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Distribution, diversity, length-weight relationship and recruitment pattern of deep-sea finfishes and shellfishes in the shelf-break area off southwest Indian EEZ

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Abstract

The results of an exclusive fishing cruise, No. 241, undertaken by FORV *Sagar Sampada* (Ministry of Earth Sciences) during January-February 2006, in the shelf-break area (500-1000m depth) in the southwest region of Indian EEZ (Lat.9°-16° and Long. 72°-75°46) are presented. Bottom trawling was conducted at 33 stations. A total catch of 1795 kg was realised, out of which the discards formed 311 kg. A variety of non-conventional finfishes (77 species) and shellfishes (shrimps 8 species, crabs 3 species, one species of lobsterette) have been recorded. Depth-wise 235m zone indicated the maximum catch. The total catch during the entire cruise was dominated by *Psenopsis cyanea.* The various population parameters such as L_{α}, K, total mortality (Z), natural mortality (M), fishing mortality (F), exploitation ratio (E), recruitment pattern and length-weight relationship of some of the important species have been worked out. In most of the deep-sea fishes, the recruitment appeared to take place almost throughout the year and showed great similarity among the various species except *Luciobrotula bartschi.* Presently, all these resources remain unexploited, except the shrimps. The trawlers based at Cochin, Quilon and Munambam have been exploiting the deep-sea shrimp resources like the red-ring *Aristeus alcocki* from the Quilon Bank and other similar areas off west coast for the last five years. Interestingly *Psenopsis cyanea* has been found to occur as bye-catch in these fishing operations. Therefore, these two species showed higher fishing mortality compared to practically nil value in other finfishes and shellfishes. The occurrence of the deep-sea glass sponge, *Hyalonema* sp. off Mangalore is also reported. Bio-silica, extracted from this sponge, has a vide range of applications in the medical field from novel biomaterials for bone replacements to the stabilization of tissue. Most of the resources being non-conventional there is need to evolve new processing methods, product diversification and develop export avenues to make deep-sea fishing venture a success. Inventorisation of the deep-sea biodiversity and preparation of fishery atlas also merit serious consideration.

Keywords: Deep-sea finfishes, shellfishes 500-1000 depth zone, southwest Indian EEZ

Introduction

The production from marine capture fisheries in India had been stagnating around 2.7 million tones (Anon, 2001) for the last few years against a potential of 3.9 mn.t. Except for the marginal exploitation of some of the oceanic tunas, most of the deep-sea resources, especially the demersal varieties remain under exploited or unexploited. Ever since the declaration of the EEZ, great responsibility has been bestowed on the country to collect real time data on the deep-sea resources from distant waters and high seas for evolving suitable fishing technique for their exploitation and utilisation. This involves prolonged shipboard research to conduct fishing operations in different parts of the ocean. Lack of adequate information on the availability and extend of commercially exploitable conventional and non-conventional resources beyond the present fishing grounds has been a major constraint for the development of deep-sea fishing in Indian waters. Though information on the oceanic pelagic resources is available, their exploitation is still far below the potential. Sudarsan and Somavanshi, (1988), Sivakami (1990) and Venu and Kurup (2002) have reported the existence of fairly rich grounds of deep-sea fish resources in the EEZ of India. FORV *Sagar sampada,* (Ministry of Earth Sciences) has been conducting pelagic/bottom trawling ever since she was commissioned for fishery-oceanography surveys in Indian EEZ, two decades ago. The results of these surveys on the distribution and availability of various fishery resources are available in the Proceedings of the First and Second Workshops conducted at Cochin (Mathew, 1990; Pillai *et al.*, 1996). However, no information is available on the deep-sea demersal resources beyond 500-m depth zone. Recently, during January-February 2006, FORV *Sagar Sampada* in her cruise No.241, undertook an exclusive fishing survey employing bottom trawl in the 500-1000m depth zone in the southwest region of our EEZ and considerable data on finfishes and shellfishes have been collected. The results of the cruise are discussed in this paper. The information provided is new and would be of great interest and curiosity. The study calls attention to various deep-sea finfishes, shellfishes caught from these depth zones, their diversity, availability, distribution, biology and population parameters. The information could be used to answer key questions such as unknown stock structure of deep-sea living resources, and their diversity in order to improve the advice on how to economically exploit and manage this wealth for future nutritional requirements. There is need for inventorisation of the diverse groups of finfishes and shellfishes and preparation of fishery atlas.

Materials and methods

Materials for the present study were collected by operating Expo- model (EXPO) Demersal Trawl and High Speed Demersal Trawl (HSDT) from onboard FORV *Sagar Sampada*. EXPO was operated at 19 stations and HSDT at 14 stations in the shelf-break area between 200 to 1070 m depth of the southwest region (Lat.9°-16° N and Long. 72°-75°46 E, off Karunagappally in south to off Goa in the north) during January-February 2006. The entire study area was divided into seven transects (Table 1) Fishing was conducted at 33 stations (Fig.1). The duration of fishing was for one hour at each station. Hence the index of abundance is taken as catch per hour. The various finfishes, shellfishes and other organisms after hauling were sorted out and the catch composition was worked out. The species were identified onboard

