Indian J. Fish., 60(4) : 1-6, 2013

Abundance, bathymetric distribution and diversity of deep sea demersal finfish resources along the south-west coast of India

SUDHAKAR V. S. GOVINDAM, U. SREEDHAR AND B. MEENA KUMARI*

Research Centre of Central Institute of Fisheries Technology, Ocean View Layout, Panduranga Puram Andhra University (P.O.), Visakhapatnam-530 003, Andhra Pradesh, India

* *Indian Council of Agricultural Research, Krishi Anusandhan Bhawan - II, New Delhi - 110 012, India*

e-mail: sreedharcift@gmail.com

ABSTRACT

Abundance, bathymetric distribution and diversity of deep sea demersal finfish resources along the south-west coast of India were studied. A total catch of 4255 kg (96.7 kg h^{-1}) was recorded by sampling in the depths ranging from 100 to 1100 m. The major constituents were finfishes *i.e.*, teleost fishes (67%) followed by elasmobranchs (14%), crustaceans (13%), cephalopods (2%) and others (4%). Maximum abundance (113.81 kg h^{-1}) of finfishes was observed in the depth zone of 100-300 m, followed by 500-700 m (86.91 kg h^{-1}), 700-900 m (67.71 kg h^{-1}) and 900-1100 m (7.58 kg h^{-1}). *Nettastoma* sp. (12.13 kg h^{-1}), *Lamprogrammus exutus* (5.22 kg h^{-1}), *Chlorophthalmus bicornis* (4.19 kg h^{-1}), *Bembrops caudimaculata* (5 kg h^{-1}) and *Uranoscopus* sp. (4.95 kg h^{-1}) were the dominant fish species. The bathymetric distribution of the fishes which occurred more than one time were analysed using measures of the centre of gravity (COG) and the habitat width (HW). The analysis revealed that most of the species exhibited a wide distribution range, although a few were restricted to the greatest depths. Species richness index was maximum (8.25) at 500-700 m depth zone and minimum (3.20) at 900-1100 m depth zone. Species diversity did increase up to the depth of 900 m and declined beyond this depth, whereas the species evenness increased with depth.

Keywords: Abundance, Bathymetric distribution, Deep sea, Demersal, Diversity, EEZ, Finfishes

Introduction

Out of the total estimated harvestable potential of 3.92 million t of marine fish from the exclusive economic zone (EEZ) of India, the present exploitation is about 3 million t, which is mainly from the inshore waters (Anon, 1991; Somavanshi, 1998; Dehadrai, 2006). The remaining potential of about 0.92 million t is largely from deep sea and oceanic regions which remains untapped (Somavanshi, 1998; Dehadrai, 2006). Although the deep sea shrimps and lobsters from Indian waters are being exploited by several private trawlers, the finfishes remain unexploited (Jayaprakash *et al*., 2006; Rajan *et al*., 2001). This is mainly due to the lack of knowledge on their abundance, distribution and diversity. In recent decades, there were few reports on the abundance and biology of deep sea fishery resources from the Indian EEZ (Silas, 1969; Raghu Prasad and Ramachandran Nair, 1979; Sivakami, 1989; Sudarsan and Somavanshi, 1998; Venu and Kurup, 2002; Sreedhar *et al*., 2007). Sparing these few reports, there is no detailed description of the diversity and bathymetric distribution of deep sea fishes from Indian waters. Realising this, a study was undertaken focusing on the abundance, bathymetric distribution and diversity of the deep sea finfish resources collected between 100-1100 m depth along the south-west coast of India.

Materials and methods

Data were collected during two deep sea fisheries expeditions of Fisheries and Oceanographic Research Vessel (FORV) Sagar Sampada, namely cruise no. 241 (January–February 2006) and 250 (September 2006). Sampling was done at 44 stations, between 9°N lat. to 16°N lat., off the south-west coast of India (Fig. 1). The sampling depth ranged from 168 to 1070 m. Samples were collected using two demersal trawls *i.e.*, EXPO model fish trawl (45.6m) and HSDT (crustacean version) (44.5 m). The fishes were identified to species level using the standard keys. The specimens collected at each station were measured in weight (kg) and numbers. Species abundance was estimated as catch per unit effort [CPUE (kg h^{-1})]. The data generated from the count in numbers was used to estimate the diversity parameters using PRIMER 5 (version 5.2.9). Margalef species richness index (d'), Shannon-Wiener diversity index (H') and Pielou's evenness index (j') were calculated as, $(d') = (S-1)/\text{Log } N$; $(H') = -\Sigma(p_i * \text{Log}(p_i))$; $(j') = H'/\text{Log}(S)$; where S = number of species, N = number of individuals, p_i = proportion of the total count arising from the i^{th} species, log base is '*e*'. The bathymetric distribution of demersal species captured on more than one occasion were calculated in a quantitative manner using the 'centre

