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†Alpha, beta and gamma diversity of fished marine taxa along the southwest coast of India during 1970-2005

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Abstract

The data on species-wise marine fish landings at Kerala and Karnataka during 1970-2005 were used to examine diversities of fished taxa through alpha, beta, and gamma diversities which are the fundamental descriptive variables of ecology and conservation biology. In Kerala, fishing zone K5 (Kochi) and K3 (Kollam-Neendakara) and in Karnataka, fishing zone KN4 (Gangolli-Coondapur - northern Udupi district) followed by KN11 (Mangalore) had high alpha diversity values. These zones are major trawling zones. The beta diversity values and the species turnover rates were also high for these zones. The high beta values indicate uniqueness in species diversity when compared to other zones. The gamma diversity was 818 for Kerala and 524 for Karnataka. Beta diversity index showed a positive relationship with alpha index, indicating dependence of beta on alpha values. While the arthropod diversity was similar in Kerala and Karnataka, the chordate and mollusc diversity was higher in Kerala. The results from the present study indicate that similar studies have to be carried out from other ecosystems along the Indian coast, so that it becomes benchmark information for studying the anthropogenic impacts on biodiversity.

Keywords: Alpha, beta, gamma diversity, fished marine taxa, southwest coast of India

Introduction

The three terms for measuring biodiversity over spatial scales are alpha, beta, and gamma diversity (Whittaker, 1972). Alpha diversity refers to the diversity within a particular area or ecosystem, and is usually expressed by the number of species (*i.e.*, species richness) in that ecosystem. Beta diversity is a comparison of diversity between ecosystems usually measured as the amount of species change between the ecosystems. Gamma diversity is a measure of the overall diversity for different ecosystems within a region or as 'geographic-scale species diversity' (Hunter, 2002). The importance of β-diversity in indicating the extent to which habitats have been partitioned by species as a means of comparing habitat diversity and together with α-diversity, as a measure of overall biotic heterogeneity of an area is well known. Operationally, alpha diversity may be defined as the average number of species (or diversity) found in a set of sample units or areas and beta may be defined as the average number of species that is absent from a randomly

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chosen sample (Veech *et al.*, 2002). Hence, beta diversity is expressed in units of species richness or diversity.

Both Kerala and Karnataka along the southwest coast of India have highly developed coastal fisheries and average annual yields are close to one million tonne. Since the start of recorded history a large number of marine species are exploited from the southwest coast using a variety of gears (Pillai and Katiha, 2004). With the advent of modern gears like trawl, the number of species exploited has increased and there is fear of over-exploitation, decrease in abundance of many species and even disappearance of many species. However, as yet, there are no baseline records of the marine biodiversity of fished marine taxa from India.

The objective of the present study therefore is to find the fished marine taxa diversity in different marine fishing zones along Kerala and Karnataka to compare the variation in species richness within zones and to find out the beta diversity which is a measure of the uniqueness of zones in terms of biodiversity. This information can be used as a benchmark to discern changes in biodiversity in the future due to anthropogenic impacts.

Material and Methods

For the analysis, primary records containing species-wise and gear-wise catch and effort of marine fish landings of Kerala and Karnataka maintained by the Central Marine Fisheries Research Institute (CMFRI) in NMLRDC (National Marine Living Resources Data Centre) were the principal data source (period: 1970-2005). These data were collected by trained enumerators who could identify fished organisms to the species level in most cases. Although, the introduction of multi-day trawlers which fish without taking cognizance of state boundaries cause some distortion in the species landings records, this was treated as insignificant.

The CMFRI estimates marine fish catch and effort data from all along the Indian coast based on a stratified multi-stage random sampling design (Srinath *et al.*, 2005). In this design the stratification is over space and time. Although the taxonomic resolution of the data collected is high, there is considerable data reduction during the data processing to facilitate easier reporting. Consequently the catch data records which have more than 1000 species, are reduced to 83 species groups.