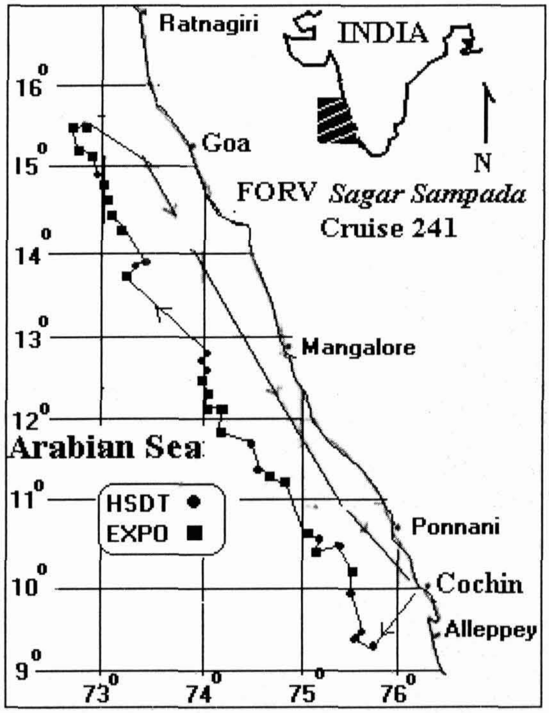

Fig.1. Area of fishing operations during cruise 241

itself or after bringing to the laboratory. The total length and weight were recorded for the individuals to the nearest millimeter and gram respectively. The length measurements were grouped into 1 or 2-cm size groups depending on the size of specimens available. The growth parameters were estimated using FiSAT (Gayanilo Jr. *et al.*, 1995). To do ELEFAN I type of fitting growth curves we should preferably have time series of samples. However, if a time series is not available we can circumvent the problem by assuming a time series, simply by repeating the sample for a suitable range of growth curve (Sparre, 1985) as has been done here with the length frequency data collected during the cruise. Getting time series or monthly data on deep-sea fishes is a problem as the fishing cruises of this vessel are widely placed over time and space both along the east and west coasts of India. However, the various population parameters of deep-sea fishes could be updated as and when further data on length frequency data are acquired based of future fishing cruises in the same area. The total length of the largest specimen in each species caught was taken as L_{α}. The corrected data was then run in the search routine in the ELEFAN I programme using Response surface analysis and scan of K values. Total mortality rate Z was estimated by the length converted catch curve method (Pauly, 1983)

Table 1. *Different transects covered during the cruise*

Transect	No. of Hauls	Southwest region of EEZ		Depth (m)	
Lat.		From	To	From	To
9°-10°	4	Karunagappally	Kochi	115	596
10°-11°	5	Kochi	Beypore	432	781
11°-12°	5	Beypore	Ezhimala	168	691
12°-13°	7	Ezhimala	Mangalore	229	1070
13°-14°	3	Mangalore	Bhatkal	177	905
14°-15°	5	Bhatkal	Karwar	268	692
15°-16°	4	Karwar	Goa	269	844

and natural mortality (M) by following the empirical formula (Pauly, 1980) The annual sea surface temperature was taken as 27°C. The Z and F values were used for deriving the exploitation rate (E). Recruitment pattern was studied following the FiSAT programme.

Results

Bottom trawling was conducted in the shelf-break area of the southwest region in Indian EEZ. Out of 35 stations, fishing at two areas could not be carriedout due to problems in the operation of the gear. Fishing in the remaining stations indicated the availability of a variety of finfishes and shellfishes. HSDT was operated at 14 stations at bottom depth varying from 168m to 862m and EXPO at 19 stations of depth 269m to 1070m (Table 2, Fig.2).

Gear-wise catch: The total catch and c/hr was 976kg and 70 kg in HSDT and 536 kg and 28kg in EXPO. In the HSDT the total catch/hr varied from 8 kg at st.12 (229m) to 387 kg at st.9 (238m). In the EXPO the catch per hr ranged from 6 kg at st.17 (564m) to 107 kg at st.10 (630m).

Deep-sea fishes: A total of 77 species of deep-sea fishes belonging to 51 families under 20 orders were recorded. The catch per hr of deep-sea fishes varied from 6kg at st.17 to 374 kg at st.9.The fish catch of the entire cruise was dominated by *Psenopsis cyanea* (8.6%), followed by *Lamprogrammus exutus* (7.7%) and *Bembrops caudimaculata* (7.2%). In the EXPO model gear *L.exutus* dominated (18.4%) followed by *Saurenchelys taenicola* (10.9%) compared to *P.cynaea* (14%) and *B.caudimaculata* (13%) in HSDT-CV. The Chimaera *Neoharriota pinnata* was recorded at st.18 from a depth of 538m.

Deep-sea shrimps: Eight species of shrimps belonging to four families (Order:Decapoda) were encountered. They showed distribution from 177m to 706m depth zone. HSDT showed a higher catch rate than EXPO. A catch per hr of 10 kg recorded at 706 m was comparable to 13 kg observed from 238m depth. At all stations *Aristeus alcocki* dominated (85%) followed by other species like *Heterocarpus woodmasoni, H.gibbosus, Hymenopenaeus equalis* and *Solenocera hextii. A.alcocki* showed its abundance from 250m to further depth upto 1070m. The maximum abundance was from 300-350m.

Indian Ocean Lobsterette: The Indian Ocean Lobsterette *Nephropsis stewarti* was recorded from 250-m depth off Mangalore at st. 13. The total length ranged from 95- 132 mm. The species has a cylindrical body. It is interesting to note the absence of the deep-sea lobster *Puerulus sewelli.*

The pelagic crab: The free swimming crab, *Charybdis smithi,* was found to occur at st.8 and was netted by the HSDT at a catch per hr of 88kg. In EXPO, the crabs were caught (6 kg/hr) at station 11. The depth at station was 565m.

Squids: Three species of squids belonging to 3 families were noticed. Young ones of squids such as *Ancistrocheirus lesueurii, Sepioteuthis lessoniana* and *Symplectoteuthis oualaniensis* occurred in stray numbers.

Glass sponge: Glass sponge *Hyalonema* sp. was recorded at station 25 (Lat.13°41'42N -Long. 73°15'88E) from a depth of 900m. They looked like a broomstick. The large glass rod like structures appeared sprouting from a stalk. These rod like structures measured 70 cm to 125 cm in length (Fig.3). The diameter varied from 4mm to 8mm.

Isopod: Five numbers of isopod *Bathynomus giganteus* (Milne Edwards) were recorded from station 25 (Lat. 13 °37'02 - Long. 73 °17 86) from a depth of 905m (Fig.4). Related to the pillbug, sowbug, lobsters, crabs, and shrimps the species live on ocean floor. The largest one measured 19cm in total length (width 9 cm).

