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Abundance and check list of available *Conus* species in Thoothukudi of southeast coast of India

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Abstract

A detailed study was undertaken on the biodiversity of *Conus* species in Gulf of Mannar coast from September 2011 to July 2012. In addition, various biodiversity indices were estimated using PRIMER V6 software. The poisonous gland was separated and its radular structure was explained. A total of 16 *Conus* species were recorded from three different stations of Gulf of Mannar belonging to the single genus *Conus*. Therespuram representing the highest number of species (201) followed by Keelakarai and Vembar. The catch of *Conus* species was very high in Pre-monsoon and summer. The species diversity was highest in Therespuram whereas lowest diversity found from Vembar stations, while Keelakarai station represents moderately. The highest Margalef species richness (d) was estimated in Keelakarai station with eight species and the lowest d' value found in Vembar with five species. Compared with three stations the species evenness was highest in Therespuram and lowest was observed from Vembar station. Bray-Curtis similarity observed that pre-monsoon has representing highest similarity from all three stations of Gulf of Mannar. Therespuram and Vembar showed that highest similarity in pre-monsoon and monsoon seasons. Through the study it could be concluded that Gulf of Mannar region has rich *Conus* diversity and the cone, *Conus betulinus* has neuromodulatory property.

Keywords: *Conus*, Diversity, Vembar, Keelakarai, Primer

1. Introduction

Biodiversity is defined as the variety and variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes. It is estimated that nearly 1,60,000 species were discovered and about 10 million species are yet to be identified from the marine environment of the world. Of the 34 known phyla, 32 are found in the sea and 15 are exclusively marine. Study of marine fauna in India has drawn greater attention from the 18th century onwards. Marine organisms constitute a wide range of forms, shapes and sizes, i.e., from zooplankton to whales. The coastal habitat and marine environment offer areas for reproduction, recruitment, feeding, shelter for variety of fauna and flora. Hence, these areas are rich in biodiversity. However in India, focus of studies on biodiversity was not made on many phyla [1]. India is one among the 12 mega biodiversity countries. However, the marine fauna of India are not same elsewhere. A survey of moderately sheltered rocky shore on the east coast will reveal a slight different suite of species from west coast and the island ecosystem may be equally rich in species diversity.

Further, many species may simply be common at one geographical extreme than the others, occurring with diminishing frequency along the north-south or east-west gradient. Tamil Nadu is endowed with a rich biodiversity. The members of the molluscan family Conidae is one of the major group of gastropod animals that represent the superfamily Toxoglossa, are mainly characterized by the possession of intense venom apparatus. All over the world nearly 500 *Conus* species are known, which are belonging to single genus *Conus* and highly predacious and nocturnal in feed and feeding habits. These are with few exceptions, almost inhabitants of tropical and subtropical water bodies. From the Indian waters various studies on the taxonomy and distribution of Conidae along the coast were reported 77 *Conus* [2]. Of this 48 *Conus* species was reported from the Gulf of Mannar. Cone snails, members of the genus *Conus*, are a remarkable group of predatory gastropod molluscs that have undergone spectacular speciation since the Upper Pliocene to produce over 500 extant species [3]. The objectives of the present study are as follows.

- To estimate the diversity of *Conus* species in Thoothukudi Coast.
- To prepare a checklist of available *Conus* species of Thoothukudi Coast.

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2. Material and methods

The present study on the biodiversity of *Conus* species of Thoothukudi Coast in Gulf of Mannar was carried out for eleven months from September 2011 to July 2012.

1.1. Collection

Initial sample survey was conducted from seven localities of Gulf of Mannar starting from Rameswaram to Manapad. Based on the availability of *Conus* species three locations were selected viz., Therespuram, vembar and Keelakarai coasts. The live and dead *Conus* species were collected and Sampling was done once in a month from the above landing centers for a period of eleven months from September 2011 to July 2012. The specimens were collected from various stations by using the bottom set gill net and skin diving. The data were pooled together station-wise as well as season-wise for calculating various biodiversity indices. To study the seasonality in distribution, specimens of *Conus* species were collected once in a month from the above said landing centers in summer (Apr-June), pre-monsoon (July -Sep), monsoon (Oct-Dec) and post-monsoon (Jan-Mar) for the study period. Species abundance data were calculated based on the total number of individual *Conus* species collected from these three stations during the study period.

1.2. Species identification

Cone shells with meat were dried under sunlight for two days for easy picking of meat. After completing the drying process, the meat portion was picked out from the shell with forceps. Shells with clear surfaces were cleaned with clean fresh water and periostracum of the shell was cleaned by placing them in a solution containing household bleach and water for two hours or otherwise removal of periostracum was done effectively by using the concentrated KOH. Then the surface of cone shells was gently brushed out to remove the periostracum completely. The cleaned specimens of *Conus* species were identified by using the guides given by [4]. As these guides have figurative keys, the identity of the gastropods *Conus* species was established without any ambiguity.

2.3. Preparation of check list

A checklist of various *Conus* species collected and recorded from the Thoothukudi coast during the study period, was prepared.

2.4. Biodiversity assessment

The total number of individuals for each species was recorded for eleven months from September 2011 to July 2012 from the landing centers of Therespuram, Vembar and Keelakarai. The occurrence and abundance data were collected once in a month. The collected data were pooled into four seasons and the seasonal data were used for the biodiversity assessment studies. By using the seasonal species abundance data as an input data, the following biodiversity indices were calculated using the PRIMER V6 for three landing centres.

