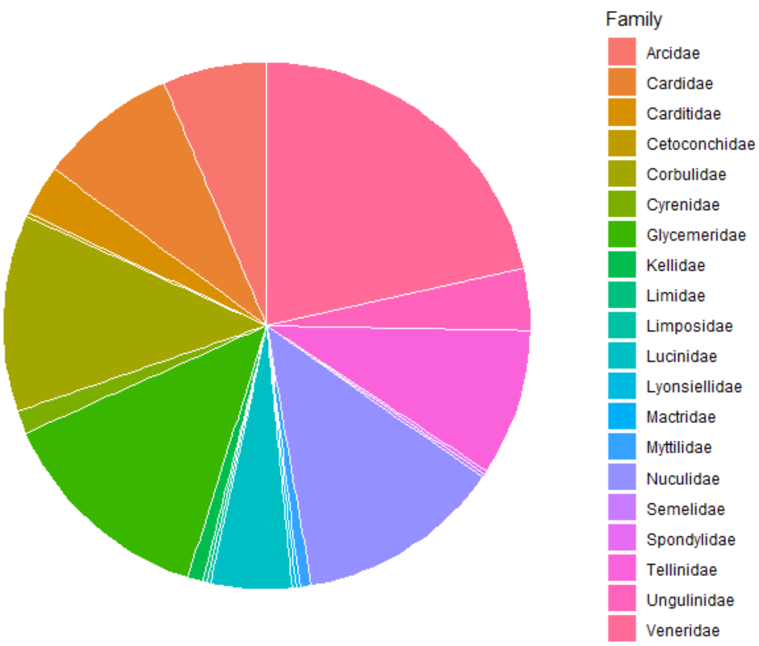

Fig4:- Pie chart showing the distribution of various families of bivalves with Veneridae being the most represented

Effect of sample size

The weight of the fraction used for picking the bivalves was not uniform across stations. However, the abundance is not significantly correlated with weight (rho = 0.3, p = 0.052) (Fig 5(ii)). The weight mentioned here refers to the >125µm coarse fraction used for picking.

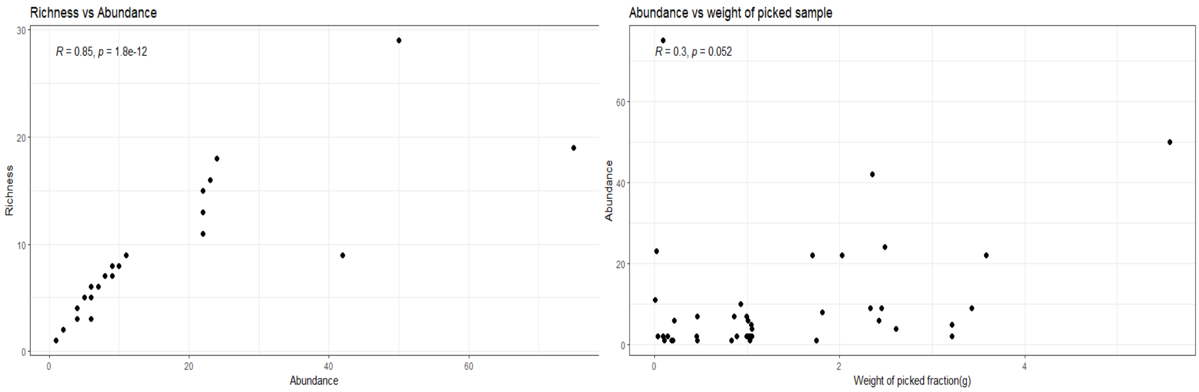

Fig5:- (i) Richness vs abundance (ii)Abundance vs weight of picked fraction

The species richness shows a strong positive correlation with species abundance (R= 0.85, p<<0.01). We saw earlier abundance is not related to weight, but still to ensure there is no sampling bias and weight of picked fraction does not affect the species richness, we accounted for the rarefied richness which took into account random sampling. In the first plot of Fig 6 we see that in areas of high abundance the richness values does not fall within the 95% confidence interval of rarefied richness, this suggests that the abundance does not strictly control the species richness. Overall all these plots suggest that the species richness is not biased by the weight of the fraction picked.

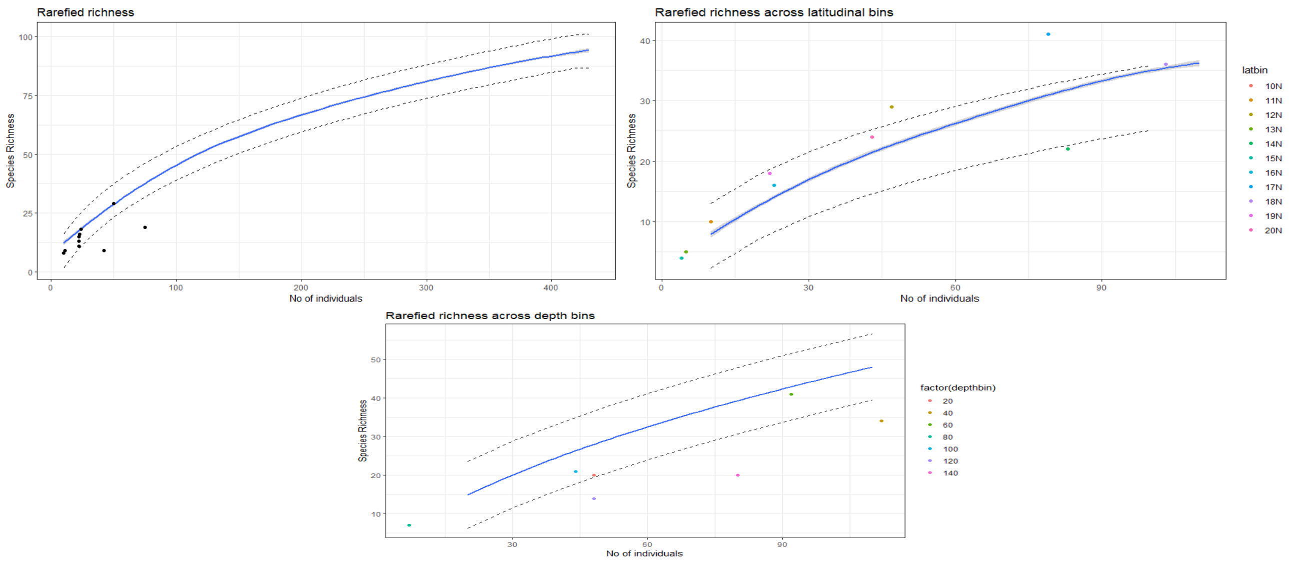

Fig 6:- Plots of rarefied richness as function of individuals, latitudinal bins and depth bins

Effect on community structure

There is no significant correlation between number of morphospecies (Richness) and depth at which the sample was collected (rho = 0.28, p = 0.073) (Fig 6(i)). Owing to almost no specimens found beyond 250m there is no accounting of the components of diversity beyond that depth. Majority of the sample is accounted for in the photic zone till where sunlight is available and barely any species was sampled in the bathyal zone.

