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HABITAT DIVERSITY OF HERMIT CRAB *CLIBANARIUS LONGITARSUS* (DE HAAN) IN VELLAR ESTUARY, SOUTHEAST COAST OF INDIA

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Abstract

The habitat diversity of hermit crab *Clibanarius longitarsus* was studied in 5 stations of Vellar estuary. This hermit crab was found to occupy the shells of as many as 44 species of gastropods. The abundance of this hermit crab (144/m^2- 41/m^2) so also the number species of gastropod shells it occupied decreased from the mouth to the upper reaches of estuary (39-11 species). The Shannon diversity (H'log2) was in the range of 4.08-2.64 in stations 1-5. The Margalef species richness showed clear differences between the stations and it varied from 7.52 in station 1 to 2.69 in station 5. The evenness was more in station 1 (0.77) and decreased to 0.65 in station 2 and thereafter it increased in stations 3 and 4 to reach 0.76 in station 5. The taxonomic diversity index decreased from station 1 (75.48) to station 4 (58.59) and increased in station 5 (62.2). The total phylogenetic diversity index which was more in station 1 (1840) decreased through stations 2-5 to reach 660 in station 5. The variation in taxonomic distinctness index increased from station 1 (362.67) to station 3 (468.78). The similarity in species composition of gastropod shells among the stations was in the range of 50.55%-81.73%. In cluster analysis the grouping was quite clear with stations in the lower reaches (stations 1 and 2) forming a group and stations in the middle of the estuary (stations 3 and 4) forming a group to which the station in the upper reaches (station 5) got linked. The cluster analysis and MDS clearly showed the variation in species composition between the stations. The average dissimilarity in species composition between stations 1 and 5 was 63.61%. Gastropod species which contributed to greater percentage of dissimilarity were *Cerithidea fluviatilis, Umbonium vestiarium, Pila globosa, Babylonia spirata and Turritella acutangula*. The abundance shown as bubble plot clearly showed the decreasing abundance of *Cerithidea cingulata, Babylonia spirata* and *Turritella acutancula* from the mouth to the upstream stations. The taxonomic relatedness tests carried out (95% funnel and 95% ellipse) also clearly showed the differences in the habitat diversity of the hermit crab in different stations of Vellar estuary.

Key Words: Habitat Diversity; Hermit Crab; Gastropods; Diversity indices; Similarity.

Introduction

Hermit crabs, the most interesting group of organisms among the decapod crustaceans, have a soft abdomen and to protect this they take refuge inside the empty gastropod shells. To eke out a life inside the empty gastropod shell, they have modified their body form to suit the shape of the shell. This behaviour of hermit crabs living in empty gastropod shells has intrigued naturalists down through the ages from Aristotle [1] to the present [2,3]. Reese [4] suggested that increased availability of snail increases the density of natural population of hermit crabs. Vance [5] proved this experimentally by adding empty gastropod shells which increased the number of hermit crabs subsequently.

Hermit crabs occupy empty gastropod shells, and these shells act as shelters from biotic factors including predation [6,7,8,9], and abiotic factors such as desiccation [10,11] and osmotic stress [12,13]. Particular gastropod shells are non-randomly chosen based on shell characteristics that optimally match requirements of individual hermit crabs [4, 14,15,16,17]. Shell choice occurs following shell investigation, which can vary depending on hermit crab condition and gastropod shell quality [18,19,20,21]. These portable shell habitats are exchanged frequently for new shells as hermit crabs grow, thus shell choice behavior continues to be important throughout the lifetime of a hermit crab [22,23].

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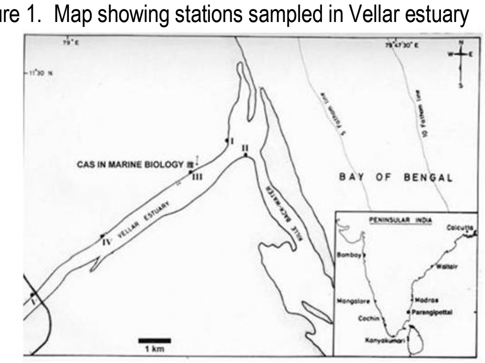
Hermit crabs need increasingly larger shells during their life cycle, a fact that keeps them in constant activity searching for suitable shells [24]. The life cycle of hermit crabs depends mostly on the processes that make suitable gastropod shells [23]. According to the hypothesis more commonly used, in their natural habitat, hermit crabs inhabit smaller shells than in laboratory experiments [25,26]. Hermit crabs seem to select among the available empty gastropod shells the most suitable one for their size and shape [27]. As empty gastropod shells constitute an important resource for hermit crabs, in the present study the habitat diversity of hermit crab *Clibanarius longitarsus* that occurs abundantly in the Vellar estuary was studied in different stations.