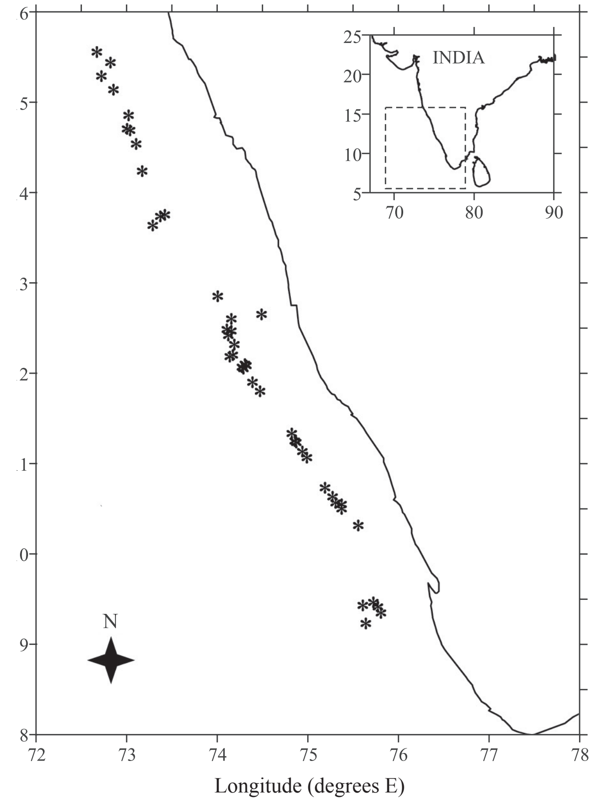

Fig. 1. Map showing the sampling stations

of gravity' (COG) (Daget, 1976) and 'habitat width' (HW) (Pielou, 1969) analyses. The COG model allows one to calculate and locate with precision the centre of species distribution by means of a descriptor (in this case, depth). The HW model gives measure of heterogeneity of the species distribution. These techniques have been previously applied to describe the bathymetric distribution of demersal species (Moranta *et al.,* 1998). Prior to the analysis, the bathymetric range was divided into five strata of 200 m each, and then the COG and HW were calculated using the following formula:

$COG = (x_1+1x_2+3x_3+\ldots+nx_n)/\sum x_i$ and $HW = e^{H'}$

where, x_i represents the calculated mean abundance values of the species *x* present in the stratum *i*; e is the natural log and H' the Shannon-Wiener function.

Results and discussion

A total catch of 4255 kg was obtained from 44 trawling stations, spending 44 trawling hours. The catch mainly comprised of fin fishes *i.e*., teleost fishes (67%) and elasmobranchs (14%) (Fig. 2). Teleosts were represented by 45 families and 74 species, whereas elasmobranchs were represented by 8 families and 14 species. Crustaceans represented 13% of the catch (Fig. 2) and the catch mainly comprised of *Aristeus alcocki, Heterocarpus gibbosus, Oplophorous* sp., *Parapandalus* sp., *Solenocera hexti, Nephropsis stewarti, Panulirus* sp., *Puerulus sewelli* and

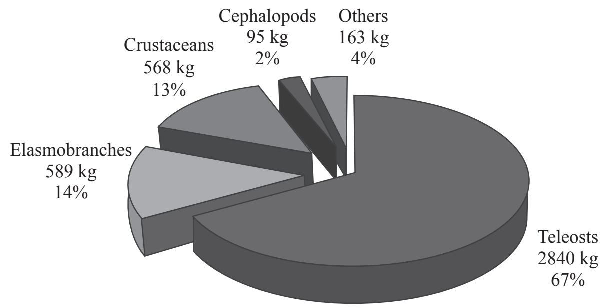

Fig. 2. Catch composition of deep-sea demersal fishery resources along the south-west coast of India

Charybdis smithii. Cephalopods constituted 2% of the total catch, which comprised of *Ancistocheirus lesueurii, Sepioteuthis* sp., *Simplectoteuthis oualaniensis, Octopus* sp. and *Nautilus* sp. Others (4%) consisted of amphipods, squilla, jelly fish, star fishes, corals and sponges.