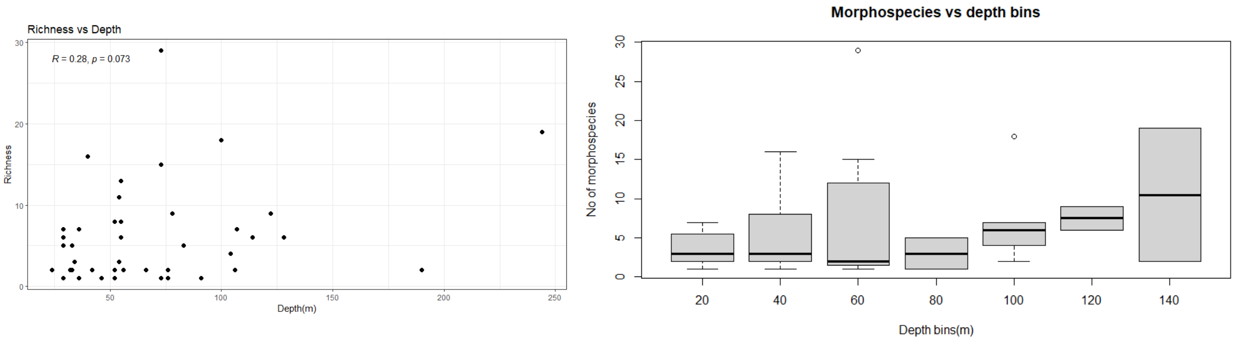

Fig 7:- (i)Number of different morphospecies vs depth (ii) Number of morphospecies vs depth bins.

We further divided the complete gradient of depth into depth bins of 20m each, depth bin n refers to the range [n,n+20)m, for example the depth bin 20 refers to all the stations which fell in the depth range 20-40m. We encountered three depths of 190m, 244m and 738m and plotted them together in 140m bin. Highest values were seen in 140m bin. Majority of the stations fell in the depth range 20-80m (Fig 7(ii)).

In figure 8, latitude bin x depicts stations lying between latitude x to (x+1). Latitude bin 15N depicts all stations lying in between 15-16°N. In the next plot (fig 19) the latitudinal bins having 2 or less stations were removed in order to get the trend. Warmer colours represent southern part of Bay of Bengal and colder shades represent the northern parts .Figure 8 shows highest species richness is found in mid latitudinal bins in 17N in Krishna and Godavari delta regions. Even in 14N at a depth of 244m there was high species richness, having multiples species distributed evenly with 25% of species showing drill holes as well.

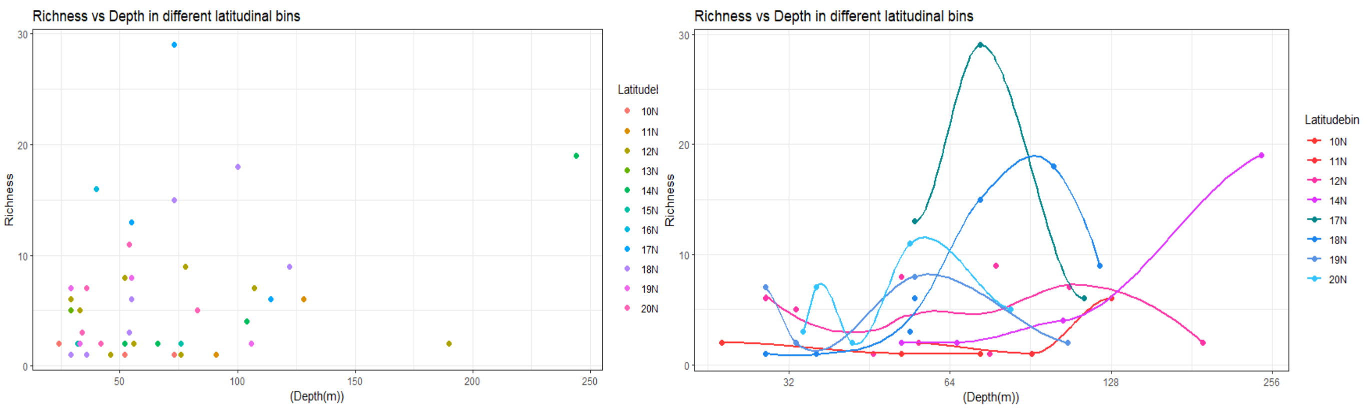

Fig 8:- Scatterplot and Trendlines of richness vs depth at different latitudinal bins.