This data reduction is irreversible within the old data processing software capabilities. To enable the reporting of actual species caught (fished taxa biodiversity), the data records were re-entered from the original field data sheets using appropriate software and finally estimates were made and stored in MS ACCESS by developing an *estimation software* in C++ and Visual Basic code for exporting data. For each species (totaling 1628 records) the taxonomic tree was traced back to the phylum level by developing SQL queries of the database following the Linnaean system which breaks down organisms into seven major divisions, called taxa – Kingdom, Phylum, Class, Order, Family, Genus and Species.

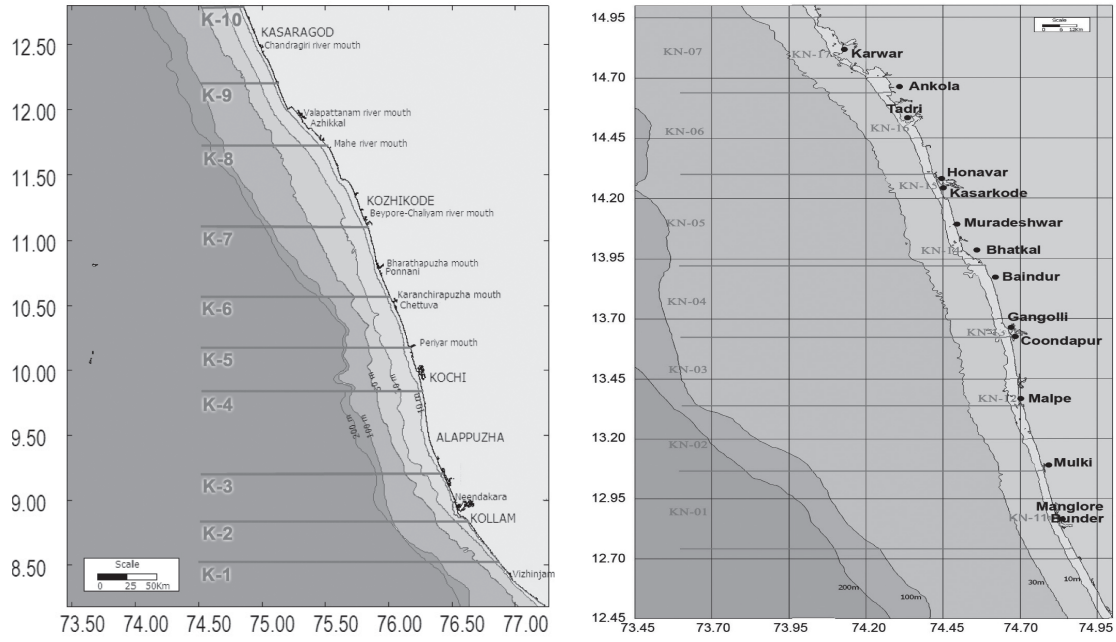
On a spatial scale, Kerala and Karnataka had 24 fishing zones as per the stratification of the sampling design developed by CMFRI, 14 in Karnataka and 10 in Kerala (Fig. 1. A and B). For the 35 year period 0.189 and 0.112 million records were created for Kerala and Karnataka, respectively. In the present analysis, each fishing zone was taken as a habitat unit and the fished taxa richness was represented as the alpha diversity. The inter-zone comparison was done for deriving the beta diversity and the sum total of all fished taxa richness was taken as an estimate of gamma diversity. The biodiversity rich and poor areas in Kerala and Karnataka were identified through beta diversity. The beta diversity was also used for calculating the species turnover rate as below:

$$TurnoverRate = \left[\left(\frac{a+b}{c}\right)\right] \times 100\%$$

where, a is the number of species unique to area "A"; b is the number of species unique to area "B" and c is the total species pool or γ diversity.

Results and Discussion

Following the Linnaean system, the number of phyla, class, order, families, genus and species in Kerala and Karnataka is shown in Table 1. The arthropod diversity is almost similar in Kerala and Karnataka both at lower and higher taxon levels.