The maximum abundance of fin fishes (113.81 kg h^{-1}) was observed in the depth zone of 100-300 m (Table 1). Comparatively good catches of 86.91 kg h^{-1} and 67.71 kg h^{-1} were recorded at the depth zones of 500-700 m and 700-900 m respectively (Table 1). As compared to other depth zones, relatively less catch (33.62 kg h^{-1}) was recorded at 300-500 m depth zone (Table 1). The reason may be credited to the fact that this zone is a transition zone of continental shelf and slope, with uneven bottom and sudden depth changes, which is relatively different from its adjacent shelf and slope regions (Jayaprakash *et al*., 2006). So, the fishes in this zone might inhabit the shelf or rock edges and are excluded from the bottom trawling. To have a precise knowledge on the abundance of fishery resources of this transitional zone, other sampling methods like long lining or trap fishing would be appropriate. The effort put in beyond 900 m depth showed relatively lower abundance of fish (Table 1). In the catches, teleosts were mainly dominated by *Nettastoma* sp. (12.13 kg h^{-1}), *Lamprogrammus exutus* (5.22 kg h^{-1}), *Chlorophthalmus bicornis* (4.19 kg h^{-1}), *Bembrops caudimacula* (5.00 kg h^{-1}) and *Uranoscopus* sp. (4.95 kg h^{-1}), whereas the elasmobranchs were dominated by *Eridacnis radcliffei* (3.38 kg h^{-1}) (Table 2). Recently, Thirumilu and Rajan (2003) evaluated the commercial viability of deep sea fishery resources collected between 200-500 m depths off south-east coast of India. They proved that deep sea fishing beyond 200 m could be a profitable venture. Likewise, the reasonably good catches in this study between 500-900 m depths substantiate that deep sea fishing could be possible up to 900 m depth.

The bathymetric distribution of the species established using measures of the centre of gravity (COG) and the habitat width (HW) revealed that most of

Table 1. Abundance and diversity of deep sea demersal fin fish resources collected along the south-west coast of India

Parameters	Depth zone				
	1 (100-300 m)	2 (300-500 m)	3 (500-700 m)	4 (700-900 m)	5 (900-1100 m)
Effort (h)	11	6	14	11	2
CPUE (kg h^{-1})	113.81	33.62	86.91	67.71	7.58
CPUE (No. h^{-1})	2630	413	298	344	22
No. of species	27	26	48	43	11
Species Richness (d`)	3.30	4.15	8.25	7.19	3.20
Diversity (H`)	2.05	2.18	2.74	2.84	2.11
Evenness (j`)	0.62	0.67	0.71	0.75	0.88

Table 2. CPUE (kg h^{-1}) of demersal finfish resources collected from the various depth zones of south-west coast of India