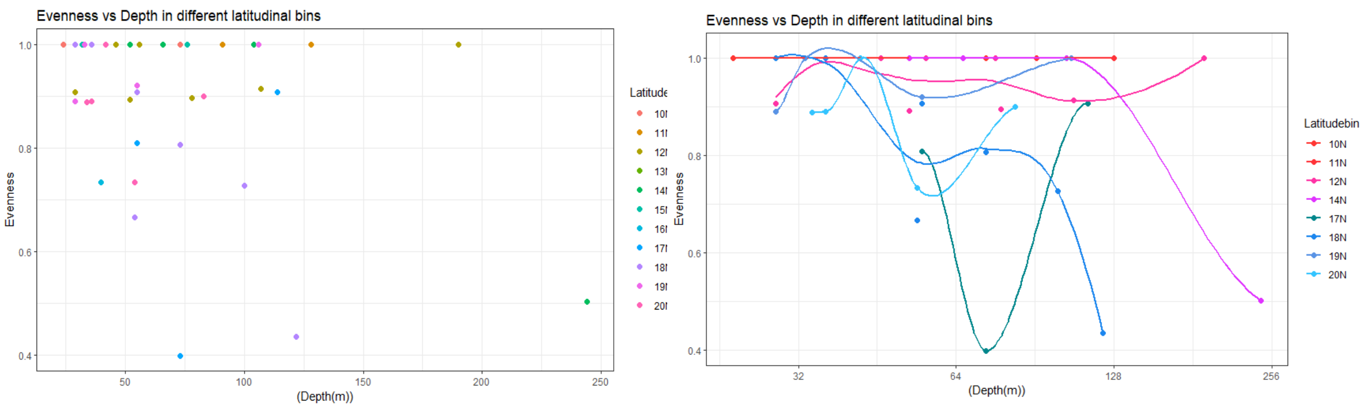

Fig 9:- Scatterplot and trendlines of evenness vs depth at different latitudinal bins

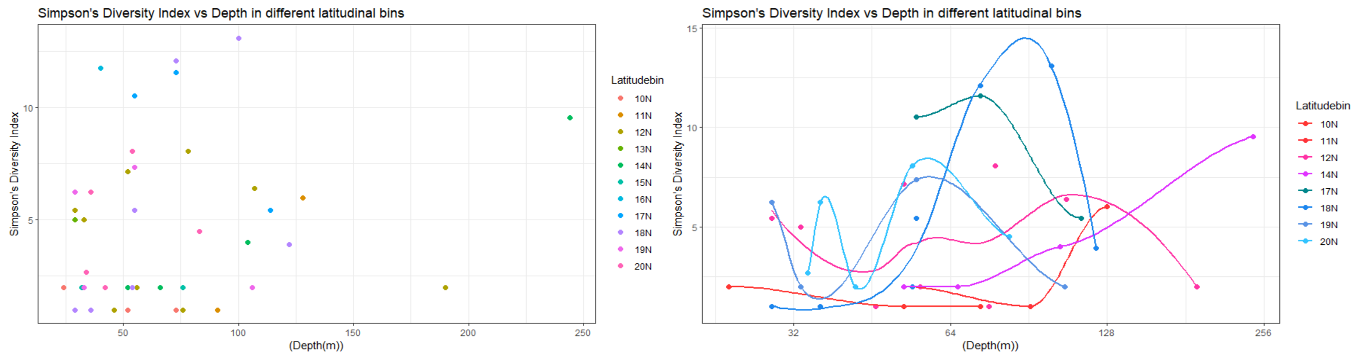

Fig 10:- Scatterplot and trendlines of simpson diversty index vs depth at different latitudinal bins

Figure 9 depicts lowest value of evenness is found in the mid latitudinal bins in the river Godavari delta. The lowest value of evenness is found at MC-41 in the cruise SK308, this is due to the high abundance of MS_026 belonging to the family corbulidae found at the station contributing to almost 25% of the total species found at the site. In figure 10, contrary with the above trends there is high value of diversity index in 18N followed by 17N. Overall values of richness, evenness and diversity index suggests that, mid latitudinal bins show the highest richness and diversity accompanied by lowest evenness.

Effect on community composition

The NMDS plots are made on base of presence absence data. In figure 15, the depth bins are made at 20m interval, for example 20m depth bin represents 20-40m below sea level. In figure 12, latitudinal bins are considered. In both these NMDS there is no proper cluster observed so no comment can be made about similarity of species based on presence absence data. No particular depth bin or latitudinal bin is represented by any particular assemblage and the species do not show any particular pattern and are randomly scattered.