2.4.1. Species diversity

The diversity of *Conus* species was calculated following Shannon -Wiener index using the following formula

$$H' = \frac{3.3219(N \log - \sum ni - \log ni)}{N}$$

Where, H' is the species diversity in bits of information per

individual, ni is the proportion of the sample belonging to i^{th} species (number of individuals of i^{th} species) and N is the total number of individuals in the collection and \sum is the summation.

2.4.2. Species richness: Species richness is a measure of the total number of the species present, making some allowances for the number of individuals. Species richness for each sample was calculated following Margalef index (d) using the formula,

$$d = \frac{(S-1)}{\log_e N}$$

Where, S is the total number of species in each sample i.e. species with non-zero counts and N is the total number of individuals in each sample.

2.4.3. Species evenness

This is the measure of equitability, a measure of how evenly the individuals are distributed among the species. Evenness was calculated following Pielou's evenness (J') using the formula,

$$J' = \frac{H'}{\log_2 S} \text{ or } \frac{H'}{\ln_2 S}$$

Where, H' is the diversity in bits of information per individual and S , the total number of species.

2.4.4. Dominance plot

To compare the individual species dominance between different stations and for different seasons, dominance plots were drawn by ranking the species in decreasing order of abundance. Relative abundance expressed as percentage of abundance in the sample was plotted across the species, against the increasing rank as x -axis, the latter on a log scale. On the y - axis, the cumulative percentage was plotted. This cumulative curve is referred as the dominance plot.

All the diversity indices and other calculations were done using the PRIMER v6 statistical package developed by Plymouth Marine Laboratory, UK [5].

2.5. Radular teeth preparation for microscopy:

The collected specimens were identified based on the morphology and colour pattern of the shells [6]. The radular sacs were removed from the body cavities and stored in 70% ethanol. From each specimen 1 to 6 radular teeth were taken from the short arm of the radular sac for morphometric analysis. The teeth were later cleaned in dilute sodium hypochlorite solution (20%), followed by double distilled water. Cleaning was repeated two or three times until the soft tissues were completely dissolved, leaving the radular whole. Then the teeth were mounted in water on the glass slides and observed under a compound microscope as described by [7]. The length of the teeth was measured by using the optical micrometer. The ratio of shell to tooth length was determined as the mean of values for each tooth taken from a healthy specimen and the illustrations of radular tooth were made by Camera Lucida.

2. Results

A detailed study was taken up for eleven months (September 2011 to July 2012) to assess the biodiversity of *Conus* species along the coast of Thoothukudi in the Gulf of Mannar. The

study area was divided into three stations namely Therespuram, Vembar and Keelakarai coasts where the *Conus* species are available in more numbers. Employing bottom set gill net samples were collected from these three locations. The mesh size ranged between 35- 60 mm. The nets were operated in between 5 and 15 fathoms. There are sixteen species collected from these three stations.

3.1. Check list of *Conus* species

The check list of collected *Conus* species was prepared. There were about sixteen *Conus* species identified from the Gulf of Mannar region (Table. 1).

3.2. Species composition and dominance

The total number of *Conus* species recorded from Therespuram, Vembar and Keelakarai during different seasons is given in Table.2, 3 and 4. It reveals that Therespuram has relatively high number of *Conus* species when compared with other two stations. Overall 201 *Conus* specimens were collected from Therespuram region followed by Keelakarai and Vembar. The spatial variations in the total number of species recorded among different stations and indicated that Therespuram and Keelakarai have equal number of species followed by Vembar.

The seasonal variations in the total number of species recorded between different stations are given in Table. 6. The number of species reported was higher during the pre-monsoon season in all the three stations followed by summer, post-monsoon and monsoon.

3.3. Biodiversity assessment

Biodiversity indices such as Shannon-Wiener species diversity [$H' (\log_2)$], Margalef's species richness (d), and Pielou's evenness (J'), were calculated for all the three stations during all the seasons. The spatial and seasonal variations in the above indices are provided as follows.

3.3.1. Species diversity

The Shannon-wiener diversity [$H'(\log_2)$] in Therespuram, Vembar and Keelakarai were in the range of 2.75779-2.9356, 1.982439-2.234512 and 2.231091-2.87754 respectively.

The spatial variation in H' among different stations are given in the following descending order Table.7.

Therespuram>Keelakarai>Vembar

The seasonal variation in H' for all the stations (Table 8) are in the following descending order.

Pre-monsoon> summer > post monsoon > monsoon.

The highest H' value was observed in Therespuram during pre-monsoon whereas the lowest was observed at Vembar during monsoon season.

3.3.2. Species richness

The spatial variation in 'd' among different stations are given in the following descending order (Table. 9).

Therespuram>Keelakarai>Vembar

The Margalef species richness (d) for Therespuram was in the range of 2.5161-2.9782. In Vembar this index was in the range of 1.6224-2.0922 and in Keelakarai it was in the range of 2.2136-2.8423 (Table. 10). The seasonal variations in Margalef richness for Therespuram is given in the following descending order.

Monsoon> summer > post monsoon > pre-monsoon

This sequence differs for Vembar and Keelakarai.

3.3.3. Species evenness

The Pielou's evenness (J') for Therespuram, Vembar and Keelakarai were found to be in the range of 0.977833-0.986421, 0.962352-0.999751 and 0.95918-0.970173 respectively.

The spatial variation in J' among different stations are given in the following descending order.

Vembar>Keelakarai>Therespuram

The seasonal variation in J' are given in the following descending order among the Therespuram, Vembar and Keelakarai stations.

