Indian Journal of Geo Marine Sciences
Vol. 48 (09), September 2019, pp. 1435-1442

Geo-spatial distribution and faunal diversity in the trawling grounds off Mumbai coast, Maharashtra, India

S. N. Bhendekar[1], Anulekshmi Chellappan[1], A.E. Sonavane[2], Prakash Mohanty[3], Ram Singh[4], & Latha Shenoy[4*]
[1]Mumbai Research Centre of Central Marine Fisheries Research Institute, Mumbai, India
[2]College of Fisheries, Ratnagiri, India
[3]Earth System Science Organization-Indian National Centre for Ocean Information Services, Hyderabad, India
[4]Central Institute of Fisheries Education, Mumbai, India
*[E-mail: lathashenoy@cife.edu.in]

Received 24 April 2018; revised 12 June 2018

Investigations were carried out to assess the spatio-temporal distribution and ichthyofaunal diversity along the Mumbai coast of Maharashtra, India, with the help of GIS technology. The catch data from single-day and multi-day trawlers for the period September 2013 to February 2014 were recorded. A total of 120 fish species belonging to 85 genera, 56 families and 23 orders were caught by 55 hauls of multi-day and single-day trawlers. Bathymetric distribution showed availability of maximum number of species at the depth of 15-19 m (70 species) followed by the depth of 20-24 m (65 species) and that of 10-14 m (64 species). Biodiversity in terms of number of species was found to be maximum during January 2014. The value of Shannon-Wienner index (H') was recorded between 1.42 and 1.63 indicating less diverse nature of fishes along Mumbai coast. Value of Margalef richness index (d) ranged between 7.08 and 8.79. The average value for Simpson index (λ) recorded was 0.047. K-dominance plot clearly demonstrated the diversity pattern during the study period.

[**Keywords***:* Spatio-temporal distribution; Diversity indices; Abundance; Trawling]

Introduction

Marine fish communities in tropical regions are characterised by large number of species and complex interactions as compared to those in temperate regions[1]. The trawl fishery resources in tropical coastal areas of Asia consist of highly diverse and multi-species complexes[2]. It may not be appropriate to manage these fisheries on the assumption of a single target species. Therefore, managing the fisheries requires a thorough understanding of the spatio-temporal distribution of fishes and their biodiversity in different fishing grounds. Spatial characteristics of the fishery remained unknown to researchers and policy makers for a long time. No fishery management policies are comprehensive without incorporating the knowledge about the spatial distribution of fishes.

However, the majority of problems with regard to management of fishery resources presently are related to spatial domain due to overexploitation of specific fishing grounds, habitat loss and exploitation of small and medium-sized fishes. In this framework, spatial component of fisheries becomes a priority and the entire discipline becomes highly compatible with GIS[3]. Analysis of fisheries data is also complicated by spatio-temporal limitations in the sampling programmes. Any temporal analysis without spatial concepts will lead to incomplete results and vice-versa. GIS can be the primary research tool in this area[4]. Trawl surveys form an important tool in assessing fish populations, their locations and habitat use[5]. The spatio-temporal information on catch from the trawlers is almost a replica of resource distribution in the commercial fishing grounds[6].

GIS allows integration of different layers of information, such as bathymetry, catch, catch per unit effort (CPUE) etc., which is impossible when traditional methods are used. However, marine GIS applications[7] and relevant literature are still less than terrestrial GIS[8]. This is especially true in Indian fisheries sector where application of GIS has been considerably slow compared to other countries. In India, GIS applications have so far been used only for near-shore, inland fisheries management and aquaculture site selection[9,10,11,12,13].

Hence, the study was carried out with the objective of assessing the spatio-temporal distribution and ichthyofaunal biodiversity in the trawling grounds off Mumbai coast.

Materials and Methods

Area of study

Data for this study was collected from commercial multi-day and single-day trawlers operating from Sassoon Dock fishing harbour and Versova fish landing centre of Mumbai district of Maharashtra (Fig. 1). The study area of Mumbai region covered fishing grounds 18^0 53'45'' N to 19^0 15' N latitude and $72^0$45' E to 73^0 00' E longitude, respectively. To get information from commercial fishing grounds, data was collected from a commercial trawler using their traditional technical knowhow for fishing operations. Wooden boat having a length of 15 m fitted with 120 hp engine and engaged in multi-day trawling for a period of 7 to 15 days per trip was selected. It operated from Sassoon Dock fisheries harbour in Mumbai. Single-day trawlers selected were 10 (83 hp) wooden boat and 10 m (86 hp) FRP boat at the Versova fish landing centre, Mumbai. Total 55 hauls of multi-day and single-day trawlers were carried out. Eight depth strata were selected for studying the depth wise distribution of fishes, viz., 5-9 m, 10-14 m, 15-19, 20-24 m, 25-29 m, 30-34 m, 35-39 m, and 40-44 m.