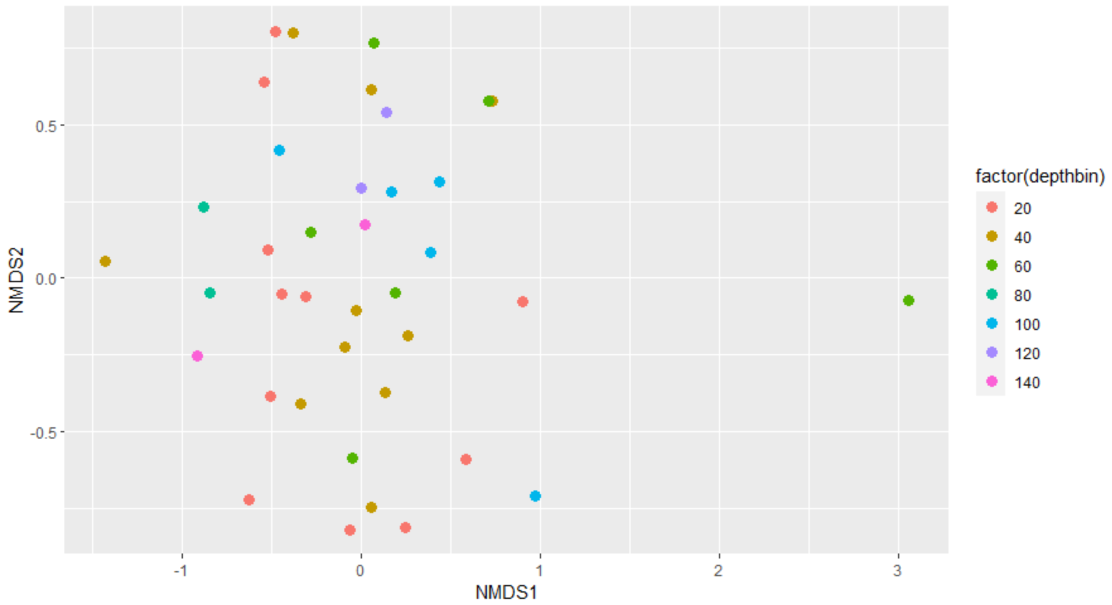

Fig 11:- NMDS based on depth bins spaced at 20m each

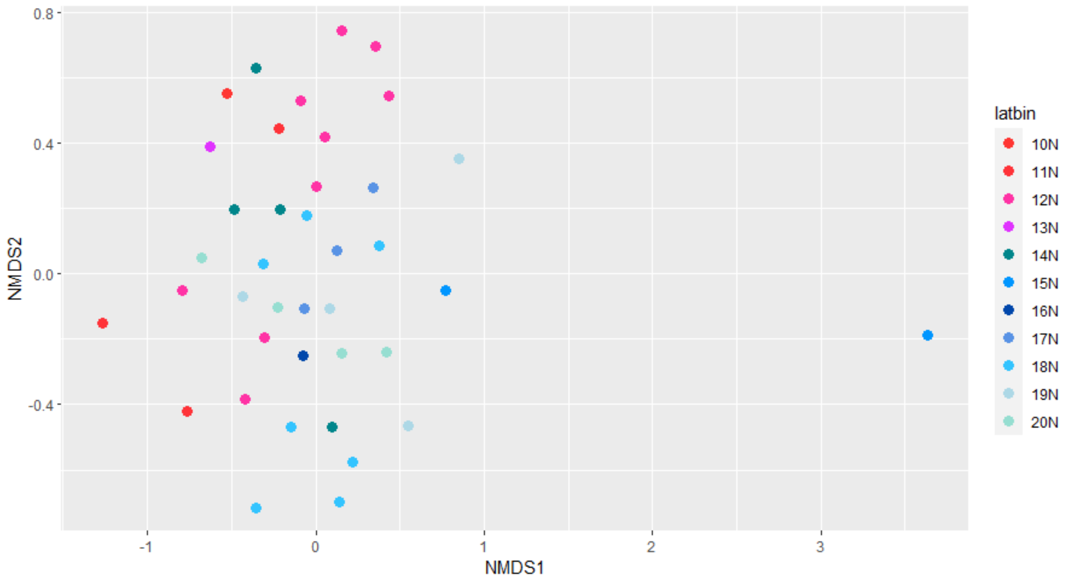

Fig 12:- NMDS based on latitudinal bins

Drivers of diversity indices

Abundance shows negative correlation with temperature. It also shows positive correlation with nitrate, phosphate and silicate content.

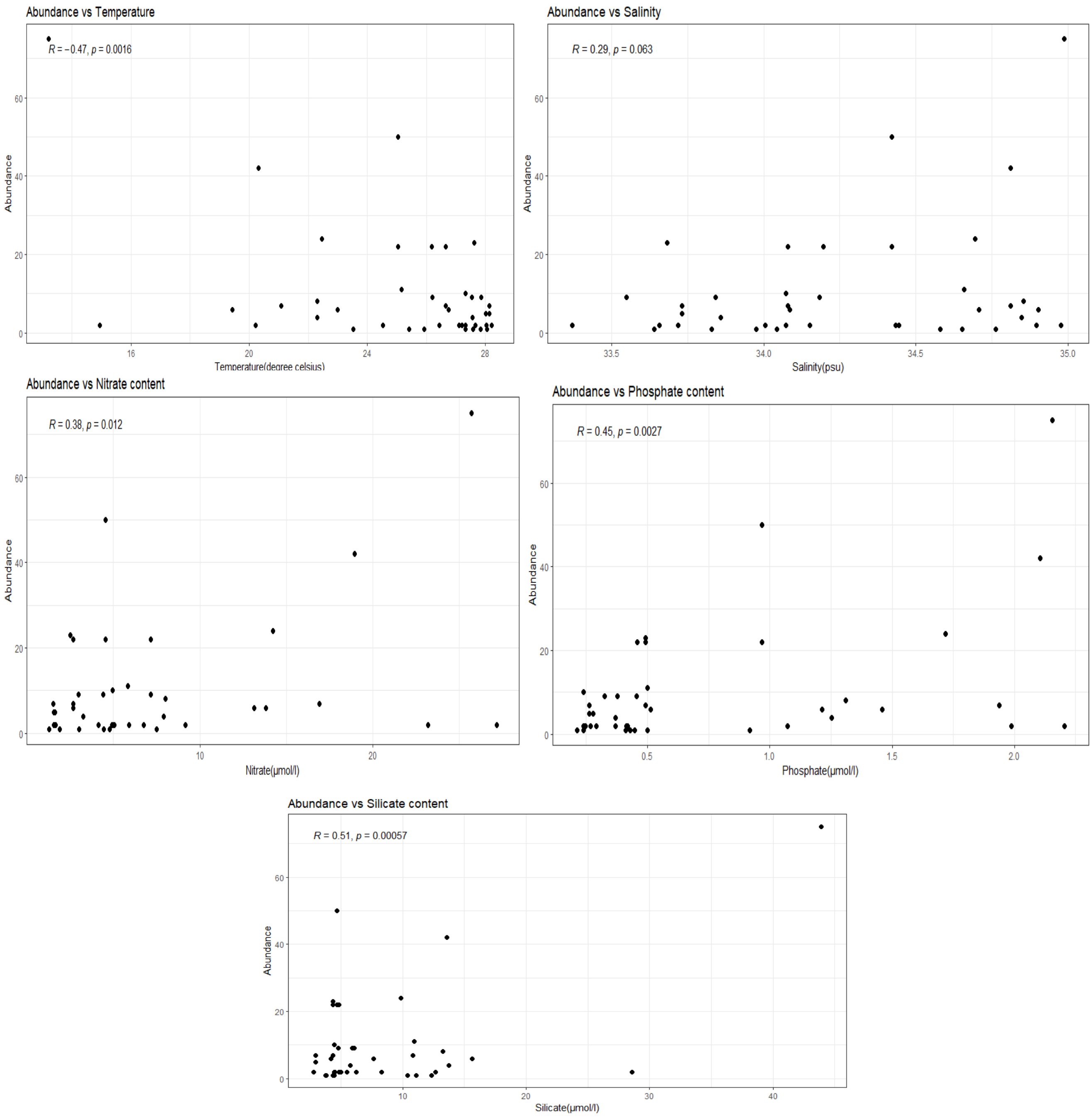

Fig 13: Plots of abundance vs oceanographic variables

Species richness does not show any significant correlation with any of the oceanographic variables.