Summer > pre-monsoon > post-monsoon > monsoon

3.3.4. Bray-Curtis similarity

Bray Curtis similarity index was calculated and given in table for season wise and location wise (Table.15&16). The similarity was found to be high between summers and pre-monsoon in all the locations in Therespuram and Vembar (Table.15) but between summer and post-monsoon at Keelakarai.

3.3.5. Dominance plot

The spatial variation and the seasonal variation in dominance plot among different stations in Gulf of Mannar are shown in Fig. 1 and 2. The dominance plots for different seasons in Therespuram, Vembar and Keelakarai stations are shown in Fig. 3, 4 and 5 respectively. In all the stations, a slight variation between the seasonal curves among different seasons was not noted.

3.3.6. Cluster analysis

The purpose of cluster analysis is help to organize the individuals into classes or groups such that within-groups and among groups similarities are analyzed. The dendrogram results are given in Fig. 6, 7, 8 and 9. The fig. 9 revealed that Therespuram data are forms a separate cluster indicating unique habitat for the *Conus* species. Finally the analysis of similarity was done and the result is given in Fig. 10.

3. Discussion

4.1. Checklist of *Conus* species

In the present study, 16 species belonging to single genus *Conus* were recorded in Gulf of Mannar, southeast coast of India. Among the 16 species the Therespuram station representing highest number of species followed by Keelakarai and Vembar stations. This agrees with earlier studies of [2] but the number of species recorded were relatively less during the present study. But the catch of *Conus* species was very high in pre-monsoon and summer season itself. The number of individual species collected was higher at Therespuram. Nearly 200 species were collected from this fish landing center and the lowest were collected from Vembar.

It differs from the earlier observations of [2] indicated that Keelakarai represented with higher number of *Conus* species than Therespuram. Among 16 species recorded *C. Leopardus* species dominated with 19.95%. The second highest contributed species was *C. eburneus* with the 14.18%. The number of species collected was higher during July followed by September.

4.2. Biodiversity indices

4.2.1. Species diversity

The Shannon-Wiener diversity $H' (\log_2)$ is the most widely used index for comparing diversity between various habitats

[8] and also seasons. In the present study, Shannon - Wiener diversity (H') was estimated to be in the range of 2.4473-2.9186 with the presence of 16 *Conus* species in the different stations of GOM. The high value of Shannon diversity index (H') observed in Therespuram region whereas the lower value was observed at Vembar. This is resulted due the increase in number of *Conus* species and their abundance at Therespuram. As revealed by [9] the Shannon index values indicate the differences between areas that possibly due to habitat type.

In all the three stations, the H' value was highest in pre-monsoon season due to the presence of conducive environmental factors such as water temperature and salinity [10]. The lower biodiversity indices were observed during the monsoon and post-monsoon periods.

4.2.2. Margalef Species richness

The Margalef species richness calculated in the present study ranged from 1.8465 to 2.4865. This value indicating that narrow range in 'd' value in the present study is due to less difference in the number of species recorded in Gulf of Mannar. Calculated 'd' value in the range of 0.999 – 0.967 in Hare Island, Gulf of Mannar. Among the three stations, the highest 'd' value was estimated for Keelakarai coast (2.4865) with 8 species and the lowest value was estimated from Vembar coast (1.8465) with 5 *Conus* species. In Therespuram, the Margalef species richness was the highest in monsoon followed by summer season. In Keelakarai species richness was observed in pre-monsoon followed by summer. Whereas at Vembar the highest Margalef species richness was estimated during monsoon followed by pre-monsoon.

4.2.3. Species evenness (J')

Compared with three regions, the species evenness values ranged between 0.8158 and 0.9729 and moderately higher evenness was observed at Therespuram. Generally, this index decreases when the species richness and species diversity increases. Species evenness decreases when the individual species dominance increases [8]. The above hypothesis holds good as observed in the present study. Season wise Pielou's evenness calculated in the present study found in similar ranges. The species evenness (J') was the lowest at Vembar. It should be due to low species richness and high individual dominance. In Keelakarai the species richness was observed as moderate. From the result it could be recognized that the *Conus* species at Therespuram is more diverse and heterogeneous than other two regions.

4.2.4. Dominance plot

In the species dominance plot, the curve for Therespuram coast lies on lower side and rises gradually due to less individual species dominance compared to the curves for Keelakarai and Vembar coasts.

In the dominance plots for all three stations of Gulf of Mannar Viz., Therespuram and Vembar and Keelakarai coasts showing the curve for Therespuram Pre-monsoon lies on lower side, rises slowly with higher number of species and less species dominance than the other curves for summer, monsoon and post-monsoon. When compared to all other stations Therespuram has dominance in *Conus* species. The dominance plot for individual station indicates the pre-monsoon dominance curve lies below. From Vembar station the curve has lower down rises quickly with maximum number of species representing from summer season. From

Keelakarai coast initially the summer season lower down and rises quickly with the maximum number of species. So, it is indicating that species dominant from all three stations were representing from the pre-monsoon season. The curve that peaks slowly, the Therespuram pre-monsoon curve has relatively greater number of species and more evenness as indicated by [11]. As lower diversity was found during the monsoon season at Vembar, the curve for this season was found at the top (Fig.8).