Data collection

On-board information collected consisted of date, depth of shooting and hauling of net (5-44 m), geo-location of fishing operation, time of shooting and

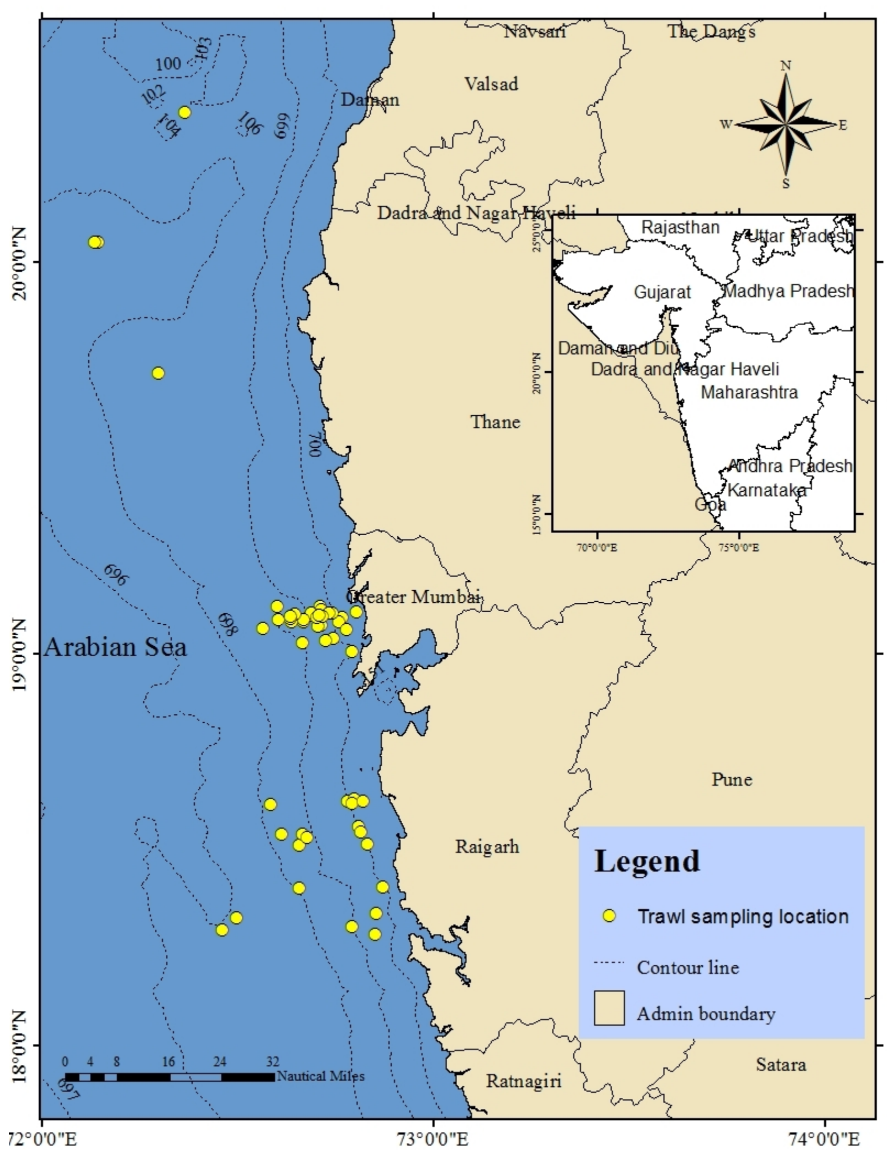

Fig. 1 — Geographical location of study area showing sampling location

hauling of net, net type, mesh size (cod end), total catch (kg), total discard (kg) and number of hauls (3) per day. Along with fishing information, an unsorted portion of discarded catch was collected as sample representing the haul. Samples were taken from unsorted trawl catch and preserved in ice and stored in fish-hold. During laboratory analysis, all fishes in the sample were identified up to species level. Number of the fishes in the sample and their length-weight measurements were recorded. Numbers of fish specimen in samples were raised for each trawl haul[12,13].

Analysis of data

Maps showing geographic distribution of fishes were prepared using ArcGIS 10.2, world's popular desktop mapping and GIS software developed by Environmental System Research Institute (ESRI), Redlands, California. ArcGIS 10.2 has great visualization, query analysis and integration capabilities along with the ability to create and edit geographic data. Initially, database was digitized and interpolated using inverse distance weighting in statistical analyst tool in ArcGIS based on number of individuals of species at different geographical coordinates.

The diversity was calculated using Shannon-Weiner and Pielou's evenness indices. K-Dominance plot was drawn by ranking the species in decreasing order of abundance to compare the biodiversity between the months. All the diversity indices and multivariate analyses were performed using Plymouth Routines in Multivariate Ecological Research (PRIMER) version 6. This statistical software is a statistical package, i.e., collection of specialist univariate, multivariate, and graphical routines for analysing species sampling data for community ecology[14].

