STUDIES ON SPATIO-TEMPORAL VARIATION AND COMMUNITY STRUCTURE OF DEMERSAL RESOURCES OF GOA, WEST COAST OF INDIA

A THESIS SUBMITTED TO GOA UNIVERSITY FOR THE AWARD
OF THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
MARINE SCIENCES

BY

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RESEARCH GUIDE

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II *Shri Ganesh* II

Dedicated to

my parents and fishermen

community

Statement

As required by the University ordinance 0.19.8 (vi), I state that the present thesis entitled "***Studies on spatio-temporal variation and community structure of demersal resources of Goa, West coast of India***" is my original contribution and the same has not been submitted on any previous occasion. To the best of my knowledge the present study is the first comprehensive work of its kind from the area mentioned.

The literature related to the problem investigated has been cited. Due acknowledgements have been made wherever facilities and suggestions have been availed of.

Mahabaleshwar R. Hegde

Certificate

This is to certify that the thesis entitled "***Studies on spatio-temporal variation and community structure of demersal resources of Goa, West coast of India***", submitted by **Mr. Mahabaleshwar R. Hegde** for the award of Doctor of Philosophy in Marine Sciences is based on his original studies carried out by him under my supervision. The thesis or any part thereof has not been previously submitted for any degree or diploma in any Universities or Institutions.

8/8/2014

Prof. C.U. Rivonker
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Certified that all the corrections suggested are incorporated in the thesis by the Candidate.

M.I. Khan
8/8/14

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Chapter 1.

General Introduction

1.1. Background information

The coastal ecosystems constitute less than 20 % of earth surface, and about 66 % of human population is associated with these habitats. The world's coastlines are one of its most important and intensively used areas for human needs. Coastal ecosystems exhibit high variability in ecological parameters largely influenced by land use pattern and runoff resulting in seasonal anomalies. The prevalence of wide range of abiotic factors provide wide array of habitats for marine opportunistic species those navigate between coastal and estuarine environments, thus providing enormous scope for increased diversity (Venkataraman and Wafar, 2005).

An important product of marine biodiversity research should be necessary tools for adequately managing and protecting our resources. Hutchings (2000) indicated that except a few commercially exploited species, the recovery of fishable stock is very little after the collapse and that about 69 % of species need conservation and management. Further, Caddy and Sharp (1986) suggested that over-exploitation of fish resources alters stock size and affects ecosystem functioning through successive removal of higher trophic species.

In marine ecosystems, niche overlap seems to play an important role as it is directly related with their diet and feeding behaviour (Brodeur and Pearcy, 1992). Biagi *et al.* (2002) conducted studies on spatio-temporal variations among demersal resources and suggested that they are largely influenced by depth and prey availability.

Over the last few decades, the coastal ecosystems are under tremendous human pressure. Alteration in coastal land use patterns, over-exploitation of marine resources, pollution, destruction of mangrove habitats and beach vegetation, and serious interference in the estuaries are threatening coastal ecology and livelihoods of the inhabitants. Long-term trawling activity may lead to habitat destruction (Labropoulou and Papacostantinou, 2005) as well as alteration in the composition and structure of the resident faunal assemblages (Longhurst and Pauly, 1987). Therefore, near shore trawling areas are of great concern as they are subjected to indiscriminate removal of non-targeted (including rare and non-commercial) species using variety of fishing gears (Kumar and Deepthi, 2006; Padate *et al.*, 2009; Hegde and Rivonker, 2013).

Recent trends in biodiversity research highlight the growing concern in respect of rare species because most of these are represented by relatively few individuals, and have a rather narrow / patchy geographical distribution being characteristic constituent of distinct habitat type and assemblages (Fenchel and Uiblein, 2010). Although rare species are considered economically less important, they do play a significant role in the food web structure and ecological functioning (Cheung *et al.*, 2007). This issue gains further importance in the context of the present study as rare species caught incidentally in trawl catches along the west coast of India, including the Goan coast, are discarded back to the sea (Kumar and Deepthi, 2006; Padate *et al.*, 2009; personal observation). Such indiscriminate removal of non-commercial and rare species leads to considerable loss of biodiversity (Bianchi *et al.*, 2000; Hall *et al.*, 2000). Hence, creating a database of the regional demersal faunal diversity is inevitable (Ray and Grassle, 1991).