Family	Species	Depth zone					Total
		1 (100-300 m)	2 (300-500 m)	3 (500-700 m)	4 (700-900 m)	5 (900-1100 m)	
Acropomatidae	*Synagrops japonicus*	0.01	2.15	-	-	-	0.30
	Synagrops philippinensis	-	0.87	-	-	-	0.12
Alepocephalidae	*Alepocephalus bicolor*	-	-	5.38	3.15	-	2.50
	Alepocephalus blanfordii	-	-	-	2.08	-	0.52
	Bathytroctes sp.	-	-	-	0.32	-	0.08
	Narcetes sp.	-	-	-	0.39	5.30	0.34
	Rouleina sp.	-	-	0.29	1.43	-	0.45
	Talismania longifilis	-	-	0.00	0.06	-	0.02
Ateleopodidae	*Ateleopus indicus*	-	0.36	-	-	-	0.05
Bathyclupeidae	*Bathyclupea elongata*	-	-	0.02	0.09	-	0.03
Berycidae	*Beryx splendens*	-	-	-	0.91	-	0.23
Bothidae	*Chascanopsetta lugubris*	0.46	-	-	-	-	0.11
	Psettina sp.	0.04	-	-	-	-	0.01
Champsodontidae	*Champsodon* sp.	0.01	-	-	-	-	0.00
Chlorophthalmidae	*Chlorophthalmus agassizi*	10.01	0.60	-	-	-	2.58
	Chlorophthalmus bicornis	16.74	0.08	-	-	-	4.19
Centrolophidae	*Psenopsis cyanea*	12.72	0.07	0.24	-	-	3.27
Ceratiidae	*Cryptopsaras couesii*	-	-	-	0.00	-	0.00
Chaunacidae	*Chaunax pictus*	-	0.59	0.05	0.15	-	0.13
Colocongridae	*Coloconger raniceps*	0.42	-	1.96	0.42	-	0.84
	Coloconger sp.	-	-	0.34	0.33	-	0.19
Congridae	*Bathyuroconger braueri*	-	-	0.46	1.63	0.64	0.58
	Bathyuroconger vicinus	-	-	0.15	-	-	0.05
	Xenomystax trucidans	-	-	1.14	1.98	-	0.86
Cynoglossidae	*Cynoglossus carpenteri*	2.77	0.01	-	-	-	0.69
Diceratiidae	*Bufoceratias wedli*	-	-	-	0.00	-	0.00
Gempylidae	*Neoepinnula orientalis*	2.74	1.23	0.02	-	-	0.86
	Rexea prometheoides	-	0.08	-	-	-	0.01
Gobiidae	*Gobies*	0.09	-	-	-	-	0.02
Gonostomatidae	*Gonostoma* sp.	-	-	0.01	-	-	0.00
Holocentridae	*Ostichthys archiepiscopus*	4.83	-	-	-	-	1.21
Lophiidae	*Lophiomus setigerus*	0.60	-	-	-	-	0.15
	Lophiomus sp.	2.73	-	0.27	5.27	-	2.08
Macrouridae	*Bathygadus melanobranchus*	-	-	0.05	0.07	0.09	0.04
	Coelorinchus flabellispinnis	-	-	-	0.18	-	0.05
	Coryphaenoides macrolophus	-	-	1.00	3.92	0.18	1.31
	Coryphaenoides sp.	-	-	0.75	0.01	-	0.24
	Macrurus sp.	-	-	0.78	1.50	-	0.62
Moridae	*Physiculus roseus*	-	2.83	0.06	-	-	0.40