Results and Discussion

Spatio-temporal distribution of fishes

The geographical distribution of some commercially important species, viz., *Coilia dussumieri* (Fig. 2a), *Harpadon nehereus* (Fig. 2b), *Johnieops vogleri* (Fig. 2c), *Lepturacanthus savala* (Fig. 2d), *Parapenaeopsis stylifera* (Fig. 2e), and *Sepiella inermis* (Fig. 2f) were given with the support of maps generated by inverse distance weighted (IDW) model based on number of individuals of species at different geographical coordinates.

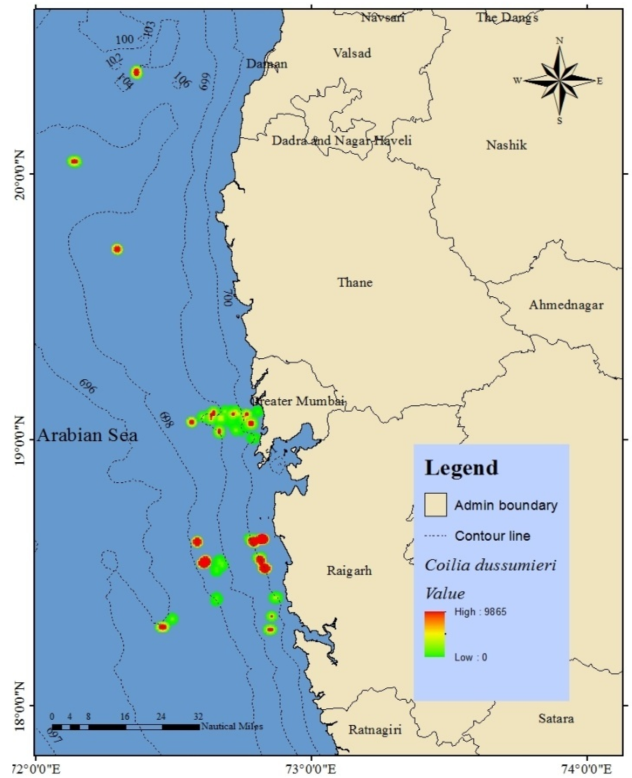

Fig. 2a — Geographical distribution of *Coilia dussumieri*

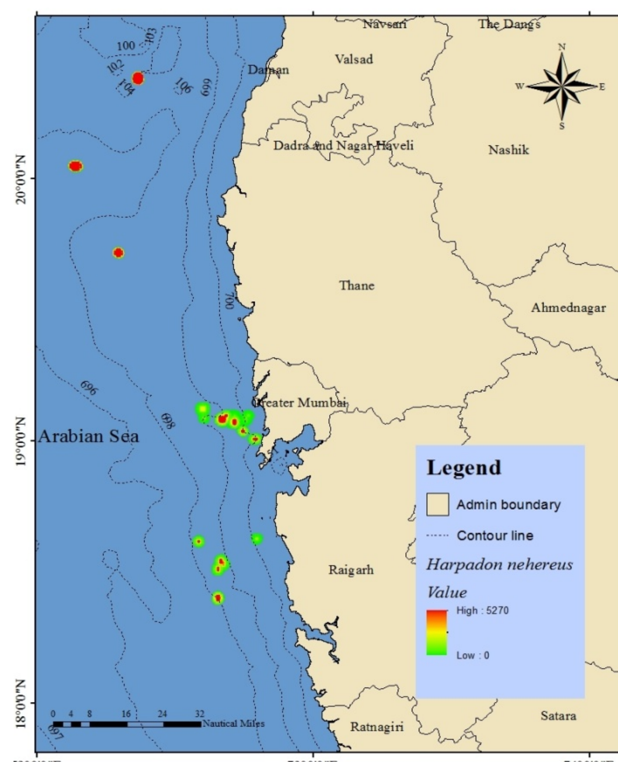

Fig. 2b — Geographical distribution of *Harpadon nehereus*

(*Contd.*)