Table 2. *Depth-wise catch per hour (kg) in HSDT and EXPO*

Stn.No.	Jan/Feb 2006	Gear Type	Av. Depth	Lat. – Long	Prawns	Crabs	Fishes	Total
35	08 / 2	HSDT	115	*	-	-	-	-
8	25 / 1	HSDT	168	11° 22 65-74° 49 31	-	88	1	89
15	28 / 1	HSDT	177	13 °48 26-73 °24 17	7	-	5	12
1	23 / 1	HSDT	286	09 °22 58-75 °47 39	-	-	-	-
12	27 / 1	HSDT	229	12 °39 88-74 °08 03	5	-	3	8
9	26 / 1	HSDT	238	11 °44 98-74 °30 14	13	-	374	387
14	28 / 1	HSDT	238	13° 47 78-73° 21 21	3		11	14
13	27 / 1	HSDT	259	12° 49 37-74° 02 17	-	5	47	52
23	02 / 2	HSDT	268	14° 54 02-72 °59 31	-	-	32	32
34	08 / 2	HSDT	301	09° 58 51-75 °3402	-	-	16	16
2	23 / 1	HSDT	333	09° 24 6-75° 43 91	9	-	66	75
3	23 / 1	HSDT	596	09° 23 93-75° 36 37	-	-	-	-
4	24 / 1	HSDT	438	10 °32 75-75 °21 73	-	-	-	-
5	24 / 1	HSDT	706	10 °36 02-75° 17 80	10	-	201	211
27	04 / 2	HSDT	862	12 °42 42-74° 00 36	8	-	12	20
20	30 / 1	EXPO	269	15 °30 32-72° 48 47	-	-	-	-
22	31 / 1	EXPO	373	15° 12 01-72 °49 85	-	-	-	-
18	29 / 1	EXPO	546	14 °44 03-73 °00 35	-	-	38	38
17	29 / 1	EXPO	564	14° 34 81-73 °05 35	-	-	6	6
11	27 / 1	EXPO	565	12° 22 87-74° 09 83	6	6	34	46
7	25 / 1	EXPO	599	11° 16 41-74° 51 30	-	-	25	25
24	02 / 2	EXPO	602	14 39 23-73° 01 51	-	-	27	27
10	26 / 1	EXPO	630	11 °52 07 -74° 24 69	8	-	99	107
32	06 / 2	EXPO	687	10° 38 60-75 °16 18	6		23	29
6	25 / 1	EXPO	691	11° 11 95-74 °53 84	-	-	25	25
16	29 / 1	EXPO	692	14 °17 62-73° 08 98	1	-	40	41
26	03/ 2	EXPO	717	*	-	-	-	-
28	04 / 2	EXPO	722	12° 26 22-74 °07 06	12		14	26
19	30 / 1	EXPO	751	15° 30 12-72 °40 84	-	-	23	23
33	07 / 2	EXPO	777	10 °16 22-75° 33 37	8	-	39	47
31	06 / 2	EXPO	809	10 °47 40-75° 09 10	-	-	-	-
21	31/ 1	EXPO	844	15 °13 58-72°44 39	-	-	15	15
25	03 / 2	EXPO	905	13 °41 42-73 °15 88	-	-	20	20
29	05 / 2	EXPO	918	12° 09 48-74 °12 218	19	-	17	36
30	05 / 2	EXPO	1070	12 °09 15-74° 09 994	10	-	21	31

Grand Total (1795kg) = 1457.8kg + 311kg (Discards)+26.2kg (Others)

* No Net Operation.

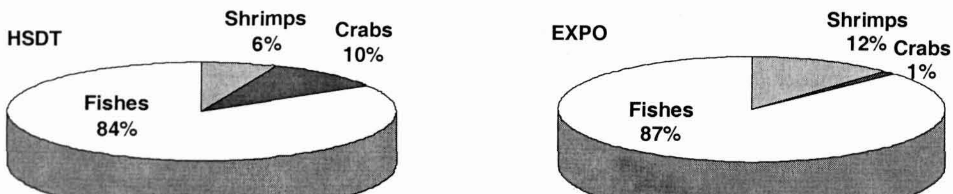

Fig.2. Percentage contribution of shrimps, crabs and fishes in HSDT and EXPO

The total length of other specimens was 17.5cm, 16.2 cm, 12.4cm and 11.5cm. However, this species may attain 18" in length and weigh up to 3 pounds. Their feeding habits are extremely diverse. Some groups are parasitic and some travel in large groups at night.The occurrence of this species off Thoothukudi has been reported by Krishnadhas and Venkatasamy (2003) and from 520m depth off Ezhimala (Cannannore Dt. in Kerala) by Jacob and Narayanan Kutty (2006). The specimen from Ezhimala measured 28cm (width 11cm). The species shows dis-

Table 3. *The diversity of deep-sea finfishes and shellfishes off southwest Indian EEZ.*

Deep-sea fishes

Order - Anguilliformes
- Family – Congridae
  - *Bathyuroconger braueri*
- Family – Muraenidae
  - *Gavialiceps microps*
  - *Saurenchelys taeniola*
  - *Xenomystax trucidans*
- Family – Nemichthyidae
  - *Nemichthys scolopaceus*
- Family – Synaphobranchidae
  - *Synaphobranchus affinis*
  - *Illyophis brunneus*

Order - Aulopiformes
- Family – Chlorophthalmidae
  - *Chlorophthalmus punctatus*
  - *Bathypterois atricolor*
- Family – Paralepididae
  - *Stemenosudis macrurus*

Order - Beryciformes
- Family – Berycidae
  - *Beryx splendens*
- Family – Melamphaidae
  - *Melamphaes simus*
- Family – Trachichthyidae
  - *Hoplostethus mediterraneus*

Order – Carcharhiniformes
- Family – Proscyliidae
  - *Eridacnis radcliffei*
- Family – Scyliorhinidae
  - *Apristurus microps*

Order – Chimaeriformes
- Family – Rhinochimaeridae
  - *Neoharriotta pinnata*

Order – Gadiformes
- Family – Macrouridae
  - *Bathygadus melanobranchus*
  - *Coelorhynchus flabellispinis*
  - *Coryphaenoides macrolophus*
- Family – Moridae
  - *Physiculus roseus*