4.2.5. Bray-Curtis similarity

This tool is useful in studying assemblages. This method classifies objects to be similar according to distance or similarity measures. Bray-Curtis similarity using Group-average clustering appears to give a useful hierarchy of clusters [12]. This coefficient varies from 0 to 100% with the ends of the range representing the extreme possibilities. The similarity is 100% if the two samples are totally similar and it is 0 if the two samples are totally dissimilar. In the present study, similarity was used to ascertain the degree of relationship among the stations of Therespuram, Vembar and Keelakarai for various seasons. While comparing three stations individually, the dendrogram of Therespuram, Vembar and Keelakarai stations shows that pre-monsoon have more similarity than the other seasons. The Therespuram and Vembar shows that more similarity in pre-monsoon and monsoon seasons. Whereas Keelakarai station shows dominant in pre-monsoon and summer seasons. Therespuram, Vembar and Keelakarai had 89.773, 90.098 and 92.30589 of similarity respectively during pre-monsoon and monsoon seasons. While comparing all the three stations, Keelakarai had the higher level of similarity (92.30589), than the other stations during Pre-monsoon and monsoon seasons followed by Vembar (90.098) while Therespuram had the lower level of similarity. Different groups of stations were formed according to the cluster analysis results and three similarity levels in all the three stations (Fig. 6, 7 and 8). The dendrogram clearly indicates clustering effect of individual regions and nearly 80% similarities among them (Fig.9). It also indicates these regions have different types of animals with limited species common between them. In between seasons, only 40% similarities could be observed highlighting there is variations in *Conus* species availability.

Data were analyzed by non-metric multi-dimensional scaling (NMDS) and agglomerative, group-average linkage, hierarchical clustering on a similarity matrix generated with the Bray-Curtis similarity measure, using the PRIMER6 statistical package [8]. The purpose of using this is to represent the samples collected as points in a map (low dimensional space usually 3-d). The same pattern was also evident in the MDS plot where the samples from Therespuram during Pre-monsoon and monsoon had close similarity in species composition than other stations. This tool is useful in viewing the inter-relationship between the samples in a map and indicating similarity of *Conus* species available at individual stations and forms distinct clustering. The stress value is indicating the goodness of the fit [12]. In the present study, MDS stress value which was overlying on the MDS plot (0.01), showed an excellent ordination of the samples collected. This stress value, indicating distortion [8] was less than 0.2 indicating very good group separation [8]. The Bray Curtis similarity resemblance clearly indicates that clustering effect of individual stations in different seasons which ultimately exhibit clear variation in between the sampled regions.

4.2.6. ANOSIM

The Analysis of Similarity (ANOSIM) procedure was used to assess any significant differences among three locations. The ANOSIM procedure calculates a relative global R-value from 0 to 1, with 0 being no difference and 1 being complete difference between groups. Permutation based comparison is done between samples collected from regions, periods etc. The ANOSIM is not only doing this function but also does the function of MRT (Multiple Range Test) through which each and every sample is compared ^[12]. In present study, the range

of ANOSIM value is one which also confirms that the studied regions differed in *Conus* species diversity.

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Table 1: Total number of *Conus* species reported from Gulf of Mannar during the present collection.

Sl. No	Species Name
1.	<i>Conus araneosus</i> (Linnaeus, 1758)
2.	<i>Conus aulicus</i> (Linnaeus, 1758)
3.	<i>Conus betulinus</i> (Linnaeus, 1758)
4.	<i>Conus eburneus</i> (Hwass in Bruguiere, 1792)
5.	<i>Conus flavidus</i> (Lamarck, 1810)
6.	<i>Conus generalis</i> (Linnaeus, 1767)
7.	<i>Conus leopardus</i> (Roding, 1798)
8.	<i>Conus litoglyphus</i> (Hwass in Bruguiere, 1792)
9.	<i>Conus litteratus</i> (Linnaeus, 1758)
10.	<i>Conus nivalis</i> (da Motta, 1985)
11.	<i>Conus neptunus</i> (Reeve, 1843)
12.	<i>Conus planorbis</i> (Born, 1778)
13.	<i>Conus suratensis</i> (Hwass in Bruguiere, 1792)
14.	<i>Conus striatus</i> (Linnaeus, 1758)
15.	<i>Conus textile</i> (Linnaeus, 1758)
16.	<i>Conus virgo</i> (Linnaeus, 1758)

Table 2: Monthwise *Conus* species collected from Therespuram region of Gulf of Mannar.

Species Name	Sep-'11	Oct-'11	Nov-'11	Dec-'11	Jan-'12	Feb-'12	Mar-'12	Apr-'12	May-'12	Jun-'12	Jul-'12	Total
<i>Conus araneosus</i>	5	1	1	1	2	1	1	2	2	3	4	23
<i>Conus aulicus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus betulinus</i>	4	2	1	1	2	2	3	2	3	3	5	28
<i>Conus eburneus</i>	5	2	2	1	3	3	2	4	3	4	5	34
<i>Conus flavidus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus generalis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus leopardus</i>	4	1	2	2	3	2	2	3	4	1	5	29
<i>Conus litoglyphus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus litteratus</i>	5	2	1	1	2	2	1	2	3	3	5	27
<i>Conus nivalis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus neptunus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus planorbis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus suratensis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus striatus</i>	1	0	0	0	0	0	0	0	0	1	0	2
<i>Conus textile</i>	3	0	0	1	0	1	1	2	1	2	4	15
<i>Conus virgo</i>	7	1	2	1	3	4	5	4	3	5	8	43
Total	34	9	9	8	15	15	15	19	19	22	36	201

Table 3: Month wise *Conus* species collected from Vembar region of Gulf of Mannar.