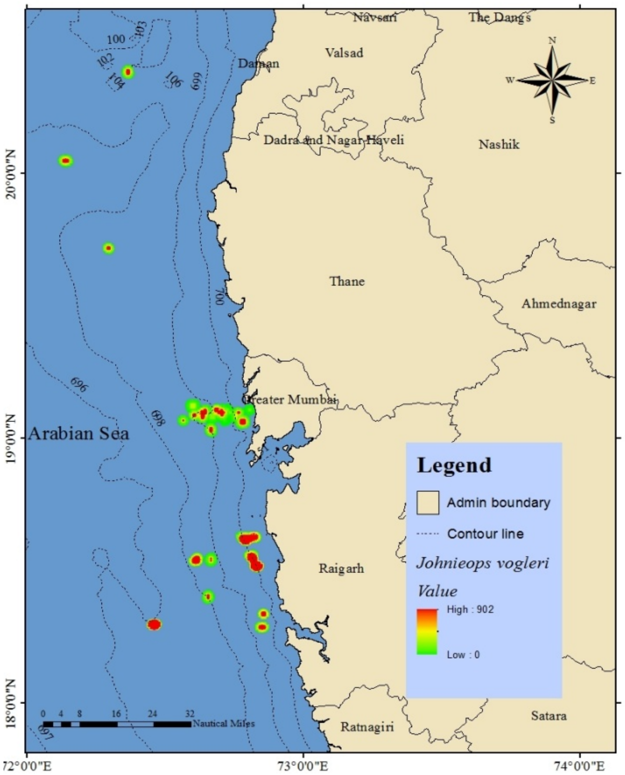

Fig. 2c — Geographical distribution of *Johnieops vogleri*

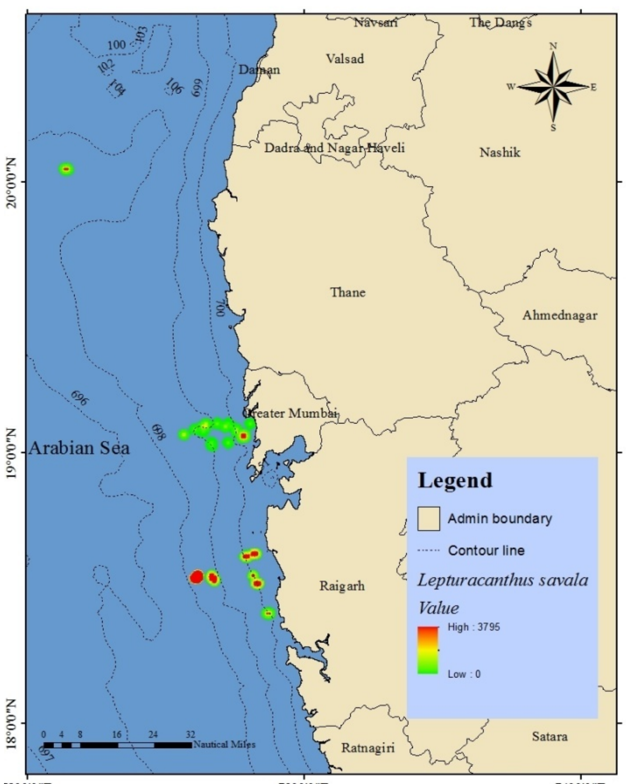

Fig. 2d — Geographical distribution of *Lepturacanthus savala* (*Contd.*)