Order - Lampriformes
- Family – Ateleopodidae
  - *Ateleopus indicus*

Order – Lophiiformes
- Family – Ceratiidae
  - *Cryptopsaras couesii*
- Family- Chaunacidae
  - *Chaunax pictus*
- Family- Diceratiidae
  - *Phrynichthys wedli*
- Family – Lophiidae
  - *Lophiomus setigerus*
- Family – Melanocetidae
  - *Melanocetus johnsoni*
- Family- Oneirodidae
  - *Oneirodes kreffti*

Order - Myctophiformes
- Family – Myctophidae
  - *Myctophum asperum*
- Family – Neoscopelidae
  - *Neoscopelus microchir*
  - *Scopelengys tristis*

Order – Myliobatiformes
- Family – Dasyatidae
  - *Dasyatis violacea*

Order – Notacanthiformes
- Family – Notacanthidae
  - *Notacanthus sexspinis*

Order – Ophidiiformes
- Family – Ophidiidae
  - *Dicrolene multifilis*
  - *Glyptophidium argenteum*
  - *Glyptophidium lucidum*
  - *Hepthocara simum*
  - *Lamprogrammus exutus*
  - *Lamprogrammus niger*
  - *Luciobrotula bartschi*
  - *Neobythites analis*

Order – Perciformes
- Family – Acropomatidae
  - *Synagrops philippinensis*
  - *Synagrops japonicus*
- Family – Apogonidae
  - *Apogon apogonides*
- Family – Bathyclupeidae
  - *Bathyclupea elongata*
- Family – Champsodontidae
  - *Champsodon capensis*
- Family – Gempylidae
  - *Neoepinnula orientalis*
  - *Rexea prometheoides*
- Family – Gobiidae
  - *Bathygobius* sp.
- Family – Nemipteridae
  - *Scolopsis bimaculatus*
- Family- Nomeidae
  - *Cubiceps baxteri*
- Family – Percophidae
  - *Bembrops caudimaculata*
- Family – Priacanthidae
  - *Priacanthus hamrur*
- Family – Serranidae
  - *Chelidoperca investigatoris*
- Family – Stromateidae
  - *Psenopsis cyanea*
- Family – Uranoscopidae
  - *Uranoscopus archionema*

Order – Pleuronectiformes
- Family – Bothidae
  - *Laeops nigromaculatus*
  - *Psettina brevirictis*
  - *Chascanopsetta lugubris*
- Family – Cynoglossidae
  - *Cynoglossus arel*
  - *Cynoglossus carpenteri*

Order – Salmoniformes
- Family – Alepocephalidae
  - *Alepocephalus bicolor*
  - *Alepocephalus blanfordii*
  - *Bathytroctes squamosus*
  - *Narcetes lloydi*
  - *Rouleina attrita*
  - *Talismania longifilis*
- Family – Platytroctidae
  - *Maulisia mauli*
  - *Normichthys yahganorum*

Order – Scorpaeniformes
- Family – Scorpaenidae
  - *Ectreposebastes imus*

Order – Squaliformes
- Family – Echinorhinidae
  - *Echinorhinus brucus*
- Family – Squalidae
  - *Centrophorous lusitanicus*
  - *Etmopterus granulosus*

Order – Stomiiformes
- Family – Chauliodontidae
  - *Chauliodus sloani*
- Family – Gonostomatidae
  - *Diplophos taenia*
- Family – Sternoptychidae
  - *Polyipnus indicus*

Order – Torpediniformes
- Family – Torpedinidae
  - *Benthobatis moresbyi*

Order – Zeiformes
- Family – Zeidae
  - *Zenopsis conchifer*

Deep- sea shrimps

Order – Decapoda
- Family – Aristeidae
  - *Aristeus alcocki*
- Family – Oplophoridae
  - *Acanthophira armata*
  - *Oplophorus* sp.
- Family – Pandalidae
  - *Heterocarpus woodmasoni*
  - *Heterocarpus gibbosa*
  - *Plesionika spinipes*
- Family – Solenoceridae
  - *Hymnopenaeus equalis*
  - *Solenocera hextii*

Deep-sea crabs

- Family – Maiidae
  - *Doclea hybrida*
- Family – Majidae
  - *Pristacantha moselei*
- Family – Portunidae
  - *Charybdis smithii*

Indian Ocean Lobsterette

Order - Decapoda
- Family – Nephropidae
  - *Nephropsis stewartii*

Squids

Order - Teuthida
- Family - Ancistrocheiridae
  - *Ancistrocheirus lesueurii*
- Family – Loliginidae
  - *Sepioteuthis lessoniana*
- Family – Ommastrephidae
  - *Symplectoleuthis oualaniensis*

tribution in the Bay of Bengal, Arabian Sea, Gulf of Mexico and southwest Atlantic off Brazil.

Population parameters

Length-weight relationship: The LWR was calculated adopting the general exponential equation $W = a L^b$ where W is the weight of the fish in gram and L = its total length in cm. The relationship in 24 species was worked out (Table 4).

Recruitment pattern: Recruitment pattern was studied in 11 dominant fish species such as *Alepocephalus bicolor, Neoepinnula orientalis, Synagrops japonicus, Lampogramus exutus, Glyptophidium argenteum, Luciobrotula bartschi, Bembrops caudimaculata, Chelidoperca investigatoris, Eridacnis radcliffei, Saurenchelys taeniola, Psenopsis cyanea* and in the shrimp *Aristeus alcocki* (Figs. 4 to 15).

Mortality and exploitation rate: Natural mortality (M) was estimated following Pauly's empirical formula.M value was higher in *Saurenchelys taeniola.* Fishing mortality (F) was higher in *Aristeus alcocki* and *Psenopsis cyanea* i.e.1. 4 and 1.24 respectively. The exploitation rate of these deep-sea resources also was higher. The results indicated that *P.cyanea* and *A. alcocki* are subjected to fishing where as the exploitation rate of other deep-sea fishes was very less.