Materials and Methods

Hermit crabs were collected from the following 5 stations of Vellar estuary (lat.11^0 29' N; long.79^0 46' E) flowing on the southeast coast of India. Station 1 was located close to the mouth region of the estuary near the fish landing centre (Figure 1) in the marine zone of the estuary.

Figure 1. Map showing stations sampled in Vellar estuary



Station 2 was located further up in the estuary where the Killai backwaters join the estuary. Station 3 was about 4 km from the mouth of the estuary just opposite to the Centre of Advanced Study in Marine Biology. Station 4 was about 7 km interior from the mouth of the estuary where Buckingham canal joins the Vellar estuary. Station 5 was located near the railway bridge about 10 km west of the mouth of estuary. Collections were made during the low tide. One of the disadvantages in sampling during low tide is that, the crabs have the tendency to clump together in the exposed intertidal area. This was overcome by making collections near the water level where that much of clumping was not noticed. One metre quadrat was used for sampling. All the hermit crabs occurring in the one square metre area was collected and counted. The species of shell occupied by the hermit crab was identified and the animals with shells were returned to the estuary. The species of gastropod shells occupied by the hermit crab was identified using the gastropod identification manual of Rajagopal et al [28]. The habitat diversity was studied using the univariate, graphical and multivariate tools available in PRIMER manual [29].

Results

The hermit crab *C. longitarsus* was found to occupy as many as 44 species of gastropod shells in all the five stations. The gastropod shells found to be occupied by this hermit crab were *Umbonium vestiarium, Clithon oualaniensis, Cymatium cingulatum, Tonna dolium, Bursa rubeta, B. spinosa, Phalium areola, P. bisulcatum, P. canaliculatum, P. glaucum, Ficus ficus, F. gracilis, Turritella acutangula, T. attenuata, Janthina roseola, Cerithidea cingulata, Telescopium telescopium, Natica didyma, N. lamarkii, N. tigrina, N. lineata, Strombus marginatus, Pila globosa, Hemifusus pugilinus, Bullia vittata, Nassarius dorsatus, N. stolatus, N. variegatus, Babylonia spirata, B. zeylonica, Cantharus tranquobaricus, Murex trapa, M. tribulus, M. virgineus, Rapana bulbosa, R. rapiformis, Thais bufo, T. regusa, Cancellaria crispa, Oliva gibbosa, O. oliva, Tudicula spirillus, Xancus pyrum and Harpa conoidalis.* The abundance of this hermit crab in the five stations was respectively 144, 134, 88, 46 and 41/m^2. In station 1 this hermit crab was found to occupy as many as 39 species of gastropod shells. *C. cingulata* was found to be dominant in this station with percentage occurrence of 36.11% followed by *T. acutangula* with percentage occurrence of 8.33%. In station 2, this hermit crab was found to occupy 26 species of gastropod shells. *C. cingulata* was found to be dominant in this station with percentage occurrence of 52.99% followed by *U. vestiarium* and *T. acutangula* with percentage occurrences of 12.69% & 7.46%. In station 3, this hermit crab was found to occupy 18 species of gastropod species. In this station also *C. cingulata* was found to be dominant with percentage occurrence of 48.86% followed by *T. acutangula* with percentage occurrence of 10.23%. In station 4 this hermit crab was found to occupy 15 species of gastropod shell. Here also *C. cingulata* was found to be dominant with percentage occurrence of 45.65% followed by *T. acutangula* with percentage occurrence of 17.39%. In station 5, the number of species of gastropod shells occupied by this hermit crab was 11. In this station also *C. cingulata* was found to be dominant with percentage occurrence of 36.59% followed by *P. globosa* and *T. acutangula* with percentage occurrences of 24.39% and 14.63% respectively. *P. globosa* was found only in this station having the influence of freshwater run-off from the nearby streams and paddy fields. As a whole *C. cingulata* was found to be dominant with percentage occurrence of 44.69% followed by *T. acutangula* and *T. attenuata* with percentage occurrences respectively of 9.93% and 5.3%.