Goa, with a coastline of 105 km supports rich, diversified demersal assemblages along the near shore fishing grounds that are subjected to exploitation throughout the year, except southwest monsoon (Goa, Daman and Diu Marine Fishing Regulation Rules, 1981). These regions exhibit varied habitats including reefs (Rodrigues *et al.*, 1998), mangroves, mudflats, estuaries (Shetye *et al.*, 2007), sandy and rocky shores those support different fauna (Rivonker *et al.*, 2008). Published literature (Ansari *et al.*, 1995, 2003) indicates the prevalence of seasonal fluctuations in relative abundance, biomass, species occurrence and community structure of demersal resources along Goa coast. The importance of the Goa region in respect of demersal fishery potential has been also emphasised in the past by Rao and Dorairaj (1968). The shallow shelf areas of Goa are subjected to relatively high fishing pressure from mechanized trawlers and varied sources of anthropogenic inputs such as pollution, water quality deterioration, alterations in land use patterns etc., which lead to environmental degradation thereby influencing the distribution and community structure of demersal living resources.

This demands holistic approach to have better insight on the role of ecological processes those govern demersal species populations and ultimately regulate species distributions. Furthermore, the study of coastal processes those overcome the deterioration effect of changing land use pattern and monsoonal sequences, thus diluting their deleterious impacts on the diverse faunal assemblages, is also necessary. Therefore, in view of the complexity of coastal ecosystems and their vulnerability to anthropogenic modification of the coastal environment, continuous monitoring of these areas is mandatory.

1.2. Literature Review

Review of literature pertaining to marine fauna from the Indian region revealed that Bloch (1785, 1787, 1801) pioneered the studies on Indian fishes. Subsequently, several efforts were made during the 18th and 19th centuries to describe fishes from the southern and eastern coasts of India (Lacépède, 1803; Russell, 1803; Hamilton, 1822; Bleeker, 1853; Blyth, 1858, 1860a, b; Day, 1865). However, the first comprehensive attempt to compile information on marine fishes of the Indian coasts was made by Sir Francis Day (1876 – 1878, 1888, 1889). He provided detailed accounts of approximately 1100 marine and estuarine species from throughout the Indian sub-continent. Subsequently, Alfred William Alcock carried out the most prolific taxonomic work on wide array of marine fauna collected on-board the *"RIMS Investigator"* from the seas off India and adjoining British colonies. His publication entitled "The Carcinological Fauna of India" (1895, 1896, 1898a, 1899a, b, 1900) contains descriptions of 605 marine brachyura including those of 126 new species. In addition, he prepared descriptive catalogues of 25 deep-sea madreporarian corals (1898b), 169 deep-sea fishes (1899c), 27 dromidean brachyura (1901a), 117 decapod crustacea – macrura and anomala (1901b), 89 anomura (1905), 21 penaeid prawns (1906) housed in the Indian Museum, Kolkata. Gardiner (1903 – 1906) compiled two volumes on the marine fauna of Lakshadweep and Maldives archipelagos. Kemp (1915) provided detailed descriptions of the marine fauna of the Chilka Lake. Subsequently, very little efforts were made during the post-independence period (Silas *et al.*, 1983; Mookherjee, 1985; Kurian and Sebastian, 1986; Rao *et al.*, 1992; Rao and Rao, 1993; Rao, 2003; Raje *et al.*, 2007) to create nationwide inventories of various marine faunal groups.

Published literature on the distribution of finfish along the coast of Goa using exploratory trawler (Prabhu and Dhawan, 1974; Ansari *et al.*, 1995) suggests that there exists a structural and seasonal variation in the distribution and occurrence of these resources along the coast of Goa. Further, Ansari *et al.* (2003) have studied the demersal fish assemblage of the bay-estuarine systems of Goa and opined that the demersal resources are largely influenced by season and are largely represented by the families Leiognathidae, Sciaenidae, Clupeidae, Cynoglossidae and Stromateidae, considered to be typical of the Indo-Pacific region. Available information about demersal resources of Goa (Rao and Dorairaj, 1968) is preliminary and does not provide complete knowledge of seasonal and structural fluctuations in the demersal resources along the Goan coast.

The bay-estuarine waters of Goa sustain a substantial demersal fishery, which is mainly exploited by the shrimp trawlers and, boat seine, shore seine etc. The trawl landings from the shelf waters of Goa reveal a multi-generic and multi-species fishery with seasonal variations (Ansari *et al.*, 1995). Besides, the Aguada and Marmugao Bays located at the western end of the Mandovi and the Zuari rivers are subjected to relatively high fishing pressure from mechanized trawlers (Ansari *et al.*, 2003). Recent studies on Goa coast (Padate *et al.*, 2010a, 2010b; Kumbhar and Rivonker, 2012; Hegde and Rivonker, 2013 and Padate *et al.*, 2013a, 2013b) have updated the information regarding the species composition and bio-geography of the few species occurring along the coast.