Discussion

The marine fish production in India from the present fishing grounds has reached a plateau around 2.7 mn tonnes. Further increase in production by 1.2 m n t out of the potential of 3.9 m n t would be possible by expansion of fishing to new geographical limits of our EEZ. The deep-sea is the largest habitat on earth. Until most recently, the great depth of the sea has made it difficult to exploit the living resources in the shelf-break area and beyond. Despite the tremendous growth in India's marine fisheries from an artisanal and subsistence status, and declaration of the EEZ in 1977, there has never been a commercial deep-sea fishing worth mentioning. The venture is capital intensive. The exploitation of around 23,000 t of oceanic tunas is only nominal compared to the potential. Presently the variety of demersal fish assemblages available in this zone die a natural death, as they do not have any commercial potential, except the shrimps. These unfamiliar species possess no attributes to develop into viable fisheries, until and unless market demand is created by evolving value added products through special processing or by finding out ways to extract bio-active compounds from them.

The Government of India chartered foreign vessels in the early 1980s and entered into joint venture arrangements with large industrial houses in the early 1990s for exploiting the far-sea resources. However, due to stiff resistance from the local fishers, the schemes were terminated a few years after commencement (Devaraj and Vivekanandan, 1999). As a result, there has been persistent poaching in the Indian EEZ by foreign vessels. The Mexican trawlers (about 170 or so) introduced in the eighties, based at Visakhapatnam, indicated for the first time the availability of shrimps in commercial concentration off northeast coast. Initially the catch rate was over 40kg/hr. However, with intense fishing the catch rate decreased to 13 kg/hr in later years. Nearly 40 such trawlers shifted their base of operation to Cochin and were exploiting the deep-sea shrimps and lobsters from the Quilon Bank. Later this venture also was abandoned.

Shrimps from deep-sea: Though CMFRI and IFP have indicated availability and potential of these resources as early in the late sixties, no effort was spared by the private entrepreneurs to exploit them. This was mostly due to lack of consumer demand. However, the scenario underwent a sea change with demand from the foreign markets. Rajan *et al.* (2001) while giving an account of the innovative exploitation of deep-sea crustaceans off Kerala have given a review of the various reports available on these resources. It is gratifying to note that, from the year 1999 there have been concerted effort from private trawl operators at Sakthikulangara (Quilon in south Kerala) who ventured into deep-sea and returned with enormous quantities of these shrimps. Trawlers based at Cochin and Munambam also followed suit resulting in a regular multi-day deep-sea shrimp fishery henceforth. Trawling area, at depth zone 175-400m, generally extended between Trivandrum in south and Beypore in north, with heavy concentration of vessels in the Quilon Bank. The important pandalid species were *Heterocarpus woodmasoni, Plesionika spinipes, H.gibbosus* and *P.martia.*Among the penaeids *Metapenaeopsis anadamanensis* and *Aristeus alcocki* (red-ring) were the major contributors apart from stray availability of *Solenocera hextii* and *Penaeopsis jerryi.* However, the trawling by FORV *Sagar Sampada* indicated that in the deeper areas and in the northern latitudes *A.alcocki* was the major constituent. The size ranged from 140-190mm. In the commercial private trawlers it is 81 to 185 mm (Rajan *et al.*, 2001). Exploitation of the deep-sea crustaceans are carried out from grounds off Tuticorin as well. *H.woodmasoni* (36%) and *Plesionika spinipes* (31%) were the dominant species. The exploitation of *M.anadamanensis* was moderate (19%), *A.alcocki* and *S.hextii* constituted less than 10% of the total catch