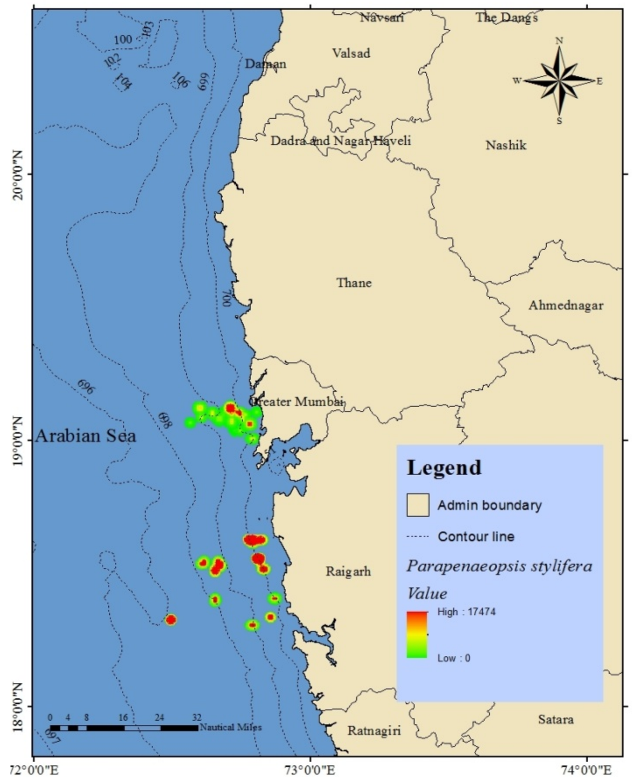

Fig. 2e — Geographical distribution of *Parapenaeopsis stylifera*

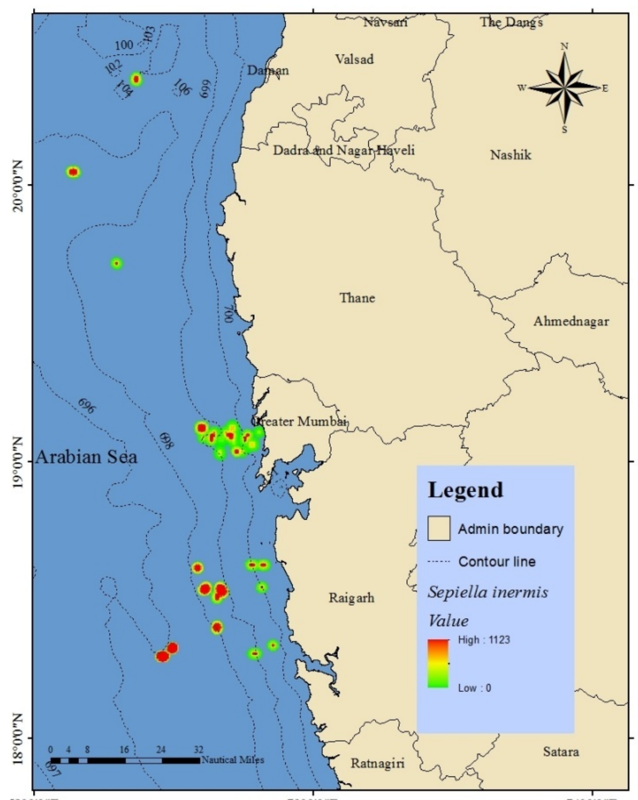

Fig. 2f — Geographical distribution of *Sepiella inermis*

Eight depth strata were selected for studying the depth-wise distribution of fishes, viz., 5-9 m, 10-14 m, 15-19, 20-24 m, 25-29 m, 30-34 m, 35-39 m, and 40-44 m. The maximum number of species was recorded at the depth of 15-19 m (70 species) followed by the depth 20-24 m (65 species) and 10-14 m (with 64 species, Fig. 3). Biodiversity in terms of number of species were maximum in the depth range of 15-19 m (species richness-70).

A total of 120 fish species belonging to 85 genera, 56 families and 23 orders were caught by 55 hauls of multi-day and single-day trawlers. Finfishes (73 species), elasmobranch (4 species), shrimps (13 species), lobster (single species), crabs (9 species), cephalopods (5 species), stomatopods (4 species) and other shellfishes (11 species) comprised the trawl catch. Family-wise species richness of fish assemblages revealed that the family Sciaenidae were dominant followed by Penaeidae, Engraulidae, Ariidae, Clupeidae and Gobiidae with species ranging from 4 to 10.

Abundance and occurrence of the species caught by multi-day and single-day trawlers is given in Table 1. Some species, such as *Coilia dussumieri*, *Cynoglossus arel*, *Cynoglossus macrostomus*, *Johnieops vogleri*, *Johnius belangerii*, *Lagocephalus lunaris*, *Lepturacanthus savala*, *Otolithes cuveri*, *Polynemus heptadactylus*, *Protonibea diacanthus*, *Terapon jarbua*, *Scoliodon laticaudus*, *Metapenaeus affinis*, *Metapenaeus brevicornis*, *Parapenaeopsis stylifera*, *Solenocera crassicornis*, *Charybdis callianassa*, *Charybdis cruciate*, *Loliolus investigatoris*, *Sepiella inermis*, *Harpiosquilla harpax*, *Miyakea nepa*, *Bursa spinosa* and *Tibia curta* were present in all the months. Maximum number of species (77) was caught in January.

Trawl surveys form an important tool in assessing fish populations, their locations and habitat use[5]. Overall, 43 species of fishes, 12 species of prawns, 6 species of crabs, 1 species of lobster and 3 species of cephalopods were encountered in trawl catch between Porbandar and Ratnagiri, in 1992[15]. Structure and seasonal variations of an inshore demersal fish assemblage have been described from 52 trawl samples collected between November 1988-November 1989 from Aguada and Marmugao Bays in Goa. A total of 12519 individuals belonging to 59 species were collected[16]. Present study recorded 120 species and probable reason for the same is the increased depth of trawl, frequency of trawl operation, participatory approach in sampling and better species description available at present.

One hundred twenty species/groups of species were observed from the commercial landing of trawlers from Mangalore Fisheries Harbour during 2007-2010. The study gave information on spatio-temporal distribution of different fishes in the fishing grounds off Mangalore[12]. A total of 97 species belonging to 72 genera, 50 families and 15 orders were recorded during the study period from August-2012 to April-2013[17]. In all, 123 species of fishes belonging to 13 orders, 49 families and 82 genera were recorded from 44 hauls of otter trawls along Cuddalore and