It is apparent from the above-cited studies that information on various aspects of finfish and other aquatic resources along the coast is scanty and does not provide adequate information about community structure and niche overlap among the species from the Goan region. The existence of lacunae in the available information on the structure of demersal marine populations along the potential fishing grounds off Goa poses considerable constraints in efficient management of these resources. Against this background, the present study was designed to focus primarily on the species composition, community structure, seasonal variations and trophic interactions to address the following objectives:

1.3. Objectives

- To study species composition of demersal population along the coast of Goa, west coast of India.
- To study the community structure and interaction among different species.
- To study the trophic relation among closely inhabiting species.

Chapter 2.

Materials and Methods

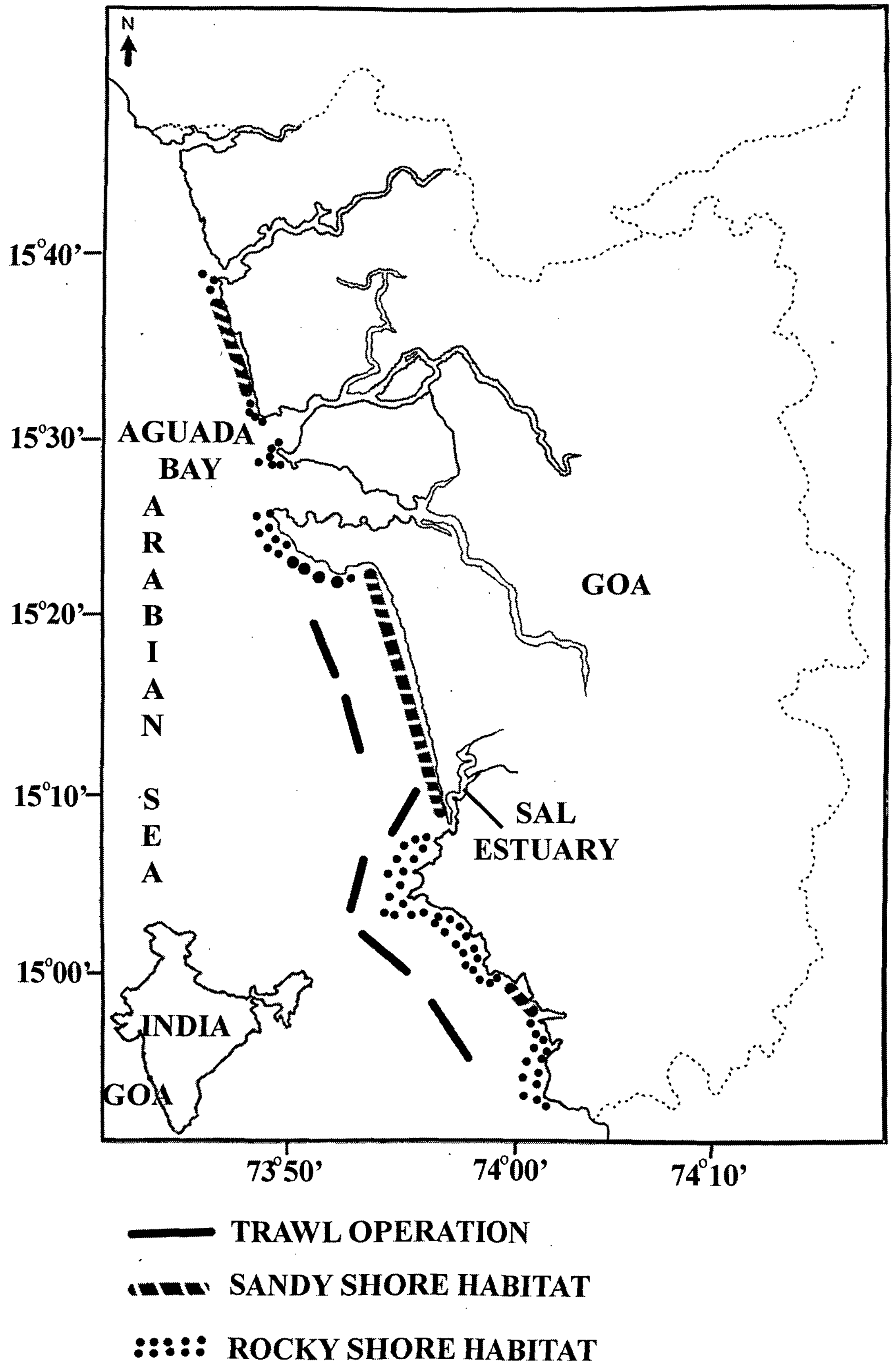
2.1. Study area

Goa, with a coastline of about 105 km along NNW – SSE, facing the Arabian Sea supports diversified geological and ecological features and forms an integral part of the central west coast of India (Wagle, 1993). The seabed consists of silty-clay up to 50 m and sandy-silt from 50 to 100 m (Modassir and Sivadas, 2003) with an average slope of 1.50 $m.km^{-1}$ up to approximately 55 m depth, and the submarine contours are approximately parallel to the coastline (Veerayya, 1972). The bathymetry is intermittently interrupted by coral reefs (Rodrigues *et al.*, 1998) and submerged rocky patches those extend from the cliffs and promontories along the adjacent rocky shores (Wagle and Kunte, 1999). The overlying waters perennially receive nutrient-rich freshwater influx from the adjoining estuaries, particularly the Mandovi–Zuari estuarine complex (between 15°25'N and 15°31'N and between 73°45'E and 73°59'E) being the most prominent with catchment area of 1700 km^2, and Sal estuary (15°08'N and 73°51'E) (Qasim, 2003).

This region experiences maximum precipitation during the Southwest monsoon accompanied by stormy weather, while quieter conditions prevail during the rest of the year (Ansari *et al.*, 1995). The intertidal estuarine marshy ecosystem is the transformation of gentle sloping of near shore banks, which is filled with silt, clay and detritus transported by riverine influx from upper reaches, where mangrove vegetation occurs in high density. The entire mudflats consist of loose muddy soil bordered by mangrove vegetation, thus making it highly productive for benthos those support large number of economically important species (Ansari *et al.*, 1995; Kulkarni *et al.*, 2003).