Family	Species	Depth zone 1 (100-300 m)	2 (300-500 m)	3 (500-700 m)	4 (700-900 m)	5 (900-1100 m)	Total
Muraenesocidae	*Gavialiceps taeniola*	-	10.18	4.54	3.86	0.10	3.80
Myctophidae	*Myctophum* sp.	-	1.15	7.51	-	-	2.55
Nemichthyidae	*Nemichthys scolopaceus*	-	-	-	0.02	-	0.01
Neoscopelidae	*Neoscopelus microchir*	-	0.21	-	-	-	0.03
	Scopelengys tristis	-	-	-	0.00	-	0.00
Nettastomatidae	*Nettastoma* sp.	2.05	-	36.50	-	-	12.13
Nomeidae	*Cubiceps* sp.	-	-	0.04	0.11	-	0.04
Notacanthidae	*Notacathus* sp.	-	-	0.03	-	-	0.01
Oneirodidae	*Oneirodes kreffti*	-	-	0.02	-	-	0.01
Ophidiidae	*Dicrolene* sp.	0.28	-	1.07	0.09	0.10	0.44
	Glyptophidium argenteum	-	-	0.63	-	-	0.20
	Glyptophidium lucidum	-	0.08	-	-	-	0.01
	Hephthocara simum	-	-	0.20	-	0.32	0.08
	Hypopleuron caninum	-	0.13	0.73	-	-	0.25
	Lamprogrammus exutus	-	-	0.30	20.50	-	5.22
	Lamprogramus niger	-	-	-	-	0.25	0.01
	Lamprogrammus sp.	-	-	-	2.99	-	0.75
	Luciobrotula bartschi	-	-	2.10	0.28	-	0.74
	Luciobrotula sp.	1.01	0.44	0.63	0.32	-	0.59
	Neobythites steatiticus	-	-	0.25	-	-	0.08
Paralepididae	*Stemonosudis* sp.	-	0.16	-	-	-	0.02
Percophidae	*Bembrops caudimacula*	19.85	0.28	-	-	-	5.00
Peristediidae	*Peristedion miniatum*	0.28	-	0.11	-	-	0.11
Platytroctidae	*Maulisia mauli*	-	-	0.04	0.11	-	0.04
	Normichthys sp.	-	-	-	-	0.20	0.01
Priacanthidae	*Priacanthus hamrur*	0.01	-	-	-	-	0.00
Scorpaenidae	*Ectreposebastes imus*	-	-	-	0.00	-	0.00
Serranidae	*Chelidoperca investigatoris*	2.66	-	-	-	-	0.67
Stomiidae	*Chauliodus* sp.	0.45	-	0.04	0.05	0.11	0.14
	Malacosteus niger	-	0.21	0.01	0.01	-	0.03
Synaphobranchidae	*Synaphobranchus* sp.	-	0.02	0.16	-	-	0.05
Trachichthyidae	*Hoplostethus mediterraneus*	-	1.09	0.38	-	-	0.27
Triglidae	*Pterygotrigla hemistica*	4.70	-	-	-	-	1.18
Uranoscopidae	*Uranoscopus* sp.	19.76	-	0.04	-	-	4.95
Zeidae	*Zenopsis conchifer*	-	0.14	-	-	-	0.02
Elasmobranchii							
Centrophoridae	*Centrophorus lusitanicus*	-	-	1.21	-	-	0.38
	Centrophorus uyato	-	-	0.46	-	-	0.15
Echinorhinidae	*Echinorhinus brucus*	-	-	1.89	-	-	0.60
Etmopteridae	*Centroscyllium fabricii*	-	-	-	0.21	-	0.05
	Etmopterus pusillus	-	0.22	-	1.12	0.31	0.32
Narcinidae	*Benthobatis moresbyi*	-	-	1.46	5.80	-	1.91
Proscyliidae	*Eridacnis radcliffei*	7.58	1.55	2.53	1.88	-	3.38
Rajidae	*Raja circularis*	0.46	-	-	-	-	0.12
	Raja sp.	-	-	2.69	1.01	-	1.11
Rhinochimaeridae	*Neoharriotta pinnata*	-	0.52	7.67	2.21	-	3.06
Scyliorhinidae	*Apristurus indicus*	-	-	0.30	0.10	-	0.12
	Apristurus investigatoris	-	-	0.06	3.13	-	0.80
	Cephaloscyllium silasi	0.55	-	-	-	-	0.14
	Halaelurus lutarius	-	8.36	0.32	-	-	1.24
Total CPUE (kg h^{-1})		113.81	33.62	86.91	67.71	7.58	77.96

the species exhibited a wide distribution range, although a few were restricted to the greatest depths (Fig. 3). In teleosts, species like *Psettina* sp*.,* gobies, *Chelidoperca investigatoris, Synagrops japonicus, Synaphobranchus* sp*., Bathyclupea elongata* and *Talismania longifilis* showed widest bathymetric distribution. In elasmobranchs, *Raja* sp. and *Echinorhinus brucus* showed the widest bathymetric distribution (Fig. 3). Species richness index was maximum (8.25) at 500-700 m depth zone and minimum (3.20) at 900-1100 m depth zone. Species diversity did increase up to the depth of 900 m and declined beyond it, whereas, the species evenness increased with depth (Table 1). These results indicate that fish variety is more in upper continental slope regions (up to 900 m) than the continental shelf and deeper slope areas. The high species richness and diversity in the upper slope region (500-900 m), are in good agreement with the reports from other areas like Gulf of Mexico (Bianchi, 1991; Powell *et al*., 2003), Mediterranean Sea (Moranta *et al*., 1998) and North Atlantic Ocean (Farina *et al*., 1997). There is usually maximum species richness at mid-slope depths (Gage and Tyler, 1991) and fewer species at abyssal depths (Merrett *et al*., 1991), and this is the case in the current study as well.

Commercial exploitation of deep sea fishery resources has been conducted in certain locations around the world for more than a century. These deep water fisheries exhibit a pattern of rapid development followed by sudden depletion and the recovery rate is very slow. The present study on diversity and bathymetric distribution will be useful in formulating measures for sustainable exploitation of deep sea resources from Indian waters. Data on the diversity can be used as a reference in future, to recognise the changes in populations due to fishing pressure or any man-made activities. The bathymetric distribution analysis based on their COG and HW gives more insight on the distribution pattern of deep sea fishes, which could be helpful in the management of target oriented deep sea fishing. Further, data on their biology, population parameters and maximum sustainable yield (MSY) is necessary for effective management. Special processing technologies, making value added products and identifying the potential bioactive chemicals in these fishes is necessary to attain the attention of the domestic and global markets.