A B

Fig. 1. A - Map depicting fishing zones off Kerala state from south (K - 1) to north (K - 10)
B - Map depicting fishing zones off Karnataka KN - 11 to 17 are exclusive fishing harbour based zones

However, the mollusc and chordate diversity is higher in Kerala than in Karnataka, both at the higher and lower taxon levels. For example, in class Elasmobranchii, order Pristiformes and family Pristidae, only two species have been recorded in Karnataka, while four are recorded from Kerala. The reasons for such differences between geographically close regions are not clear. The gradient in species diversity is clearly not just a distinctive characteristic of a few species. The fact that fishers in Kerala use fishing gears which are much more diverse (Pillai and Katiha, 2004) could also be a plausible reason. Further, the continental shelf region is less broad in Kerala particularly in the extreme south and this could result in fishers getting more oceanic species (and consequently more diversity) in their catches.

In Kerala (Table 2), the zones K5 (Kochi) and K3 (Kollam-Neendakara) had very high alpha diversity values (579 and 565 respectively). In Karnataka (Table 3), the highest alpha value as (524)

Table 1. Distribution of marine fished taxa off Kerala and Karnataka as per Linnaean taxonomic system

Phylum	State	Class	Order	Family	Species
Arthropoda	Kerala	1	3	16	86
	Karnataka	1	3	16	82
Mollusca	Kerala	4	7	22	41
	Karnataka	3	7	8	15
Chordata	Kerala	5	30	132	691
	Karnataka	5	28	125	427
Total	Kerala	10	40	170	818
	Karnataka	9	38	149	524

Table 2. Alpha, beta and gamma diversity values and species turnover rate (%) for different fishing zones of Kerala

	Beta value									Alpha
Zones	K1	K2	K3	K4	K5	K6	K7	K8	K9	value
K1										346
K2	87									259
K3	218	306								565
K4	103	17	322							243
K5	233	321	16	336						579
K6	94	8	313	9	326					253
K7	146	60	365	43	378	53				200
K8	12	100	207	115	220	107	158			358
K9	34	54	253	69	266	61	112	46		312
K10	138	52	357	35	370	45	8	150	104	208
Turnover Rate		28.5	46.0	44.4	50.5	46.3	19.5	23.3	24.7	
Gamma value						818				

Table 3. Alpha, beta and gamma diversity values and species turnover rate (%) for different fishing zones of Karnataka

	Beta value													
Zones	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN11	KN12	KN13	KN14	KN15	KN16	Alpha value
KN1														136
KN2	15													151
KN3	24	9												160
KN4	388	373	364											524
KN5	55	40	31	333										191
KN6	77	62	53	311	22									213
KN7	118	103	94	270	63	41								254
KN11	176	161	152	212	121	99	58							312
KN12	154	139	130	234	99	77	36	22						290
KN13	33	18	9	355	22	44	85	143	121					169
KN14	26	11	2	362	29	51	92	150	128	7				162
KN15	54	39	30	334	1	23	64	122	100	21	28			190
KN16	24	9	0	364	31	53	94	152	130	9	2	30		160
KN17	39	24	15	349	16	38	79	137	115	6	13	15	15	175
Turnover Rate	33.4	31.3	75.6	68.8	18.9	24.2	37.3	46.2	25.0	4.8	7.1	7.2		
Gamma value							524							

was recorded for KN4 zone (Gangolli-Coondapur – northern Udupi district) followed by (312) KN11 zone (Mangalore). The species turnover ratios were also higher in these zones. A comparison of the zone-wise alpha diversity (Fig. 2) shows that only 3 zones had values exceeding 500. Coincidentally all the zones with high alpha values are major fishing harbours from where large number of trawl vessels operate. Trawl is a gear which sweeps the sea bottom and consequently a large number of species are caught. Bijukumar (2005) recorded maximum number of species (514) (which include porifera, coelenterates, echinoderms, bryozoan, sipunculids and annelids in addition to the commercial species) in the trawls bycatch from Neendakara (zone K3) followed by Munambam (393). A comparison of the

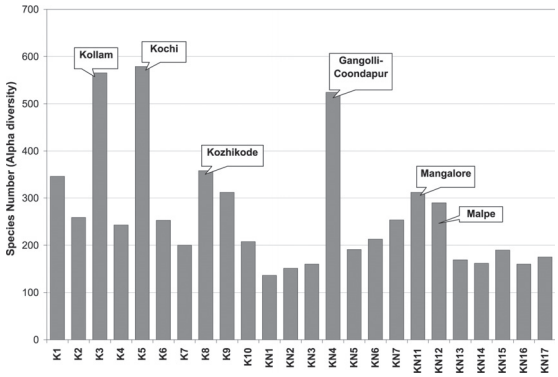


Fig. 2. Alpha diversity values in fishing zones. Note that all major trawl fishing zones have high diversity values in both Kerala and Karnataka

alpha diversity values in different gears in Kerala and Karnataka (Table 4) show that mechanised trawl which operate in the inshore waters recorded the maximum number of species from Kerala (610) and Karnataka (335) followed by non-mechanised gears.