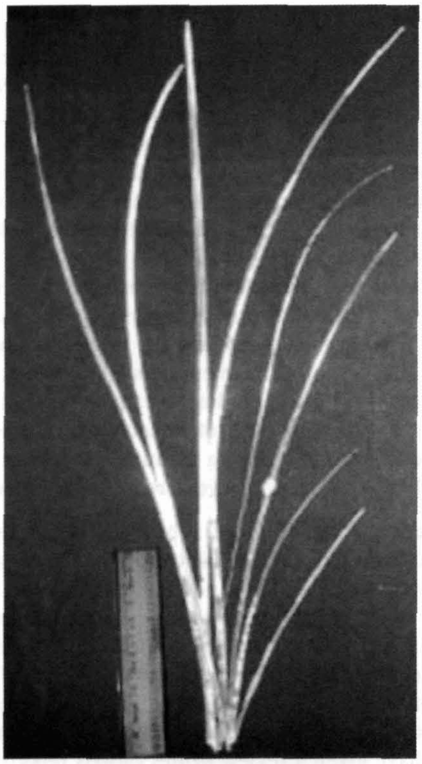

Fig.3. Glass sponge, *Hyalonema* sp. from 950m depth collected off Mangalore

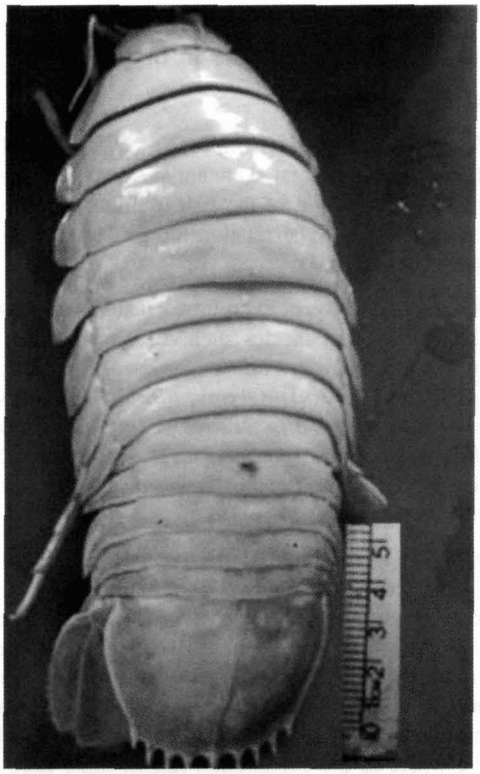

Fig.4. Isopod, *Bathynomus giganteus*, a deep-sea scavenger

Fig. 5.Recruitment pattern of *Alepocephalus bicolor*

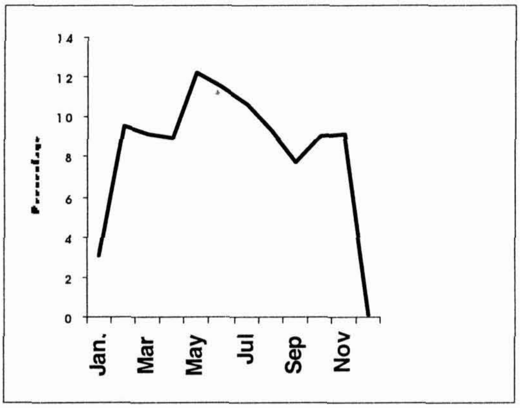

Fig. 6. Recruitment pattern of Neoepinnula orientalis

(Rajamani and Manickaraja, 2003). Commercial trawling of deep-sea fishes and cruastaceans along Tamil Nadu and Pondicherry coasts have been reported by Thirumilu and Rajan (2003). *S.hextii, A.alcocki,P.jerryi, M.anadamanensis, M.coniger, H.gibbosus* and the nephropid lobster *Nephropsis carpenteri* have been reported from this area. Apart from these a number of deep-sea finfishes such as *Psenospsis cyanea, Chlorophthalmus corniger, C.agassizi, Centropristis investigatoris, Hypopleuron caninum, Neoepinnula orientalis, Bembrops caudimaculata, Neobythites steaticus, Hoplichthys acanthopleurus* and *Eridacnis sinuans* have

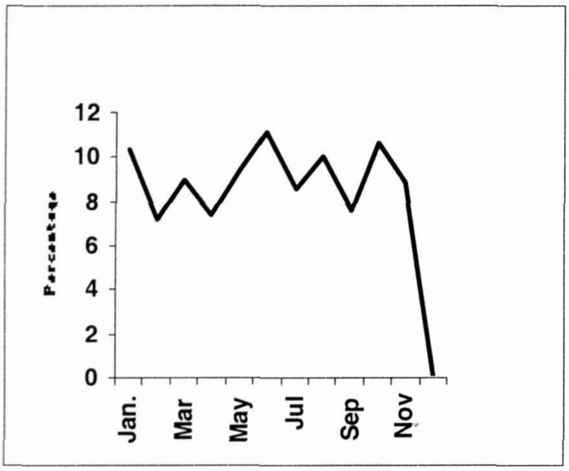

Fig. 7. Recruitment pattern of *Synagrops japonicus*

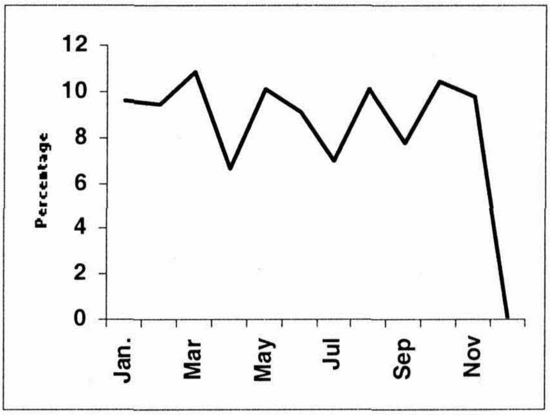

Fig. 8. Recruitment pattern of *Lamprogrammus exutus*

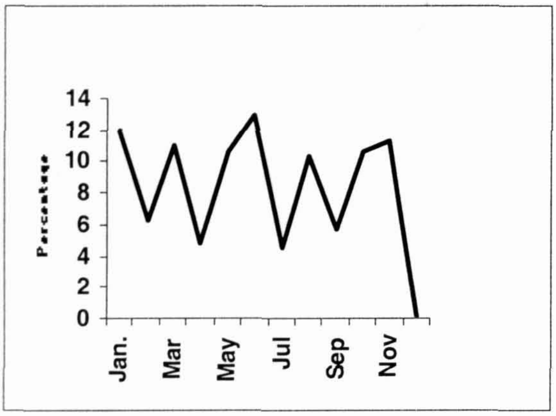

Fig. 9 Recruitment pattern of *Glyptophidium argenteum*

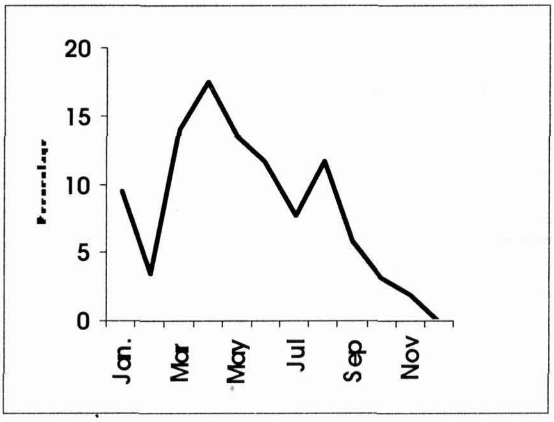

Fig. 10. Recruitment pattern of *Luciobrotula bartschi.*

been fond to occur as by-catch in these shrimp trawlers. Presently these fishes have no commercial value and are, therefore, thrown overboard. These reports and the present study indicate that a variety of deep-sea shrimps are available off the east and west coast of India. The private trawlers have been successful in effectively exploiting these resources as a result of export demand, however the fishes remain neglected. Also, this points to the need for employing innovative gear and fishing technique onboard FORV *Sagar Sampada* to get the actual index of abundance (as realised by the private trawlers) during future fishing surveys.

Yet another encouraging aspect in deep-sea resource exploitation, recently, is the case of the Indian Ocean Lobsterette *Nephropsis stewarti.* They are exploited from 250-500m off Mangalore by the private trawlers based at this centre The landings of this species was estimated to be 17, 51, 44, 22 and 11t respectively during 2000-04 as reported by Dineshbabu *et al.* (2005). The meat content is less, the price per kg varied from Rs.20-25.

