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:

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

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 \(\gamma\) 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.
Alpha, beta and gamma diversity of fished marine taxa

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>
<thead>
<tr>
<th>Table 1. Distribution of marine fished taxa off Kerala and Karnataka as per Linnaean taxonomic system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phylum</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>Arthropoda</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Mollusca</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Chordata</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td></td>
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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

<table>
<thead>
<tr>
<th>Zones</th>
<th>Beta value</th>
<th>Alpha value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K1</td>
<td>K2</td>
</tr>
<tr>
<td>KN1</td>
<td>346</td>
<td></td>
</tr>
<tr>
<td>KN2</td>
<td>259</td>
<td></td>
</tr>
<tr>
<td>KN3</td>
<td>565</td>
<td></td>
</tr>
<tr>
<td>KN4</td>
<td>243</td>
<td></td>
</tr>
<tr>
<td>KN5</td>
<td>579</td>
<td></td>
</tr>
<tr>
<td>KN6</td>
<td>253</td>
<td></td>
</tr>
<tr>
<td>KN7</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>KN8</td>
<td>358</td>
<td></td>
</tr>
<tr>
<td>KN9</td>
<td>312</td>
<td></td>
</tr>
<tr>
<td>KN10</td>
<td>208</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28.5</td>
<td>46.0</td>
</tr>
<tr>
<td>Gamma value</td>
<td>818</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Zones</th>
<th>Beta value</th>
<th>Alpha value</th>
</tr>
</thead>
<tbody>
<tr>
<td>KN1</td>
<td>136</td>
<td></td>
</tr>
<tr>
<td>KN2</td>
<td>151</td>
<td></td>
</tr>
<tr>
<td>KN3</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>KN4</td>
<td>524</td>
<td></td>
</tr>
<tr>
<td>KN5</td>
<td>191</td>
<td></td>
</tr>
<tr>
<td>KN6</td>
<td>213</td>
<td></td>
</tr>
<tr>
<td>KN7</td>
<td>254</td>
<td></td>
</tr>
<tr>
<td>KN11</td>
<td>312</td>
<td></td>
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<tr>
<td>KN12</td>
<td>290</td>
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<tr>
<td>KN13</td>
<td>169</td>
<td></td>
</tr>
<tr>
<td>KN14</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>KN15</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>KN16</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>KN17</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td></td>
<td>33.4</td>
<td>31.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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.

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

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


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