High beta values indicate uniqueness in species richness when compared to other zones. The beta diversity values and turnover ratios for K3, K5 and KN4 were very high (Tables 2 and 3) indicating the uniqueness of many species occurring in the area. However there was only a small difference (14) between K3 and K5 zones indicating closeness of the species being exploited from these two zones. These two zones include the major trawl fishing harbours of Kerala *viz.*, Neendakara-Sakthikulangara and Kochi. KN4 zone in Karnataka is very close to the Netrani Island which has been recently reported to have a submerged coral reef (Zacharia *et al.*, 2008) and this may be the reason for the high alpha and beta diversity values. Beta diversity, the spatial turnover or change in the identities of species, is a measure of the difference in species composition either between two or more local assemblages or between local and regional assemblages. For a given level of regional species richness, as beta diversity increases, individual localities differ more markedly from one another (Koleff *et al.*, 2003). This measure can be used to classify habitats or seascapes in any ecosystem.

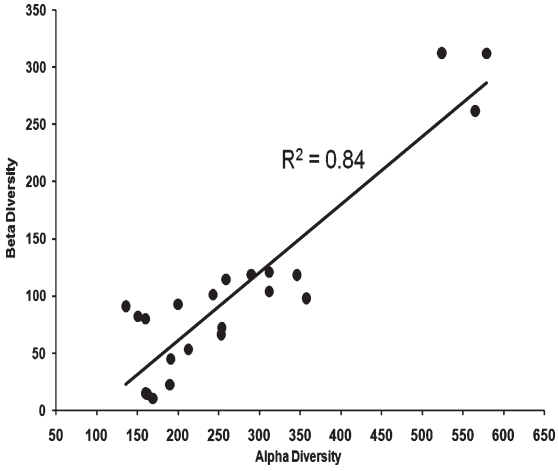


Fig. 3. Relationship between α and β diversity of marine fished taxa of southwest coast (Kerala and Karnataka)

The gamma diversity was high for Kerala (818) as compared to Karnataka (524) (Table 2 & 3). Gamma diversity depends primarily on historical and evolutionary processes that operate on the mesoscale level and is also affected by alpha and beta diversity (Whittaker, 1972; 1977). Alpha and beta diversity values appear to be well correlated (Fig. 3). Habitats (zones) with higher alpha values also have higher beta values in view of the possibilities of shared, widely distributed species. Similar observations have been made by several

Table 4. Number of species landed during 1970-2005 by different gears

Sl. No.	Name of gear	Kerala	Karnataka
1	Mechanised trawlnet	610	335
2	Mechanised multi-day trawlnet	418	158
3	Mechanised gillnet	292	200
4	Mechanised multi-day gillnet	283	64
5	Mechanised driftnet	282	185
6	Mechanised hooks & lines	221	30
7	Mechanised multi-day hooks & lines	55	0
8	Mechanised purse seine	105	215
9	Mechanised ring seine	67	0
10	Outboard gears	480	221
11	Non-mechanised gears	496	283
	Total	818	524

authors (Crist *et al.*, 2003, Nabout *et al*., 2007). Theoretically alpha and beta should be free to vary independently; a high value of the alpha component should not, by itself, force the beta component to be high (or low), and *vice versa* (Wilson and Shmida, 1984). But this does not always happen in practice.

Alpha, beta, and gamma diversities are among the fundamental descriptive variables of ecology and conservation biology and results from the present analysis indicate that similar studies have to be carried out from other marine ecosystems along the Indian coast, so that it becomes benchmark information for studying impacts on biodiversity.

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