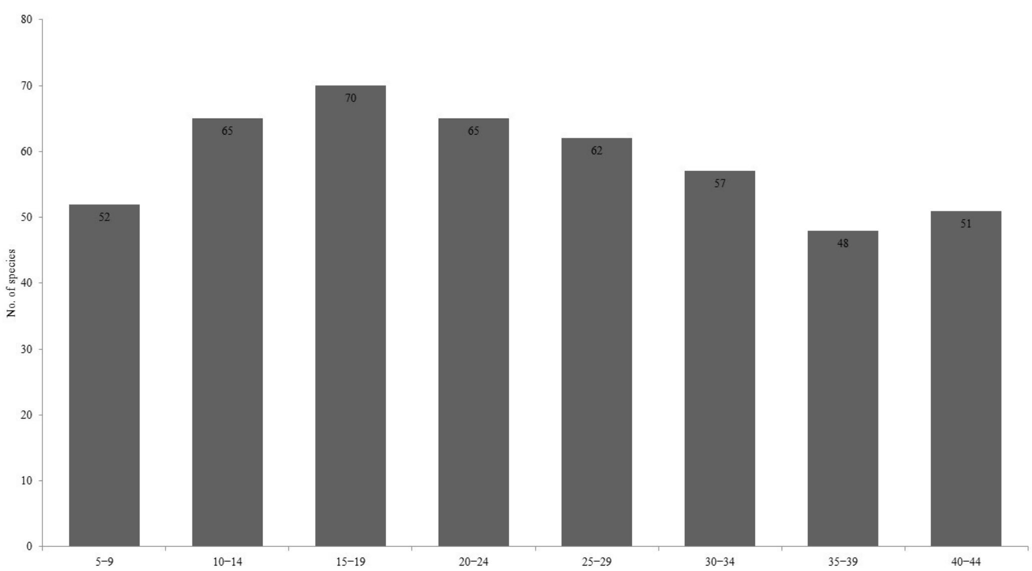

Fig. 3 — Bathymetric distribution of fishes along Mumbai coast

Table 1 — Fish species caught by multi-day and single-day trawlers off Mumbai

Finfish	*Odontamblyopus roseus*	*Nematopalaemon tenuipes*
Alepes djedaba	*Opisthopterus tardoore*	*Parapenaeopsis hardwickii*
Ambassis ambassis	*Osteogeniosus militaris*	*Parapenaeopsis nana*
Anodontostoma chacunda	*Ostorhinchus fasciatus*	*Parapenaeopsis sculptilis*
Antennarius striatus	*Otolithes cuveri*	*Parapenaeopsis stylifera*
Apogon sp.	*Otolithes ruber*	*Sicyonia lancifer*
Arius caelatus	*Otolithoides biauritus*	*Solenocera crassicornis*
Arius dussumieri	*Pampus argenteus*	**Lobster**
Arius maculatus	*Pampus chinensis*	*Panulirus polyphagus*
Arius tenuispinis	*Parachaeturichthys polynema*	**Crabs**
Bregmaceros mcclellandi	*Parastromateus niger*	*Arcania septemspinosa*
Coilia dussumieri	*Pellona ditchela*	*Charybdis annulata*
Cynoglossus arel	*Polynemus heptadactylus*	*Charybdis callianassa*
Cynoglossus macrostomus	*Protonibea diacanthus*	*Charybdis cruciata*
Cynoglossus puncticeps	*Sardinella fimbriata*	*Charybdis lucifera*
Dussumieria acuta	*Sardinella longiceps*	*Charybdis orientalis*
Eleutheronema tetradactylum	*Saurida tumbil*	*Portunus pelagicus*
Epinephelus bleekeri	*Saurida undosquamis*	*Portunus sanguinolentus*
Epinephelus diacanthus	*Scomberomorus guttatus*	*Thalamita crenata*
Escualosa thoracata	*Sillago sihama*	**Cephalopods**
Eupleuroigrammus muticus	*Stolephorus commersonii*	*Cistopus indicus*
Gerres filamentosus	*Takifugu oblongus*	*Loligo duvaucelii*
Glossogobius giuris	*Terapon jarbua*	*Loliolus investigatoris*
Grammoplites scaber	*Terapon theraps*	*Onychoteuthis banksi*
Harpadon nehereus	*Thryssa dussumieri*	*Sepiella inermis*
Ilisha filigera	*Thryssa hamiltoni*	**Stomatopods**
Johnieops macrorhynus	*Thryssa mystax*	*Harpiosquilla harpax*
Johnieops sina	*Thryssa setirostris*	*Harpiosquilla woodmasoni*
Johnieops vogleri	*Trichiurus lepturus*	*Miyakea nepa*
Johnius belangerii	*Trypauchen vagina*	*Oratosquill inainterrupta*
Johnius elongatus	**Elasmobranch**	**Bivalve & Gastropods**
Johnius glaucus	*Chiloscyllium arabicum*	*Arca bistrigata*
Lactarius lactarius	*Himantura imbricata*	*Arca granosa*
Lagocephalus lunaris	*Scoliodon lacticaudus*	*Babylonia spirata*
Leiognathus blochii	*Sphyraena obtusata*	*Bursa spinosa*
Leiognathus daura	*Torpedo marmorata*	*Bursa tuberculata*
Lepturacanthus savala	**Shrimps**	*Cantharus spiralis*
Megalaspis cordyla	*Exhippolysmata ensirostris*	*Ficus variegata*
Minous monodactylus	*Metapenaeopsis stridulans*	*Murex tribulus*
Muraenesox cinereus	*Metapenaeus affinis*	*Natica picta*
Muraenesox talabonoides	*Metapenaeus brevicornis*	*Surcula amicta*
Nemipterus japonicas	*Metapenaeus dobsoni*	*Surcula javana*
Nemipterus randalli	*Metapenaeus monoceros*	*Tibia curta*