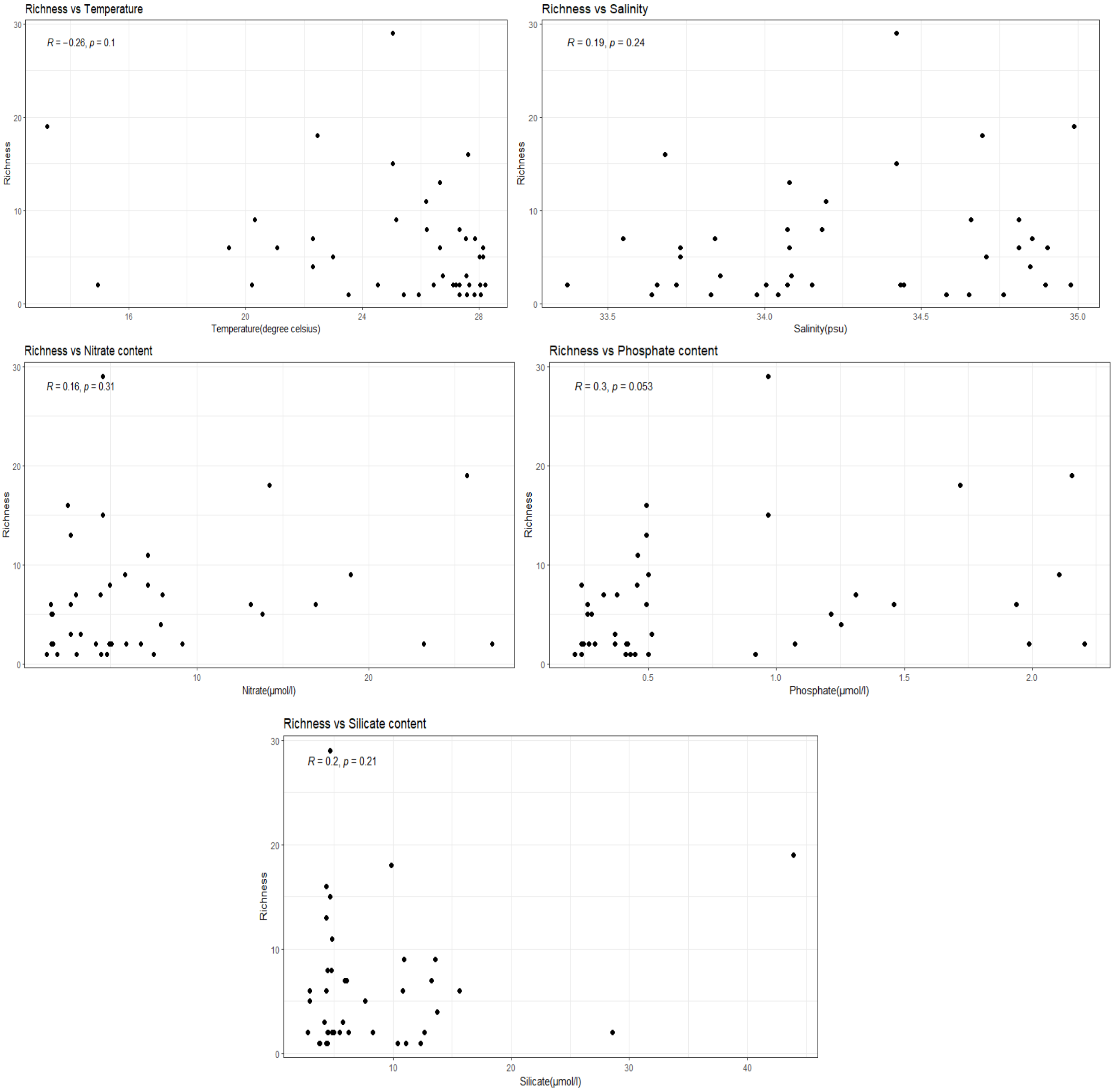

Fig 14:- Plots of species richness vs oceanographic variables

Species evenness shows positive correlation with temperature and negative correlation with phosphate content.