Media report (New Indian Express 28-6-06) indicates that the Union Ministry of Agriculture, as part of the fishing policy formulated in 2004, has decided to issue licenses for trawlers as the fish wealth had not been fully tapped. This is a promising step to increase marine fish production and is based on the recommendations of the Empowered Committee on Marine Fisheries.

The occurrence of deep-sea glass sponge *Hyalonema* sp. (Class: Hexactinellida, Family: Hyalonematidae) was interesting. The net when hauled at this station was seen with plenty of glass rod like structures entangled in the

Table 4. *Length-weight study of deep-sea fishes.*

Bathygadus melanobranchus a = 0.0027665 b = 3.07	*Coloconger raniceps* a=0.006699 b=2.89	*Hephthocara simum* a=8.16274E-05 b=4.25	*Psenopsis cyanea* a=0.0151986 b=2.86
Bathyuroconger braueri a = 0.0003655 b = 3.31	*Coryphaenoides macrolophus* a=0.000227 b=3.87	*Lamrpogrammus niger* a=0.0012006 b=3.35	*Psettodes erumei* a=0.028466 b=2.57
Bembrops caudimaculata a=0.0030266 b=3.26	*Cubiceps baxteri* a=0.006597 b=3.21	*Luciobrotula bartschi* a=0.0022458 b=3.32	*Rauleina attrita* a=0.002864 b=3.33
Chaunax pictus a=0.006757 b=3.45	*Dicrolene multifilis* a=0.0749069 b=1.95	*Neobythitis analis* a=0.0013559 b 3.45	*Chauliodus sloani* a=0.0058952 b=2.62
Chaulidontus sloani a=1.0067801 b=2.53	*Echinorhinus brucus* a=0.0012461 b=3.36	*Neoharriotta pinnata* a=0.0003545 b=3.38	*Synagrops japonicus* a=0.0728754 b=2.29
Chelidoperca investigatoris a=0.016876 b=2.72	*Etmopterus granulosus* a=0.0061998 b=2.92	*Neoepinnula orientalis* a=0.0025363 b=3.35	*Xenomystax trucidans* a=0.000355 b=3.17

Table 5. *Population parameters and mortality coefficients of deep-sea fishes.*

Species (Finfishes & shellfish)	L_α (cm)	K/yr	Natural mortality M	Total mortality Z	Fishing mortality F	Exploitation rate E
Alepocephalus bicolor	50	1. 3	1.81	1. 88	0. 07	0. 037
Neoepinnula orientalis	23	1. 5	2. 47	3. 07	0 . 6	0. 195
Eridacnis radcliffei	45	0.77	1. 32	2. 04	0.72	0. 352
Lamprogrammus exutus	68	0. 48	0. 86	1. 8	0. 32	0. 27
Glyptophidium argenteum	28	1. 0	1.79	1. 85	0. 06	0. 032
Luciobrotula bartschi	47	0. 85	1. 39	1. 61	0. 22	0. 136
Bembrops caudimaculata	22	1.7	2.71	3. 26	0. 55	0. 168
Chelidoperca investigatoris	20	1 .0	1. 96	2. 41	0. 45	0. 186
Saurenchelys taeniola	75	1. 6	3. 69	3. 94	0. 25	0. 063
Psenopsis cyanea	22	1. 2	2.15	3. 9	1. 24	0. 365
Aristeus alcocki (Shrimp)	20	1. 2	2. 09	3. 49	1. 4	0. 401

meshes and had to be physically removed. These stalked sponges are found to grow in soft sediments in very deep waters. The glass rod like structures arise from a basal stalk like the strands of a fibre-optic cable. This species is ecologically important forming "habitat islands" in the deep plains of endless mud areas (Muller *et al.* 2004). Their occurrence in large numbers indicates the existence of extensive mud plateau off Mangalore in and around the 900-m depth zone. Bio-silica, extracted from this sponge, has a vide range of applications in the medical field from novel biomaterials for bone replacements to the stabilization of tissue (Muller *et al.*, 2004). The prospects for large scale/limited exploitation of these glass sponges cannot be set aside. The area needs to be surveyed to find out the extent of the area and its abundance.

The studies indicated that in most of the deep-sea fishes the recruitment takes place throughout the year. There was considerable similarity and clear-cut synchronization in the process in most of the species studied showing peaks pertaining to a pre-monsoon, monsoon and post-monsoon season. This should be related to an efficient system of energy conversion and its transfer in the deep-sea ecosystem where food is scarce and whatever available has to be utilised more effectively. However *L.bartschi* appeared to be an exception showing peak recruitment during the pre-monsoon and monsoon. It may

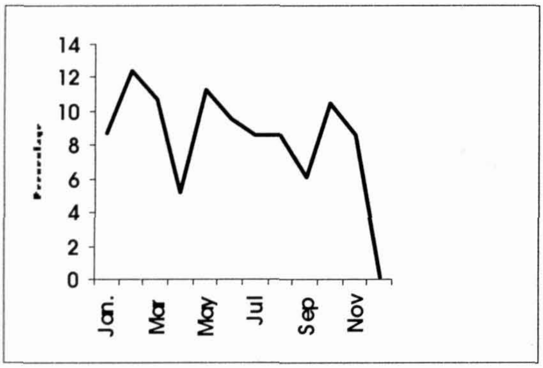

Fig. 11. Recruitment pattern of *Bembrops caudimaculata*

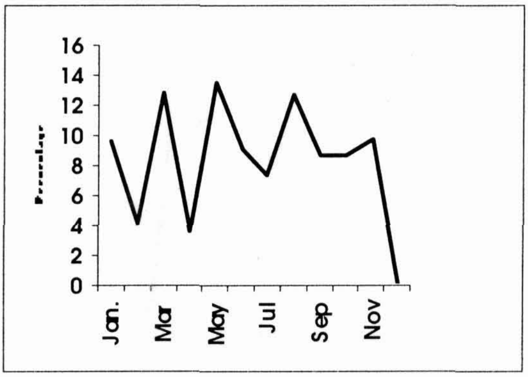

Fig. 12. Recruitment pattern of *Chelidoperca investigatoris*

be a little over ambitious to workout the various population parameters based on a single cruise. It is done with an objective to bring out first hand information on our deep-sea resources, their biology and the diversity. The catch rate obtained is poor. We do not know whether it is the actual representation or may vary according to season or an improvement in gear can yield a better result. This requires season-wise surveys. Fishing cruise comes after a gap of more than six months, because FORV *Sagar Sampada* is engaged in multi-disciplinary programmes both along the east and west coasts of India. This indicates the need for acquiring one more vessel to speed up fishing surveys.