Parangipettai, south-east coast of India from January 2009 to December 2010[18]. Similar results have been observed in the present study.

Faunal diversity

The diversity indices used in this study characterize species abundance in the community. The results showed that the value of Margalef richness index (d) ranged between 7.08 and 8.79. Shannon-Wiener index(H') showed variability during different months. Values of Shannon-Wiener index (H') (at log10) ranged between 1.42 and 1.63. Average value recorded was 1.53, whereas the highest value was recorded during January 2014. Simpson index (λ)

Table 2 — Variation in different indices based on species abundance recorded during different months

Month	S	N	d	J'	H' (log10)	λ	1- λ'	N1	N2
Sept. 2013	63	1219	8.73	0.82	1.48	0.049	0.951	30.48	20.44
Oct.	64	1834	8.38	0.83	1.49	0.053	0.947	31.06	19.01
Nov.	61	921	8.79	0.85	1.53	0.051	0.949	33.5	19.55
Dec.	62	1173	8.63	0.90	1.61	0.035	0.965	40.44	28.62
Jan. 2014	67	1908	8.74	0.89	1.63	0.031	0.969	42.64	31.96
Feb.	51	1168	7.08	0.83	1.42	0.062	0.939	26.03	16.25

S = number of species; N = number of individuals; Indexes: d = Margalef richness index; J' = Pielou evenness index; H´= Shannon-Wiener diversity index; λ = Simpson dominance index and 1- λ' = Simpson diversity index, N1&N2= Hill diversity numbers

ranged from 0.031 to 0.062. The average value recorded was 0.047. Shannon-Wiener index (H') and Simpson dominance index (λ) showed opposite trend of variation during different months (Table 2). Results of the study revealed less variability among H'. Normally, the value of Shannon-Wiener index (H') increases with the number of species in the sample.

Hill (1973) proposed a unification of several diversity measures in a single statistic. While N1 is the equivalent of Shannon diversity, N2 is the reciprocal of Simpson's index. In this study, the highest values for Hill diversity number (N1) and (N2) were recorded during January 2014 and the lowest during February 2014. Evenness index is also an important component of the diversity indices. This expresses how evenly the individuals are distributed among different species. Pielou's evenness index (J') is commonly used. Pielou's evenness index (J') is strongly affected by species richness. The value of evenness (J') ranged from 0.82 to 0.90. It was found to be the lowest during September 2013 and the highest during February 2014 and December 2013.

The result from K-dominance curve was obtained by plotting percentage cumulative abundance against species rank K on a logarithmic scale. The curve shows the most elevated curve portion has the least biodiversity. This curve shows that number of species (richness) was more in January 2014 compared to other months and the least in February 2014.

The main purpose of diversity indices is to reduce multivariate (multispecies) complexity of assemblage data into a single index evaluated for each sample which can then be handled statistically by univariate analyses[14]. The diversity indices of this study revealed that there were significant changes in fish abundance and diversity of fishes along Mumbai coast over space and time.

Shannon value of more than 3.5 is observed only in healthy and biodiversity-rich areas[14]. Hence lower Shannon index values(1.42-1.63) observed during all the months clearly showed the less diverse nature of fishes along the Mumbai coast. The low diversity along the coast may be attributed to unavailability of food resources, water pollution, habitat loss, overfishing, etc. The Margalef's richness index (d), which has the discriminating ability, showed higher values in all months (7.08- 8.79). Similar results were reported by Jitendra Kumar et al. in 2015[17].

Conclusion

A total of 120 fish species that comprised finfishes, elasmobranch, shrimps, lobster, crabs, cephalopods, stomatopods and other shellfishes were harvested by 55 hauls of multi-day and single-day trawlers that operated off Mumbai coast. Family Sciaenidae was found to be dominant followed by Penaeidae, Engraulidae, Ariidae, Clupeidae and Gobiidae with species ranging from 4 to 10. Maximum number of species was recorded in the 15-19 m depth range (70 species) followed by 20-24 m (65 species) and 10-14 m (64 species). Biodiversity in terms of number of species was in the depth range of 15-19 m. Lower Shannon index values(1.42-1.63) observed during all the months clearly showed the less diverse nature of fishes along the Mumbai coast. Geo-database on spatio-temporal distribution of fishes and diversity indices will help to implement restrictions regarding fishing ground and fishing season along the Mumbai coast.