The present study area (Figure 2.1) comprised fishing grounds off Betul and Cabo de Rama located in the vicinity of Sal estuary (between 15°00'N and 15°16'N latitudes and between 73°41'E and 74°00'E longitudes). This region comprises two different habitats i.e. silty substratum towards the north of the estuary and submerged rock

Figure 2.1. Map of the study area indicating trawl operations and habitat complexity



outcrops towards the south. The sandy shore habitats at north are a mixture of sand, silt and clay which support abundant macrobenthos and serve as nursery grounds for most juvenile fishes. Rocky habitats along the south of estuary which is interrupted by patchy algal beds and silty habitat support rich diversity of demersal faunal assemblages. Rich mangrove vegetation occupies approximately 6.7 km^2 area along the banks of the Sal Estuary (Fernandes and Achuthankutty, 2010). In addition, occurrence of tropical reef fishes in the near shore trawl catches during the present study suggests the presence of coral reef patches towards the south of the Sal Estuary (Hegde and Rivonker, 2013).

The adjacent coastal waters constitute the potential fishing grounds off Goa coast and are subjected to intensive fishing by traditional and mechanized fishing crafts (Otter Board Motor trawlers) those employ variety of fishing gear (trawl net 344, purse seines 189, gill nets 327) to exploit the abundant pelagic and demersal resources (Rao and Dorairaj, 1968; Prabhu and Dhawan, 1974; Ansari *et al.*, 1995, 2003; Department of fisheries, Goa, 2011) with the exception of the 60-day legislative ban on fishing (Goa, Daman and Diu Marine Fisheries Rules, 1981). The mechanization of fishing crafts, particularly the bottom trawlers in 1963 and the subsequent expansion in the fishing activity has led to intensive exploitation of the fish resources. Further, expansion of fishing jetties, infrastructure development for tourism industries and human settlements, have exacerbated the pressure on these estuarine and coastal ecosystems. However, as compared to north Goa, the coastal waters off the southern region are relatively less disturbed and without any measureable impact of urban sewage discharge, port activities and large scale construction within the CRZ – Notification area.