Species Name	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Total
<i>Conus araneosus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus aulicus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus betulinus</i>	4	1	0	1	2	2	1	3	2	3	5	24
<i>Conus eburneus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus flavidus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus generalis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus leopardus</i>	5	1	1	2	3	1	1	3	2	3	5	27
<i>Conus litoglyphus</i>	4	1	2	1	2	2	1	2	3	3	5	26
<i>Conus litteratus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus nivalis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus neptunus</i>	3	2	1	1	3	1	2	2	2	3	4	24
<i>Conus planorbis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus suratensis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus striatus</i>	1	0	0	0	0	0	0	0	0	0	0	1
<i>Conus textile</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus virgo</i>	0	0	0	0	0	0	0	0	0	0	0	0
Total	17	5	4	5	10	6	5	10	9	12	19	102

Table 4: Month wise *Conus* species collected from Keelakarai region of Gulf of Mannar.

Species Name	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Total
<i>Conusaraneosus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conusaulicus</i>	5	2	2	3	3	2	3	4	2	2	5	33
<i>Conusbetulinus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conuseburneus</i>	3	1	2	1	3	3	1	3	3	1	4	25
<i>Conusflavidus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conusgeneralis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conusleopardus</i>	4	2	1	2	3	2	1	3	2	2	5	27
<i>Conuslitoglyphus</i>	3	0	0	1	2	0	0	1	2	1	4	14
<i>Conuslitteratus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conusnivalis</i>	2	0	0	0	0	0	0	1	0	0	0	3
<i>Conusneptunus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conusplanorbis</i>	2	1	1	0	2	0	0	1	1	0	1	9
<i>Conusuratensis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conusstriatus</i>	0	0	0	0	0	0	0	0	0	0	1	1
<i>Conus textile</i>	1	0	0	0	0	0	0	0	0	0	0	1
<i>Conusvirgo</i>	0	0	0	0	0	0	0	0	0	0	0	0
Total	20	6	6	7	13	7	5	13	10	6	20	113

Table 5: Spatial variation in total number of species (S)

Station	S
Therespuram	8
Vembar	5
Keelakarai	8

Table 6: Seasonal variation in total number of species (S) recorded in three different locations of Gulf of Mannar.

Stations	Summer	Pre-monsoon	Monsoon	Post-monsoon
Therespuram	8	8	7	7
Vembar	4	5	4	4
Keelakarai	6	8	5	5

Table 7: Spatial Variation in Shannon – Wiener index (H' (\log_2))

Stations	H' (\log_2)
Therespuram	2.9186
Vembar	2.4473
Keelakarai	2.7882

Table 8: Seasonal variation in Shannon Wiener index (H' (\log_2))

Stations	Summer	Pre-monsoon	Monsoon	Post-monsoon
Therespuram	2.933499	2.9356	2.769235	2.75779
Vembar	1.999502	2.234512	1.982439	1.998254
Keelakarai	2.493448	2.87754	2.231091	2.252672

Table 9: Spatial variation in Margalef species richness (d)

Stations	d
Therespuram	2.2065
Vembar	1.8465
Keelakarai	2.4865

Table 10: Seasonal variation in Margalef species richness (d)

Stations	Summer	Pre-monsoon	Monsoon	Post-monsoon
Therespuram	2.810997	2.5161	2.978191	2.625868
Vembar	1.622434	1.897202	2.092163	1.817766
Keelakarai	2.549415	2.842257	2.341894	2.213555

Table 11: Spatial variation in Pielou's evenness (J')

Stations	J'
Therespuram	0.97286
Vembar	0.81578
Keelakarai	0.92938

Table 12: Seasonal variation in Pielou's evenness (J')

Stations	Summer	Pre-monsoon	Monsoon	Post-monsoon
Therespuram	0.977833	0.978533	0.986421	0.982345
Vembar	0.999751	0.962352	0.99122	0.999127
Keelakarai	0.964597	0.95918	0.960878	0.970173

Table 13: Seasonwise biodiversity indices of *Conus* species at three different locations of Gulf of Mannar

Season	S	d	J'	H'(log2)	Lambda+
Therespuram					
Summer	8	2.810997	0.977833	2.933499	0.056461
Pre-monsoon	8	2.5161	0.978533	2.9356	0.077005
Monsoon	7	2.978191	0.986421	2.769235	0.018511
Post-monsoon	7	2.625868	0.982345	2.75779	0.056218
Vembar					
Summer	4	1.622434	0.999751	1.999502	0.110119
Pre-monsoon	5	1.897202	0.962352	2.234512	0.113554
Monsoon	4	2.092163	0.99122	1.982439	0.022745
Post-monsoon	4	1.817766	0.999127	1.998254	0.072571
Keelakarai					
Summer	6	2.549415	0.964597	2.493448	0.052788
Pre-monsoon	8	2.842257	0.95918	2.87754	0.065549
Monsoon	5	2.341894	0.960878	2.231091	0.051422
Post-monsoon	5	2.213555	0.970173	2.252672	0.064707

Table 14: Biodiversity indices of *Conus* species in Gulf of Mannar

Season	S	d	J'	H'(log2)	Lambda+
Therespuram	8	2.2065	0.97286	2.9186	9.8657E-2
Vembar	8	1.8465	0.81578	2.4473	0.19169
Keelakarai	8	2.4865	0.92938	2.7882	0.10532

Table 15: Bray-Curtis similarity for *Conus* species between various seasons at three different locations of Gulf of Mannar