Acknowledgements

The financial assistance from the Ministry of Earth Sciences (MoES), Govt. of India through the project 'Resource assessment and biology of deep sea fishes along the continental slope of Indian EEZ' is thankfully acknowledged. The authors are grateful to the Director,

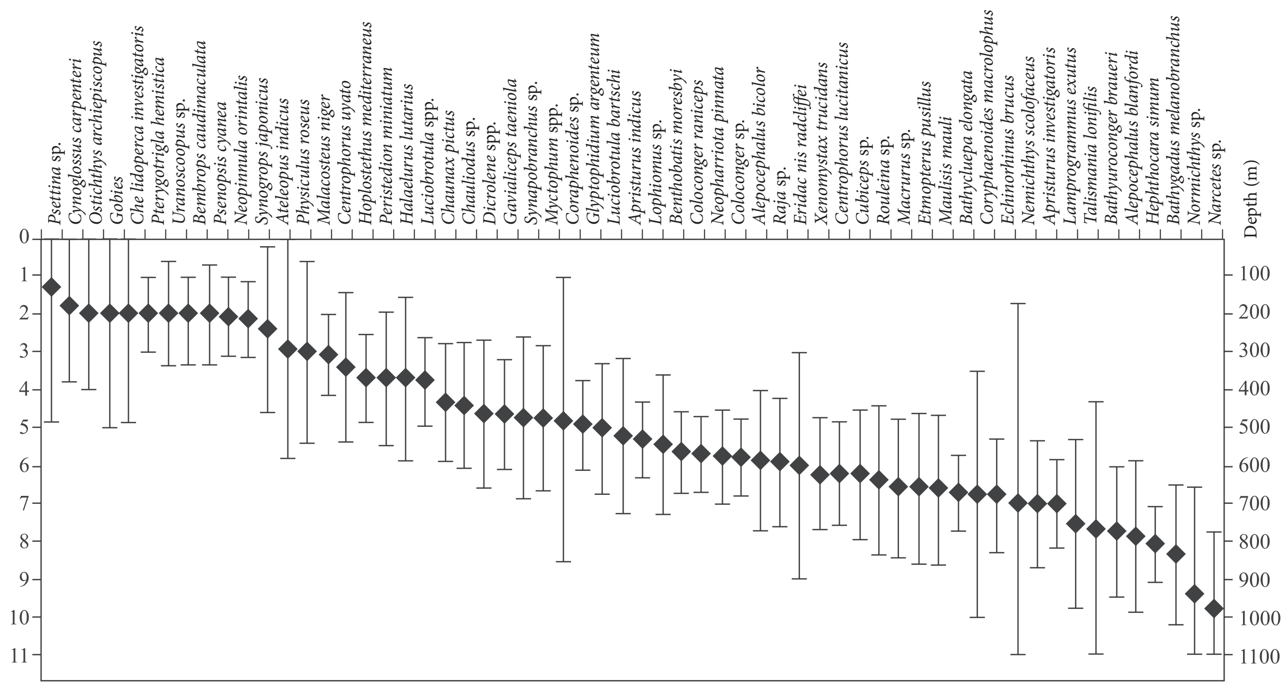

Fig. 3. Bathymetric distribution of demersal finfishes sampled more than one occasion. Square dots represent the centre of gravity (COG), black lines correspond to the habitat width (HW). Discontinuous lines indicate the bathymetric range observed beyond the sampling depth

Central Institute of Fisheries Technology for giving an opportunity to work in this project. Thanks are also due to the chief scientists, fellow participants, fishing masters and fishing hands of the cruise no. 241 and 250 of FORV Sagar Sampada. The authors are also grateful to Sagar Sampada Cell, CMLRE, MoES, Cochin for their support.

References

Anon. 1991. *Report of the working group on revalidation of potential marine fisheries resources of Exclusive Economic Zone of India.* Ministry of Agriculture, Government of India, New Delhi, 51 pp.

Bianchi, G. 1991. Demersal assemblages of the continental shelf and slope edge between the Gulf of Tehuantepec (Mexico) and the Gulf of Papagayo. *Mar. Ecol. Prog. Ser.,* 73: 121-140.