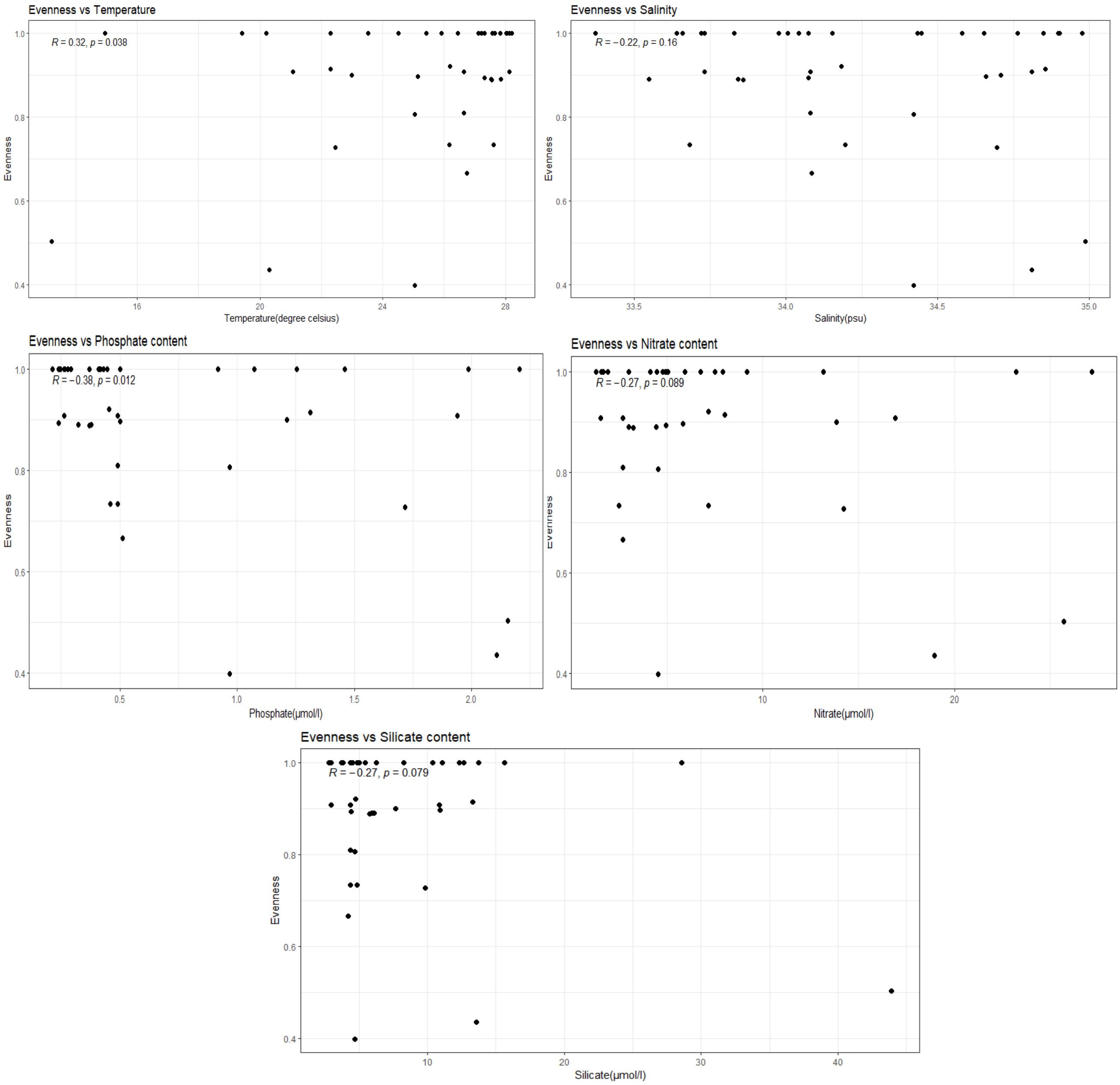

Fig 15:- Plots of species evenness vs oceanographic variables

Diversity index does not show any correlation with any of oceanographic variables.

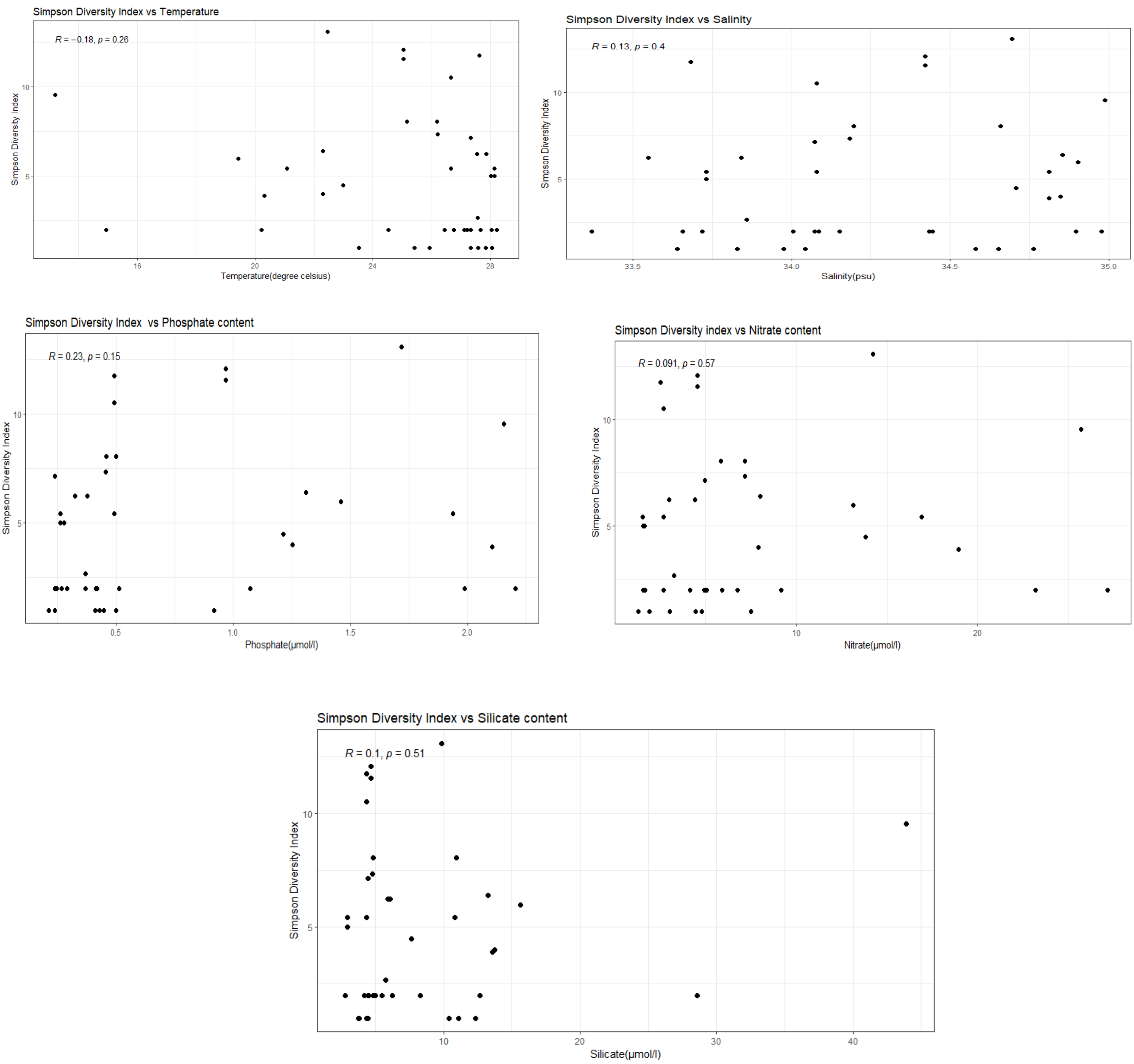

Fig 16:- Plots of Simpson's diversity Index vs oceanographic variables

Based on the presence absence data we plotted a co-occurrence matrix (Fig 17) which shows either random or positive association which in turn suggests that frequency of co-occurrence of species is either equal to the expected value or more than expected (*Cooccur: Probabilistic Species Co-Occurrence Analysis in R | Journal of Statistical Software*, n.d.)

Based on the drill holes, we observed the predation data and across latitudinal bins the highest values were seen in 18N followed by 14N and 17N. Across depth bins there was not much variation in trend (Fig 18).