	Summer	Pre-monsoon	Monsoon	Post-monsoon
Therespuram				
Summer	76.66	89.773	-	-
Pre-monsoon	63.407	75.643	85.51	-
Monsoon	-	-	-	-
Post-monsoon	86.566	--	--	-
Vembar				
Summer	79.536	90.098	-	-
Pre-monsoon	67.5	-	-	-
Monsoon	-	-	-	-
Post-monsoon	89.219	77.493	84.39	-
Keelakarai				
Summer	87.40644	92.30589	-	-
Pre-monsoon	63.9547	68.33745	75.43307	-
Monsoon	-	-	-	-
Post-monsoon	95.05261	-	-	-

Table 16: Bray-Curtis similarity between three different stations of Gulf of Mannar

	Therespuram	Vembar	Keelakarai
Therespuram	35.552	38.544	-
Vembar	-	-	-
Keelakarai	39.721	-	-

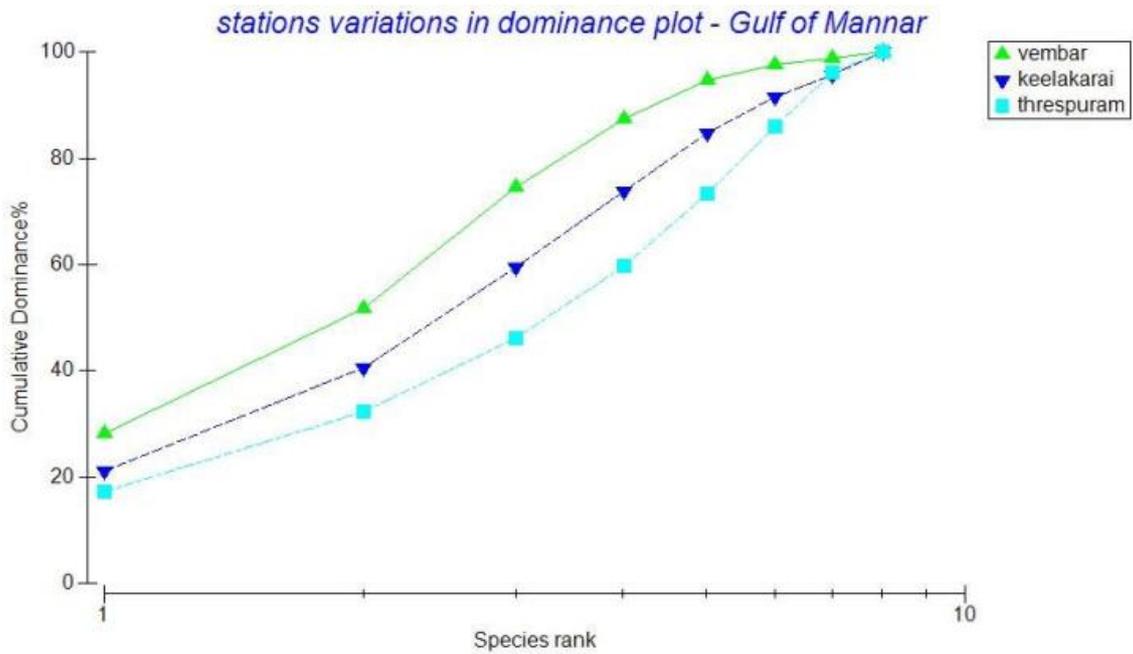


Fig 1: Seasonal variation in dominance plot among different stations in Gulf of Mannar

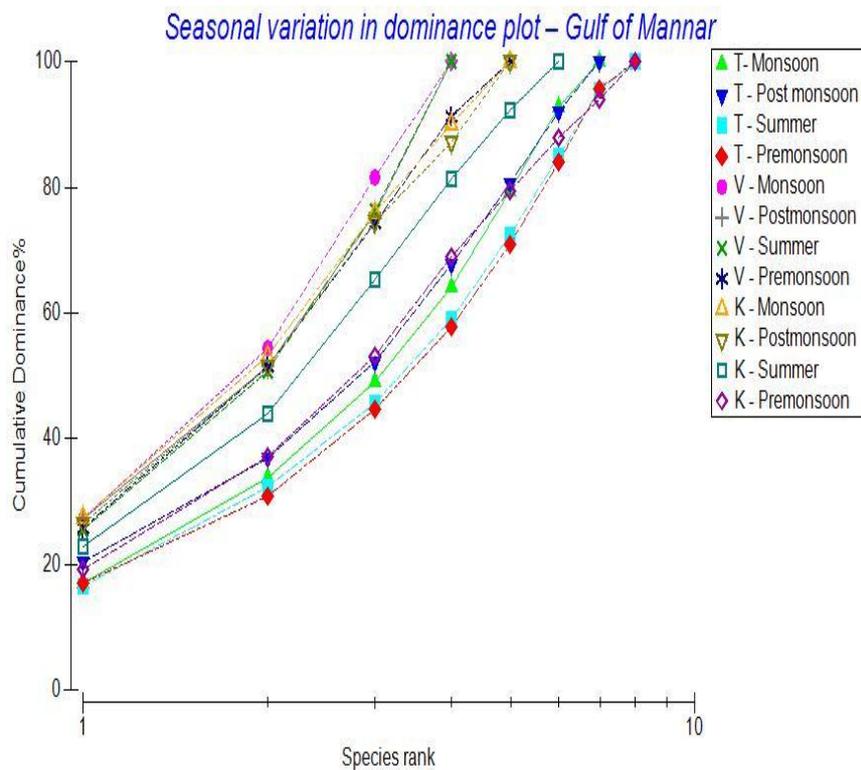


Fig 2: Seasonal variation in dominance plot among different stations in Gulf of Mannar