Table 1. Habitat diversity of hermit crab *Clibanarius longitarsus* in stations I to V of Vellar estuary

	S	N	d	J'	H'(log2)	Lambda'	Delta	Delta+	Lambda+	sPhi+
I	39	156	7.52	0.77	4.08	0.12	75.48	86.15	362.67	1840
II	26	107	5.35	0.65	3.09	0.24	65.18	85.41	403.9	1400
III	18	88	3.79	0.69	2.89	0.25	59.62	84.18	468.77	940
IV	15	46	3.65	0.71	2.8	0.23	58.58	85.14	419.26	860
V	11	41	2.69	0.76	2.64	0.20	62.19	84	529.45	660

In line with the higher number of gastropod species occupied by this hermit crab in station 1, the Shannon diversity (H'log2) was also higher here (4.08). Diversity of shells decreased in the others through 3.10 in station 2 to 2.64 in stations 5 (Table 1). The Margalef species richness (d) also showed clear differences between the stations. It decreased from 7.52 in station 1 to 2.69 in station 5. Unlike in species diversity and richness, the evenness (J'), which was, more in station 1 (0.77) decreased to 0.66 in station 2 to rise again through stations 3 (0.69) and 4 (0.72) to station 5 (0.76). The taxonomic diversity (delta) index decreased from station 1 (75.48), through stations 2 (65.19), 3 (59.62), 4 (58.59) to rise in station 5 (62.2).The variation in taxonomic distinctness index increased from station 1 (362.67) to station 3 (468.77) to decrease in station 4 (419.27) to increase again (529.45) in station 5. The phylogenetic diversity (sPhi+) index was more in station 1 (1840) and decreased through stations 2-4 to 660 in station 5. The species area plot (accumulation curve) also clearly showed the more diverse nature of station 1. The curve rose slightly with addition of sample 2 after which there was no rise with the addition of samples 3 and 4. However with addition of sample from station 5 the curve rose by 1 species (due to the presence *P. globosa* only in this station (Figure 2). The dominance plot clearly showed the variation in habitat diversity with station 1, which showed more diversity to remain at the bottom of the plot. Above this were lying stations 2-5 in that order due to lower diversity than station 1 and station 5 which had only 11 species of gastropod shell was lying above the other stations (Figure 3).

Table 2. Similarity percentage of habitat diversity of hermit crab *Clibanarius longitarsus* in stations I to V of Vellar estuary

	I	II	III	IV	V
I	0	0	0	0	0
II	72.1	0	0	0	0
III	66.64	72.62	0	0	0
IV	50.55	68.80	81.73	0	0
V	36.39	51.11	59.68	75.21	0

The similarity in species composition among stations was in the range of 36.39-81.73% (Table 2). The minimum similarity in species composition was noticed between stations 1 and 5 while the maximum similarity was observed between stations 3 and 4 where the number of gastropod species recorded was respectively 18 and 15. The dendrogram drawn revealed clearly 2 groups based on similarity percentage. Station 3 and 4 formed a group at the similarity percentage of 81.73% followed by stations 1 and 2 at similarity percentage of 72.1%. Station 5 joined the group formed by stations 3 and 4 at 67%. These two groupings were ultimately linked at the percentage similarity of 58%. Stations in the lower reaches formed a group and stations in the middle formed another group to which the station in the upper reaches got linked (Figure 4). The same pattern was also evident in the MDS plot where samples from stations 1 and 2 fell on one side and others stations on the other side of the map. The dissimilarity between the stations was quite clear as stations gradually moved from the right hand side to the left hand side clearly (Figure 5). The stress value, which was overlying on the MDS plot (0.0) showed an excellent ordination of the samples collected.

Figure 2. Species area plot showing increase in number of gastropod species occupied by hermit crab with addition of samples from stations I-V

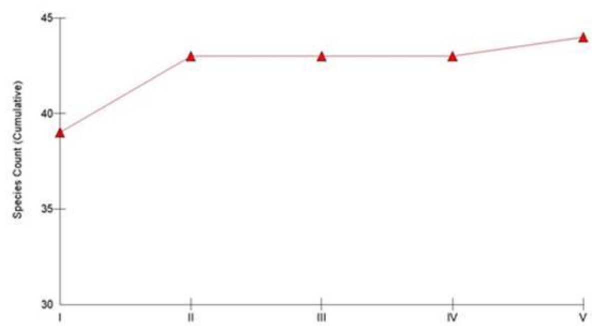
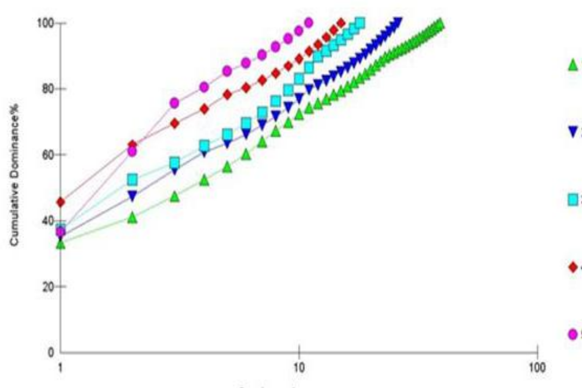