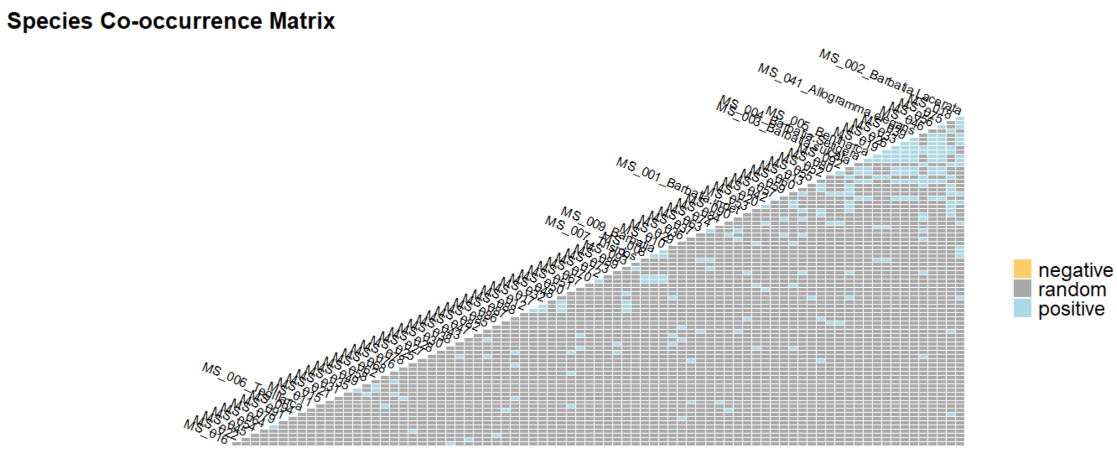

Fig 17:- Co-occurrence matrix based on presence absence data of species

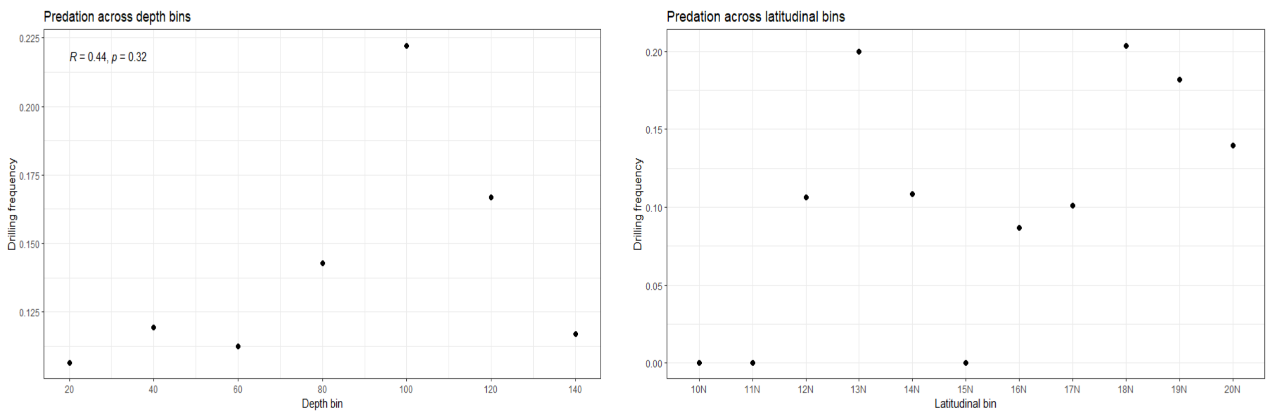

Fig 18:- Drilling frequency vs latitudinal bins and depth bins

DISCUSSIONS

As discussed in the introduction, in overall marine species globally highest diversity was observed in 400-500m, followed by 0-100m *(Costello & Chaudhary, 2017)*.In the two studies conducted on bivalves in the Gulf of Mexico and West Antarctica, peaks of diversity were encountered in the depth range of 1209-1779 and ~500m, respectively. Contrary to these, we didn't encounter any specimens in a depth range >244m, but in the range of 60-80m, we found the majority of species, and the highest species richness and diversity were also seen in this range. High species richness was also seen at 244m depth below sea level. With the other studies, our studies are consistent to some extent, as in most of the studies, the second highest richness range is seen in 0-100m, and we also see the maximum richness in the range of 60-80m. One possible reason for the high species diversity at greater depths in temperate regions might be the abundance of cold water species, sea surface temperature tends to fall with depth, and species adapted for cold conditions would prefer greater depths for the same reason. Whereas in the tropics, more species are found in the shelf region above 150m, which might be suggestive of the fact that more warm water species would be favored in the tropics.

The northern parts of our study have reported low richness and diversity despite having a high influx of nutrients from the Ganga and Brahmaputra *(Bhadra & Saraswat, 2021)*.In the central parts of our study, where rivers Kaveri and Godavari open into the sea, there is high richness and diversity. A major reason behind this can be the sediment type and size. Sediment grain size and type play a major role in the distribution of benthos *(Ganesh & Raman, 2007)*. In the region where river Godavari opens into the Bay of Bengal, sediment organic matter is too high. That might be a huge factor in high diversity indices in those regions.

In the study done on foraminifera in the same regional setting, the abundance and richness are low in the shallow region and gradually increase till the edge of the photic zone. We don't see low abundance or richness in the shallow regions, but it certainly increases till 80m, and also, at 244m, there is a sudden surge in abundance and richness, so the results are a bit consistent with the foraminifera study as well. They have stated one of the reasons as low salinity for low abundance at shallow depths, but abundance or any diversity component did not correlate with salinity. And other two reasons stated were high turbidity and high dilution by terrigenous sediments, and these two factors could have also possibly played a role in governing the diversity of bivalves. There is no particular trend of the diversity indices across the latitudinal gradient. We saw that abundance and evenness were related to temperature and phosphate content. It shows that abundance decreases with increasing temperature while evenness increases with temperature. This might be suggestive of the fact that in the shallower depths where the temperature is high, species are found and dominated by particular species as there is high evenness. This also shows that competition is lower at increasing depth, more abundance is found, and there are high chances of species co-occurrence.

On considering predation as a proxy for competition, we find that in areas of highest abundance and richness in latitudinal bins 17 and 18, there is the highest amount of predation marks found, which suggests that the mid-latitudinal bins in our area of study have strong species interaction. But predation does not erase any species, and the diversity remains high irrespective of the fact of the high predation. It was followed by the latitude 14N bin, where also we found higher values of richness and diversity compared to other areas of our study. Another important observation is that the predation is not kept restricted to one particular morphospecies, and it is evenly spread. It may be conclusive of the fact that there is less chance of erasing of any species due to excessive predation on that particular species. But the diversity across depth cannot be explained by predation as there is no significant rise or fall in no species having drill hole values across depth bins, and there is uniform competition among species.