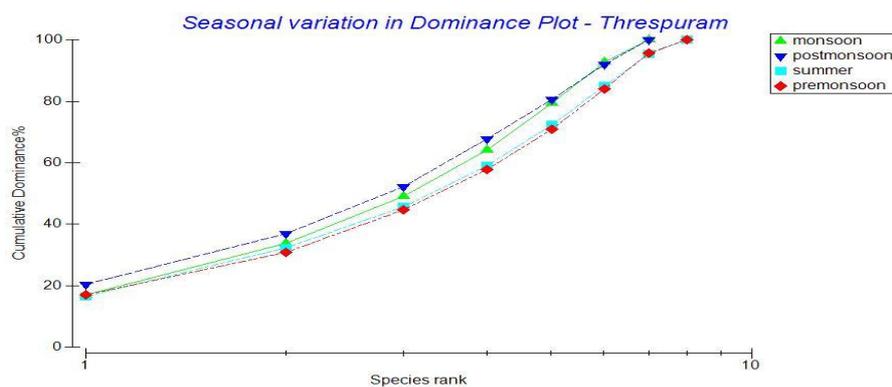


Fig 3: Dominance plots for different seasons in Therespuram, stations

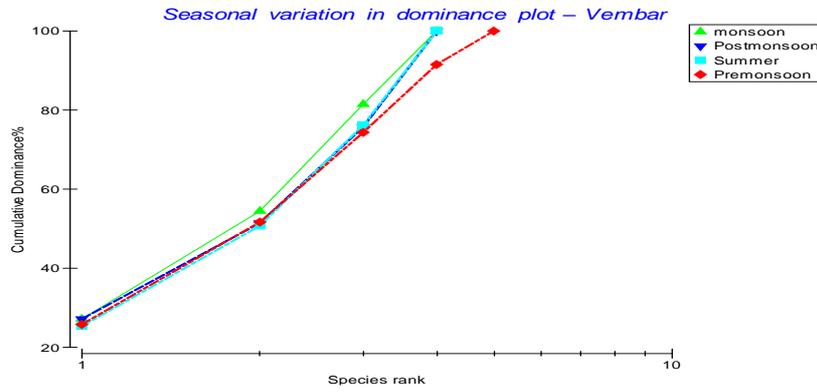


Fig 4: Dominance plots for different seasons in Vembar stations

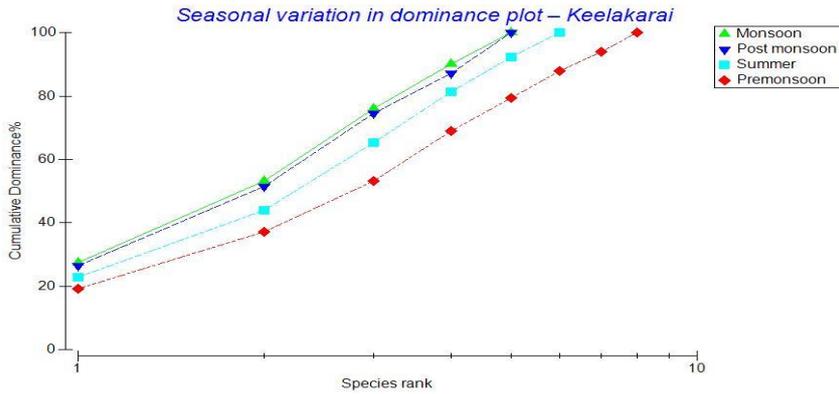


Fig 5: Dominance plots for different seasons in Keelakarai stations

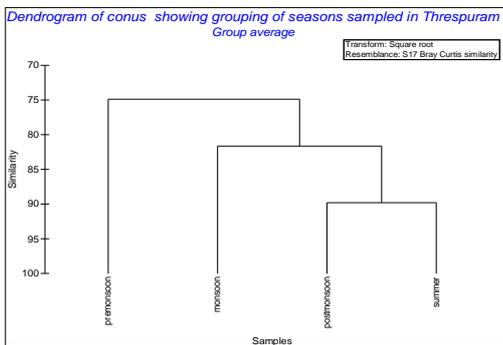


Fig. 6: Dendrogram showing similarities between seasons based on the composition of *Conus* species collected at Thersapuram

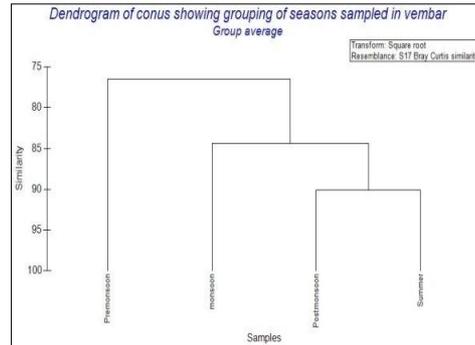


Fig. 7: Dendrogram showing similarities between seasons based on the composition of *Conus* species collected at Vembar