Daget, J. 1976. Ordination des profils ecologiques. *N. Monspel. Ser. Bot.*, 26: 109-128.

Dehadrai, P. V. 2006. Missing opportunities in marine fisheries. *National Seminar on sustainability of seafood production: reflections, alternatives and environmental control***.** National Institute of Oceanography, Dona-Paula, Goa, India, p. 23 -24.

Farina, A. C., Fereire, J. and Gonzalez-Gurriran, E. 1997. Demersal fish assemblages in the Galician continental shelf and upper slope (NW Spain): spatial structure and longterm changes. *Estuar. Coast. Shelf Sci.,* 44: 435-454.

Gage, J. D. and Tyler, P. A. 1991. *Deep sea biology: a natural history of organisms at the deep sea floor*. Cambridge University Press, Cambridge, 504 pp.

Jayaparakash, A. A., Kurup, B. M., Sreedhar, U., Venu, S., Thankappan, D., Pachu, A. V., Manjebrayakath, H., Thampy, P. and Sudhakar, G. V. S. 2006. Distribution, diversity, length-weight relationship and recruitment pattern of deep sea finfishes and shellfishes in the shelf-break area off south-west Indian EEZ. *J. Mar. Biol. Ass. India,* 48(1): 121-123.

Merrett, N. R., Gordon, J. D. M., Stehmann, M. and Haedrich, R. L. 1991. Deep demersal fish assemblage structure in the porcupine seabight (eastern North Atlantic): slope sampling by three different trawls compared. *J. Mar. Biol. Ass. U. K.,* 71: 329-358.

Moranta. J., Steianescu, C., Massuti, E., Morales-Nin, B. and Lloris, D. 1998. Fish community structure and depth related trends on the continental slope of the Balearic Islands (Algerian basin, western Mediterranean), *Mar. Ecol. Prog. Ser.*, 171: 247-259.

Pielou, E. C. 1969. *An introduction to mathematical ecology*, Wiley, New York, 294 pp.

Powell, S. M., Haedrich, R. L. and McEachran, J. D. 2003. The deep sea demersal fish fauna of the Northern Gulf of Mexico, *J. Northw. Atl. Fish. Sci.,* 31: 19-33.

Raghu Prasad, R. and Ramachandran Nair, P. V. 1979. India and Indian Ocean Fisheries, *J.Mar. Biol. Ass. India,* 15(1):1-19.

Rajan, K. N., Nandakumar, K. and Chellappan, K. 2001. Innovative exploitation of deep sea crustaceans along the Kerala coast. *Mar. Fish. Infor. Ser., T&E Ser.,* 168: 1-11.

Silas, E. G. 1969. Exploratory otter trawling surveys by R. V. Varuna and other vessels operating in association with her from the continental shelf edge and the upper continental slope off the south-west coast of India. In: Exploratory fishing by R. V. Varuna. *Bull. Cent. Mar. Fish. Res. Inst.*, 12: 1-51.

Sivakami, S. 1989. Observation on the demersal fishery resources of the coastal and deepsea demersal resources in the Exclusive Economic Zone of India. *Proc. First Workshop Scient. Resul.* FORV Sagar Sampada. 5-7 June, 1989, Cochin, India, p. 215-232.

Somavanshi, V. S. 1998. Fishery resources in the Indian EEZ: Recommendations for deep sea fisheries development. *Indian J. Mar. Sci.,* 27(3-4): 457-462.

Sreedhar, U., Sudhakar, G. V. S. and Meena Kumari, B. 2007. Deep sea fish catch from 16 stations off south-east coast of India. *J. Mar. Biol. Ass. India,* 49 (2): 183-187.

Sudarsan, D. and Somavanshi, V. S. 1988. Fishery resources of the Indian Economic Zone with special reference to upper east coast. *Bull. Fish. Surv. India*, 16:1-26.

Thirumilu, P. and Rajan, S. 2003. Commercial exploitation of deep sea fishes and crustaceans along Tamil Nadu and Pondicherry coasts. *Mar. Fish. Infor. Serv., T&E Ser.,* 178: 6-8.

Venu, S. and Kurup, B. M. 2002. Distribution and abundance of deepsea fishes along the west coast of India. *Fish. Tech.,* 39(1): 20-26.

Date of Receipt : 21.09.2012
Date of Acceptance : 18.04.2013