The growth and mortality parameters of 10 species of fishes and a shrimp worked out indicate that these resources remain unexploited and die a natural death. Mainly natural mortality was observed. Fishing mortality and the exploitation ratio in the shrimp *A.alcocki* and *P.cyanea* was comparatively higher, because the deep-sea private trawlers based at Neendakara, Cochin and Munambam carryout target fishing of the former during September to April in the Quilon Bank and other similar depth zones off southwest coast of India. Invariably, in the shrimp catch, *P.cynaea* and a number of other deep-sea fishes occur as by-catch in this gear and are mostly thrown out, as there is neither consumer demand nor any utility value at present.

A total of 1570 species of finfishes are known from Indian seas which form about 62.8% of the total fish species (both inland and marine together) from the country. The biodiversity level and endemism in the deep-sea realm is high. There is general agreement that the number of species available in the area, globally, would be around 500,000 to 100 million. Our information on various deep-sea ecosystems is scarce. The present fishing cruise in the shelf-break area assumes importance in this context. Apart from a variety of shellfishes, nearly 77 species of deep-sea fishes belonging to 51 families under 20 orders caught

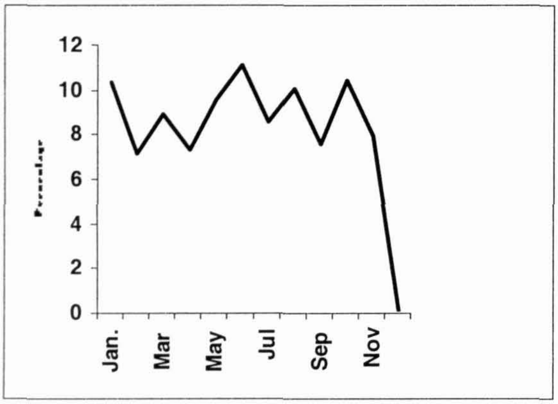

Fig. 13. Recruitment pattern of *Eridacnis radcliffei*

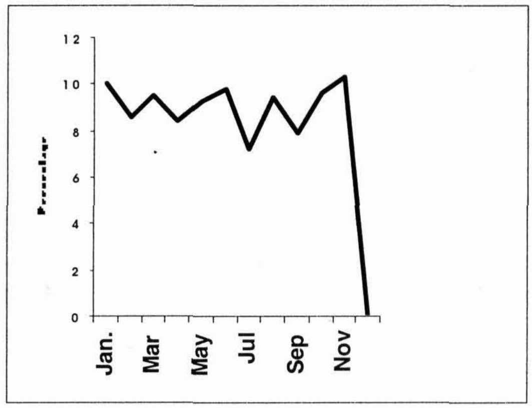

Fig. 14. Recruitment pattern of *Saurenchelys taeniola.*

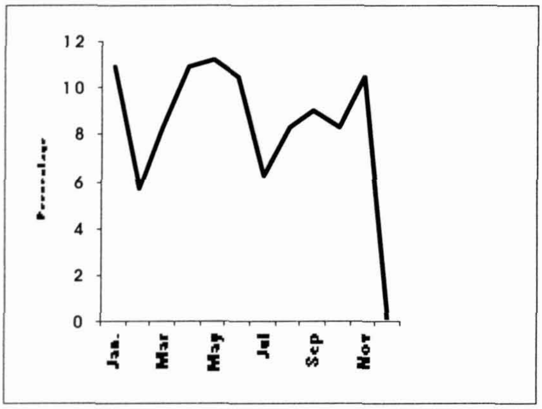

Fig.15.Recruitment pattern of *Aristeus alcocki*

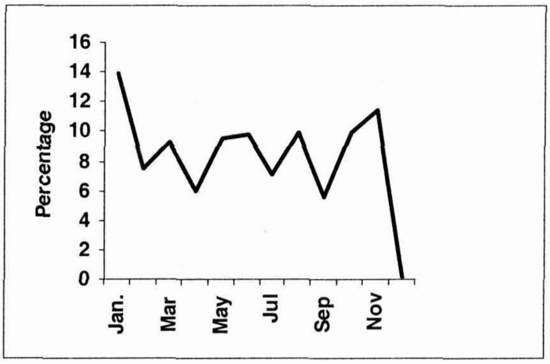

Fig. 16. Recruitment pattern of *Psenopsis cyanea.*

by the trawling indicated the rich biodiversity in the shelf-break area off the southwest region of our EEZ. Preparation of resource atlas and inventorisation of the diverse species needs special attention. Also, for identification of the deep-sea fishes we are still depending on foreign publications. Immediate attention is required to prepare manuals for identification of the deep-sea fauna of our EEZ.

The fishable potential in a unit area is considerably low in depth beyond 50 m (0.9t/km^2) compared to that in the inshore (12.2t/km^2) waters (Devaraj and Vivekanandan, 1999). All the deep-sea finfishes and shellfishes except the shrimps continue to be non-conventional. The exploitation of the deep-sea shrimp has started because of the export demand. We have been successful in developing an export market for the shrimps all these years, but the fishes were neglected till recently. The exploitation of deep-sea finfish resources needs to be put on fast track. Most of the deep-sea forms are black or brightly coloured with grotesque shape, large mouth and fang like teeth. It is essential to test how many of them are edible and further the biochemical composition has to be worked out. There is need to develop special processing technology to make various products, make them appealing to consumers and to findout export markets. An export market is essential, as the deep-sea fishing is highly capital intensive and unless it is made remunerative such ventures will remain on the anvil itself. Extraction of bioactive compounds also merits special emphasis, and such attempts are to be put on a fast track.

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