Figure 3. Dominance plot for stations I-V



The average dissimilarity in species composition of crabs between stations 1 and 5 was 63.61%. Gastropod species which contributed to greater percentage of similarity were *C. fluviatilis, U. vestiarium. P. globosa, B. spirata and T. acutangula.* The abundance shown as bubble plot (Figure 6) clearly showed the decreasing abundance of *C. cingulata, B. spirata* and *T. acutancula* from the mouth to the upstream stations. On the contrary *P. globosa* was present only in station *5.*

Figure 4. Dendrogram showing similarity in habitat diversity between stations I-V

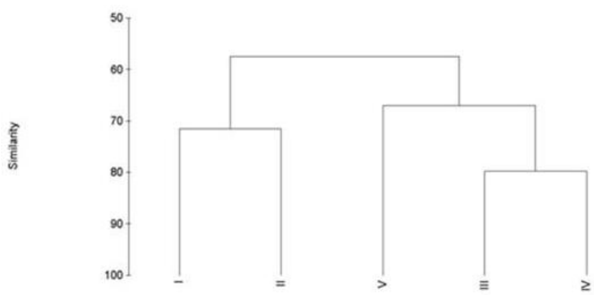


Figure 5. MDS (Multi dimensional scaling) showing dissimilarity between stations I-V

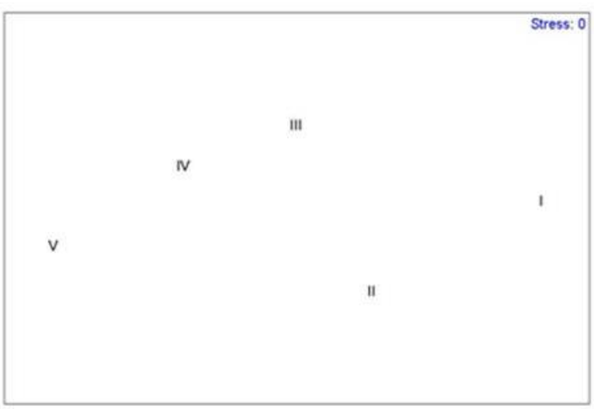


Figure 6. Bubble plot showing decreasing abundance of a) *C. cingulata*, b) *B. spirata*, c) *T. acutangula* from stations I to V and presence of d) *P. globosa* only in station V