Looking at the trend of some of the most dominant morphospecies, there was no distinct trend across depth or latitudinal bins. Among the most distinct morphospecies, some were distributed equally across latitude and depth, whereas some of them were locally reached at a particular station. But most of the morphospecies which were not uniformly spread and were concentrated more locally were found chiefly in latitudes 17-18 degrees north, so there is a chance that the conditions in these latitudes favors these locally dominant species and hence contribute to high abundance and diversity in these latitudinal bins.

CONCLUSION

This study helped to narrow down the knowledge gap regarding the bivalves diversity and components driving it extensively in the Bay of Bengal and let us have a better understanding the drivers of diversity in tropics. Our study on bivalve diversity in Bay of Bengal shows diversity pattern not so consistent with previous studies. There was no trend found between the diversity indices and depth. Predation was evenly distributed across all latitudes and depths, it was evenly distributed across families as well which minimises the chances of any family going extinct at any location. Highest values of richness and diversity index are seen in central area of our study in the mid latitudinal bins in the areas of Krishna and Godavari delta, this is also accompanied by lowest evenness. Sediment type and organic matter content seems to be a major reason for the high diversity regions in the study. Variation of richness, evenness and Simpson’s diversity index show a strong correlation with abundance of species. Species abundance showed negative correlation with temperature whereas evenness showed positive correlation. Species evenness showed a positive correlation with temperature and negative correlation with phosphate content.

In future upon the successful identification till species level, the studies can be compared to the work done on beach sample across the East coast of India *(Chattopadhyay et al., 2021)* to check if the depth accumulated assemblage are represented by the beach assemblage. The oceanographic variables and sediment influx vary across all seasons, so if the samples are collected across all seasons, it can give a better picture of how the diversity indices vary with respect to the environmental parameters.

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TABLES:-

Station	Cruise	Latitude	Depth	Temperature	Salinity	Nitrate	Phosphate	Silicate
MC52	SSD067	10.3785	24	28.21154	33.65854	1.574074	0.266393	2.8125
MC53	SSD067	10.4048	52	27.32692	34.04268	4.768519	0.237705	4.453125
MC54	SSD067	10.4125	73	25.92308	34.57927	4.444444	0.430328	10.39063
MC37	SSD067	11.4143	91	23.51923	34.7622	7.5	0.918033	12.34375
MC38	SSD067	11.4178	52	27.32692	34.07317	4.907407	0.237705	4.453125
MC36	SSD067	11.4189	128	19.42308	34.90244	13.14815	1.459016	15.625
SC-42	SSK35	12.35	56	27.11538	34.15244	5.046296	0.245902	4.84375
GR08	SSD067	12.4425	78	25.15385	34.65854	5.833333	0.5	10.9375
GR09	SSD067	12.4434	46	27.57692	33.97561	3.009259	0.213115	4.375
GR07	SSD067	12.448	29	28.13462	33.73171	1.527778	0.262295	2.96875
GR10	SSD067	12.4538	76	25.42308	34.65244	4.768519	0.5	11.09375
SC-44	SSK35	12.52	33	28.01923	33.73171	1.574074	0.278689	2.96875
SC-43	SSK35	12.52	52	27.32692	34.07317	4.953704	0.237705	4.453125
SC-45	SSK35	12.68	107	22.30769	34.85366	8.009259	1.311475	13.28125
SC-46	SSK35	12.72	190	14.94231	34.97561	27.17593	2.204918	28.59375
GR06	SSD067	13.5523	29	28.13462	33.73171	1.62037	0.262295	2.96875
GR02	SSD067	14.5473	52	27.32692	34.07317	4.953704	0.237705	4.453125
GR04	SSD067	14.5537	104	22.30769	34.84756	7.916667	1.254098	13.75
GR03	SSD067	14.5562	66	26.44231	34.43293	9.166667	0.290984	8.28125
MC-08	SK308	15.35	76	24.51923	34.44512	6.759259	1.07377	5
MC-28	SK308	15.83	32	28.03846	33.37195	1.666667	0.418033	4.53125
MC-30	SK308	16.57	40	27.61538	33.68293	2.5	0.491803	4.375
MC-39	SK308	17.44	55	26.65385	34.07927	2.685185	0.491803	4.375
SC-33	SSK35	17.59	114	21.07692	34.81098	16.89815	1.938525	10.85938
SC-32	SSK35	18.05	55	26.65385	34.07927	2.685185	0.491803	4.375
MC-51	SK308	18.13	73	25.03846	34.42073	4.537037	0.967213	4.6875
SC-28	SSK35	18.16	100	22.46154	34.69512	14.21296	1.717213	9.84375
MC-49	SK308	18.19	29	28.05769	33.82927	1.296296	0.409836	3.828125
SC-29	SSK35	18.25	54	26.75	34.08537	2.685185	0.512295	4.21875
SC-30	SSK35	18.3	36	27.82692	33.64024	1.898148	0.446721	3.75
SC-26	SSK35	18.85	122	20.30769	34.81098	18.93519	2.106557	13.59375
SC-27	SSK35	19.01	55	26.19231	34.18293	7.166667	0.454918	4.765625
SC-25	SSK35	19.16	106	20.21154	34.89634	23.20833	1.987705	12.65625
SC-23	SSK35	19.32	33	27.65385	33.71951	4.125	0.368852	5.46875
MC-68	SK308	19.36	29	27.84615	33.54878	3	0.32377	6.09375
SC-17	SSK35	20.2	34	27.55769	33.85976	3.25	0.368852	5.78125
SC-13	SSK35	20.69	54	26.17308	34.19512	7.166667	0.459016	4.84375
SC-12	SSK35	20.71	83	23	34.70732	13.83333	1.213115	7.65625
SC-15	SSK35	20.87	36	27.53846	33.84146	4.416667	0.377049	5.9375
SC-14	SSK35	20.94	42	27.21154	34.0061	5.916667	0.413934	6.25

1) Table stating the stations from where we found bivalves and oceanographic factors associated with each station