Acknowledgement

Authors are thankful to the Director and Vice Chancellor of ICAR Central Institute of Fisheries Education, Mumbai and Director of ICAR Central Marine Fisheries Research Institute, Kochi for providing necessary facilities for conducting the study. Authors also thank staff of the Mumbai Research Centre of ICAR-CMFRI, Mumbai for their help and technical assistance.

References

1 Longhurst A R and Pauly D, *Ecologia dos oceanostropicais,* (Academic Press, San Diego) 2007, pp. 419.

2 Longhurst A R and Pauly D, *Ecology of Tropical Ocean,* (Academic Press, San Diego) 1987, pp. 407.

3 Fisher W L and Rahel F J, *Geographic Information Systems in Fisheries,* (American Fisheries Society, Bethesda) 2004, pp. 275.

4 Zheng, X., Pierce, G. J. and Reid, D. G., Spatial patterns of whiting abundance in Scottish waters and relationships with environmental variables, *Fish. Res.,* 50(2001) 259-270.

5 Stoner, A. W., Manderson, J. P. and Pessutti, J. P., Spatially explicit analysis of estuarine habitat for juvenile winter flounder: combining generalized additive models and geographic information systems, *Mar. Ecol. Prog. Ser.,* 213(2001) 253-271.

6 Dineshbabu, A. P., 2013. The trawl fishery of the Eastern Arabian Sea, paper presented at the *APFIC Regional Expert Workshop on Tropical Trawl Fishery Management,* Phuket, Thailand, 2013

7 Valavanis D V, *Geographic Information Systems in Oceanography and Fisheries*, (Taylor & Francis, London) (2002) pp. 208.

8 Hill, M. J., Braaten, R., Veitch, S. M., Lees, B. G. and Sharma, S., Multi-criteria decision analysis in spatial decision support: the ASSESS analytic hierarchy process and the role of quantitative methods and spatially explicit analysis, *Environ. Modell. Softw*., 20(2005) 955-976.

9 Gupta M C, Brackish water aquaculture sites election using techniques of geographical information system (GIS), (Space Application Centre Report, Ahmadabad) 1995, pp. 14.

10 Salam, M. A., Lindsay, G. R. and Beveridge C. M. M., A comparison of development opportunities for crab and shrimp aquaculture in south-western Bangladesh, using GIS modelling, *Aquaculture*, 220 (2003) 477–494.

11 Karthik, M., Suri, J., Saharan, N. and Biradar, R. S., Brackishwater aquaculture site selection in PalgharTaluk, Thane district of Maharashtra, India, using the techniques of remote sensing and geographical information system, *Aquacult. Eng.*, 32(2005) 285–302.

12 Dineshbabu, A. P., Thomas, S., Radhakrishnan, E. V. and Dinesh, A. C., Preliminary experiments on application of participatory GIS in trawl fisheries of Karnataka and its prospects in marine fisheries resource conservation and management, *Indian J. Fish.,* 59(2012) 15-22.

13 Bhendekar, S. N., Shenoy, L., Raje, S.G., Chellappan, A. and Singh, R., Participatory GIS in trawl fisheries along Mumbai coast, Maharashtra, *Indian J. Mar. Sci.,* 45(2016) 937-942.

14 Clarke K R and Warwick R M, *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*, (PRIMER-E: Plymouth Natural Environment Research Council, UK) 2001, pp. 176.

15 Gajbhiye, S. N., Mehta, P., Mustafa, S. and Nair, V. R., Fishery potential along the Indian coastal waters between Porbandar and Ratnagiri, *Journal of Indian Fisheries Association.,* 24(1994) 63-72.

16 Ansari, Z. A., Sreepada, R. A., Dalal, S. G., Ingole, B. S. and Chatterji, A., Environmental influences on the trawl catches in a bay-estuarine system of Goa, west coast of India, *Estuar.Coast. Shelf Sci.,* 56(1995) 503–515.

17 Jitendra K., Benakappa, S., Dineshbabu, A. P., Anjanayappa, H. N., Somashekara, S. R., Kumar Naik, A. S. and Mahesh, V., Marine ichthyofaunal biodiversity in the trawling grounds off Mangalore coast, *Indian J. Mar. Sci.,* 46(2015) 879-885.

18 Purusothaman, S., Jayaprabha, N. and Murugesan, P., Diversity and seasonal variation of fish assemblages associated with trawl catches from southeast coast of India, *Reg. Stud. Mar. Sci.*, 6(2016) 29–36.