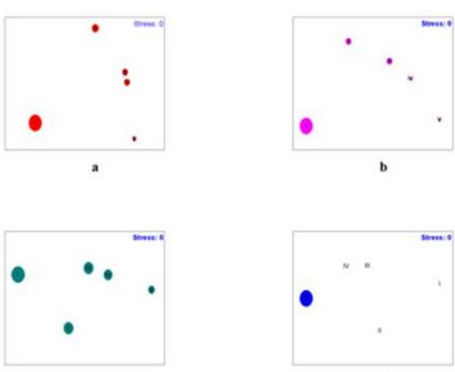


Figure 7. 95% confidence funnel showing lambda values of stations I-V

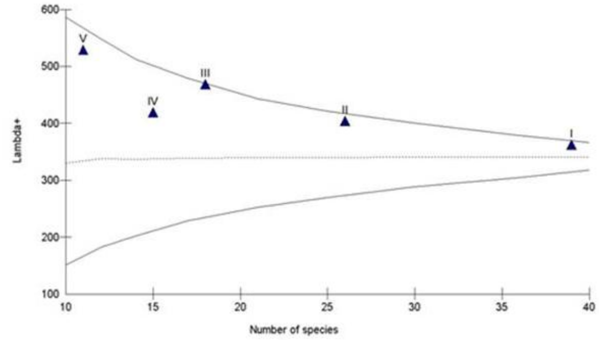


Figure 8. 95% confidence funnel showing delta values of stations I-V

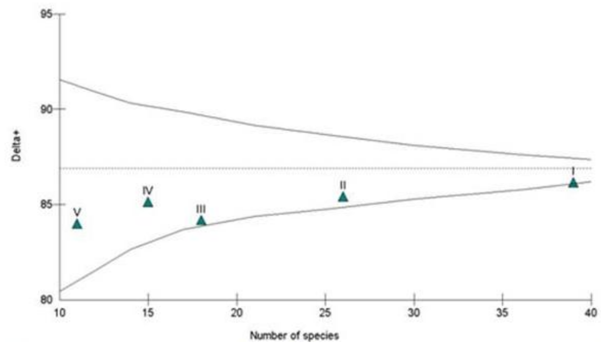
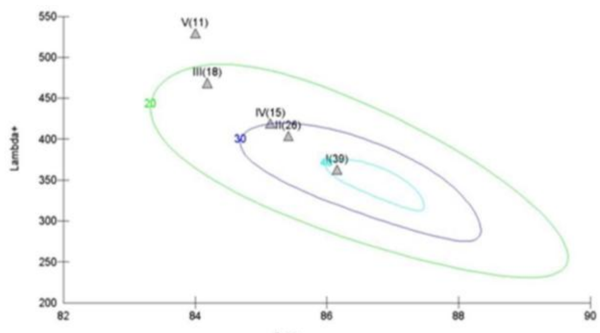


Figure 9. The ellipse plot showing combined distribution of lambda and delta value in stations I-V



The 95% confidence funnel generated for the lambda values of all the stations is shown in Figure 7. Even though all the stations fell within the confidence funnel, it clearly showed the variation in habitat diversity of the stations - gradual decline in diversity from station 1 (right hand side) to station 5 (left hand side). The same trend was noticed with respect to the 95% funnel generated for the delta values (Figure 8). In the ellipse plot drawn (Figure 9) combining the delta and lambda values also the above trend was clearly seen except of changes of places by stations 3 and 4 which showed maximum similarity percentage among themselves.

Discussion

The present study on the habitat diversity of hermit crab occurring in Vellar estuary showed interesting results. A total of 44 species of gastropod shell species was found occupied by the hermit crab *C. longitarsus* in the Vellar estuary. The number of gastropod shell species and the abundance of gastropod shell species decreased from station 1 situated near the mouth to station 5 situated in the upstream. The distribution and relative abundance of the hermit crabs could be related with the availability of shells.

Provenzano [30], Reese [4] and Hazlett [31] suggested that increased availability of snail shells increased the density of hermit crabs and Vance [25] proved experimentally that populations of Pagurus hirsutiusculus increased based on the availability of shells. Manjon-Cabeza and Garcia Raso [32] studied the gastropod shell utilization by hermit crabs Diogenes pugilator, Paguristes eremite and Pagurus forbesii along the Atlantic Ocean shores of Spain (Cadiz) and reported that these hermit crab species used many different gastropod shells, with Paguristes eremita being the largest species inhabiting heavier gastropod shell species belonging to the family Muricidae. The present study also shows that the distribution and abundance of hermit crabs are related to the distribution and availability of gastropod shells. In Vellar estuary, the distribution and abundance of small hermit crabs are influenced by C. cingulata and U. vestiarium. While the latter is available in the marine zone of the estuary, the former is distributed widely in the estuary. However, the abundance decreases from the mouth to the upstream of the estuary. This explains the decline in the abundance of smaller hermit crabs from station 1 to station 5. Coming to the larger hermit crabs, they were also found more in number in the marine zone of the estuary and the number decreased further upstream. This is mainly due to the availability of larger shells in station 1. Most of the shells occupied by the hermit crabs are of marine origin. Their availability in the marine zone of the estuary is attributed to the intensive fishing activity in the Parangipettai waters. Its coastal wasters support substantial shrimp fisheries and the fisheries are considered to be one among the best along the east coast of India [33]. During most part of the year, trawlers are operated exclusively for shrimps. The gastropod fauna is also found to be rich (more than 300 species recorded so far) and gastropods of different sizes are caught in large numbers by the trawlers. During sorting of the catch, the gastropod shells are discarded and many of the animals find their way into the estuary where the landings are brought. Unable to tolerate the estuarine conditions, the gastropods die and their shells are thus available for the hermit crabs. However the availability trickles further upstream leading to reduced diversity of the portable habitat of the hermit crabs.