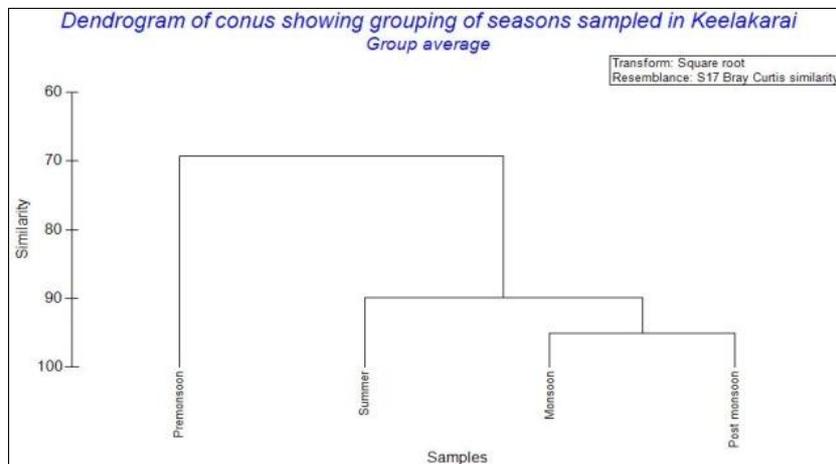


Fig 8: Dendrogram showing similarities between seasons based on the composition of *Conus* species collected at Keelakarai

Dendrogram of conus showing grouping of seasons sampled in conus
Group average

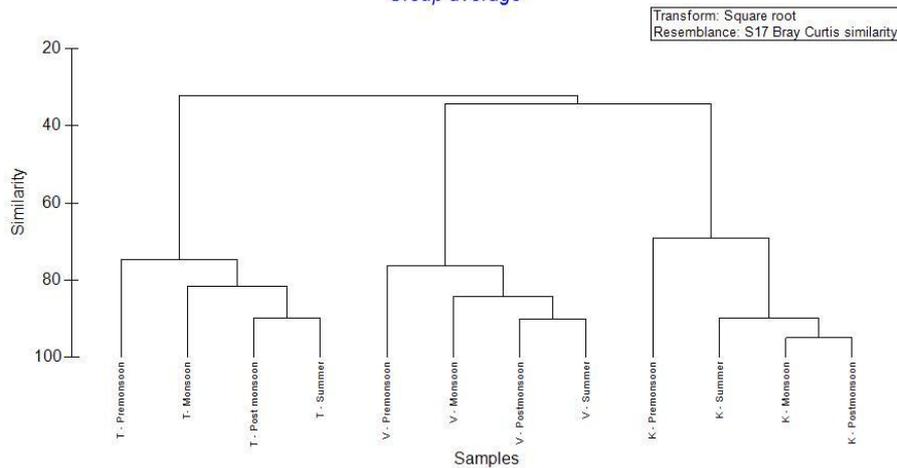


Fig 9: Dendrogram showing similarities between stations and seasons based on the composition of *Conus* species collected at three locations of Gulf of Mannar

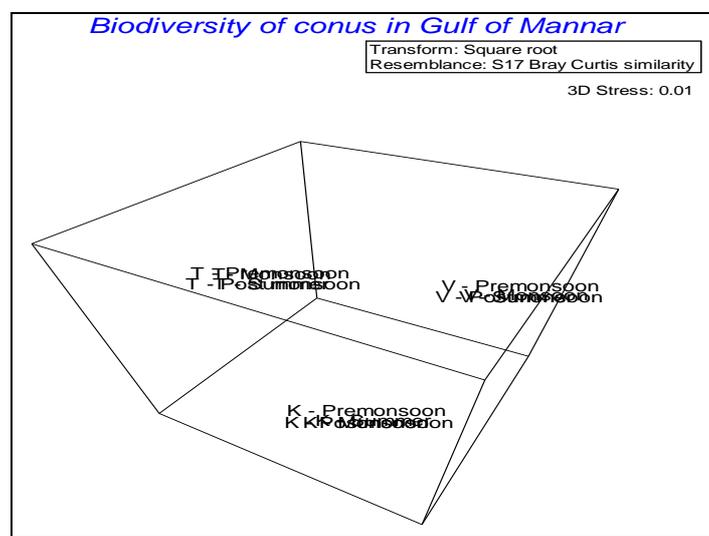


Fig 10: MDS plot produced after calculation of Bray-Curtis similarity index on square Root transformed *Conus* species data from three stations of Gulf of Mannar. (MDSStress value = 0.01).

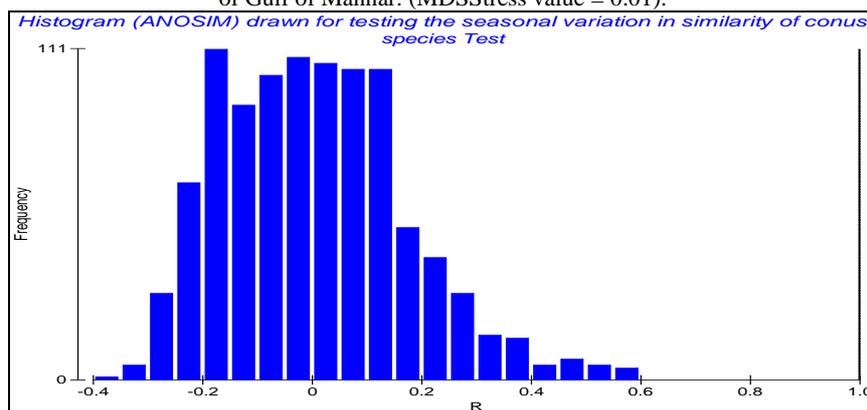


Fig 12: Histogram (ANOSIM) drawn for testing the seasonal variation in similarity of *Conus* species test

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