The Shannon-Wiener diversity which is very widely used for comparing diversity between various habitats [34] clearly showed the difference in habitat diversity of the hermit crabs between the stations studied. With the number of species only in the range of 15-11 in stations 4 and 5, the slightly higher H' values (2.81 and 2.64) recorded in these stations could be attributed to the higher evenness values recorded here [34]. However the Margalef index, which has a very good discriminating ability, clearly brought out the variation in species richness of shells between the stations. As the conventional indices as the above are very much influenced by the sampling effort and species richness, diversity indices based on relatedness of species have been introduced such as taxonomic diversity index, variation in taxonomic distinctness index and phylogenetic diversity index by Clarke and Warwick [35]. These indices were used in the present study. Even though the taxonomic diversity index decreased from station 1 to station 4, the rise in the value in station 5 is attributed again to the higher evenness value also due to the Linnean taxonomic tree of this station. True to the fact that samples from biodiversity rich areas have more stability and less variation than others, the variation in taxonomic diversity index was low in the marine zone and higher in the other stations. The total phylogenetic diversity index, which vouches for the taxonomic breadth of the biota [36] also clearly showed the highly diverse nature of the lower reaches of the estuary compared to the upper reaches.

The similarity coefficient is extensively used to find out the degree of relationship (in species composition) between samples collected from various places. Of the numerous similarity measures that have been suggested over the years, the commonly used similarity measure is the Bray-Curtis similarity [37]. Therefore in the present study this measure was used. 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. The converse concept of similarity is that of dissimilarity, the degree to which two samples are unlike each other. However similarity and dissimilarity are just opposite sides of the same coin. In the present study similarity was used to find out the degree of relationship among the stations. The similarity decreased from one station to other through marine to upstream stations. While the lowest was found between stations 1and 5, the highest was noticed between stations 4 and 5. The similarity percentage is highly useful in treating the data further through cluster and MDS (multi-dimensional scaling) analyses.

Cluster analysis (or classification) is helpful in finding natural groupings of samples such that samples within a group are more similar to each other, generally than samples in different groups. It is also used to define species assemblages, i.e. groups of species that tend to co-occur in a parallel manner across sites. In the present study the stations in the lower reaches of the estuary showed more similarity among themselves rather than with the stations in the upstream. In the same way the stations in the middle showed more similarity with the station in the upper reaches rather than with the lower reaches. Therefore these stations formed groupings in the dendrogram. However as the cluster analysis has the inherent disadvantage of linking ultimately the dissimilar groups also, ordination of the samples was done using the Multi-dimensional Scaling (MDS). The purpose of using this is to represent the samples collected as points in a map (low-dimensional space usually 2-d). Samples lying closer have more similarity in species composition and samples lying apart have more dissimilarity in species composition. As noticed in the cluster pattern, here also the samples from the lower reaches fell on one side of the map and the others on the other side. On this map, the abundance of species, which vouched safe for the dissimilarity between the lower and upper reaches, was superimposed as circles of different sizes. This is called bubble plot. Larger the bubble size, greater is the value of the superimposed variable - here abundance of the gastropod species. The bubble plots clearly showed the higher abundance of discriminating species in the marine zone than the upstream except *P. globosa* (washed into the estuary from the nearby fresh water streams and paddy fields), which showed the reverse.

Variability is more among the less diverse areas and less among the highly diverse areas. Variability can be tested through tool as taxonomic distinctness which is helpful in checking the null hypothesis that a species list from one locality (or time), has the same taxonomic distinctness structure as the master list (of all species in that biogeographic region-Vellar estuary). Given the number of species observed in a sample, the test makes repeated drawings at random from the full master list and computes the delta plus and lambda plus values for each drawing. The above computation is performed for a range of sublist sizes (5, 15, 25 and 30 presently) noticed in various habitats and the 95% limits plotted against that size to give a 95% funnel. The advantage of this 95% funnel is that all the samples can be plotted in the same funnel. In the present study, the 95% funnel separated the stations of Vellar estuary and clearly showed the variation in the habitat diversity of hermit crab in different stations. Tests combining delta plus and lambda plus values in combination by plotting 95% probability contours (ellipse) are advantageous in testing under the usual null hypothesis of random sampling from the master species list and superimposing the real values. The ellipse plot also clearly separated the samples from various stations. The change of place of stations 3 and 4 is mainly attributed to variations in the delta plus and lambda plus values of these stations. As the habitat diversity of hermit crab in Vellar estuary is highly dependent on the fishing activity, it is worth studying the variations in habitat diversity of this hermit crabs and shell sufficiency through thick and thin of the fishing activity in Parangipettai waters.

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