2.2. Sample collection

The present study encompassed three years of faunistic surveys along the bay-estuarine and offshore coastal waters of Goa, Central West coast of India down to 20 m depth (Figure 2.1) to assess the diversity and total community structure of the demersal fauna. Sampling was carried out from January, 2009 to December, 2011 and comprised 96 bottom trawl hauls with a total effort of 165 hours (Table 2.1). Among these, only 19 trawl hauls were taken from the estuarine mouth in view of the prohibition on fishing in inland waters (Goa, Daman and Diu Marine Fishing Regulation Rules, 1981). Geographical position of each sampling station was recorded with a 12-Channel Geographical Positioning System (GPS) and sampling depth for the same was obtained from the Naval Hydrographic Chart No. 2021. Trawl net with 20 m head and foot rope lengths, and mesh sizes of 25, 15 and 9 mm at mouth, middle and cod end, respectively was towed at a speed of about 2 – 3 knots (4 – 5.2 $km.h^{-1}$). The trawl catch obtained was first examined for species composition and the same was recorded. Subsequently, five sub-samples (1 kg each) were randomly picked from the catch. In order to explore the possibility of occurrence of threatened species in the study area, uncommon or rare fish specimens were collected separately, put on ice prior to transportation to the laboratory for detailed examination. Fresh specimens of sciaenids and elasmobranchs were collected and preserved in ice to study trophic dynamics. During this collection, attention was also given to collect both adult and juvenile samples to study the ontogenic shift in diet.

2.3. Taxonomic identification

At the laboratory, morphological characteristics of the samples were photographed with a 7.2 mega pixel digital camera (SONY DSC S750, 3X optical zoom). In addition,

Table 2.1. Details of trawl sampling carried out along the potential fishing grounds and bay – estuarine waters of Goa

Sr. No.	Date	Area	Geographical position	Depth (m)	Duration (min)
1	23-01-09	Off Betul beach	15° 05'56.1"N 73° 53'23.9"E to 15° 10'27.0"N 73° 50'52.9"E	14 - 15	200
2	23-01-09	Off Betul beach	15° 09'30.1"N 73° 51'06.0"E to 15° 10'36.0"N 73° 51'38.1"E	16 - 17	180
3	23-01-09	Off Betul beach	15° 09'58.1"N 73° 51'06.2"E to 15° 08' 39.0"N 73° 50' 51" E	13 -15	210
4	07-03-09	Off Agonda beach	15° 02'57.5"N 73° 58'02.9"E to 15° 01'05.2"N 73° 59'18.5"E	20 - 21	120
5	07-03-09	Off Cabo de Rama	15° 01'06.1"N 73° 59'20.5"E to 15° 02'17.7"N 73° 59'06.0"E	20 - 22	135
6	07-03-09	Off Agonda beach	15° 02'18.1"N 73° 59'05.5"E to 15° 04'06.1"N 73° 57'29.7"E	18 – 20	130
7	21-03-09	Off Agonda beach	15° 02'42.1"N 73° 58'46.2"E to 15° 02'04.2"N 73° 59'01.0"E	17 - 18	120
8	21-03-09	Off Saleri	15° 02'42.1"N 73° 58'46.2"E to 15° 03'03.5"N 73° 58'09.4"E	18 - 19	135
9	21-03-09	Off Saleri	15° 03'24.9"N 73° 57'51.5"E to 15° 02'21.5"N 73° 59'00.2"E	14 -15	130
10	10-04-09	Off Saleri	15° 03'29.4"N 73° 57'17.1"E to 15° 03'03.3"N 73° 58'49.2"E	12 -13	120
11	10-04-09	Off Palolem Beach	15° 01'29.2"N 73° 59'14.0"E to 15° 00'59.8"N 73° 59'27.5"E	14 – 15	90
12	28-04-09	Off Cabo de Rama	15° 05'37.6"N 73° 51'54.4"E to 15° 08'00.3"N 73° 51'44.0"E	11 – 13	105
13	28-04-09	Off Betul	15° 10'39.9"N 73° 52'36.7"E to 15° 11'28.3"N 73° 52'45.2"E	10 - 12	165
14	15-05-09	Off Varca Beach	15° 11'01.5"N 73° 54'54.5"E to 15° 15'52.3"N 73° 49'47.4"E	10 - 13	200
15	15-05-09	Off Varca Beach	15° 16'11.7"N 73° 49'36.7"E to 15° 14'34.0"N 73° 51'36.8"E	13 - 15	160
16	15-05-09	Off Betul	15° 14'37.3"N 73° 51'43.2"E to 15° 11'00.8"N 73° 53'08.3"E	13 -14	155

17	16-09-09	Off Cabo de Rama	15° 05'15.4"N 73° 54'41.1"E to 15° 04'38.8"N 73° 56'00.7"E	14 - 16	70
18	16-09-09	Off Cabo de Rama	15° 05'03.4"N 73° 55'21.3"E to 15° 04'56.9"N 73° 54'42.2"E	13 - 14	60
19	08-12-09	Off Canacona	15° 02'54.0"N 73° 58'40.3"E to 15° 01'58.8"N 73° 58'50.4"E	10 - 11	55
20	08-12-09	Off Cabo de Rama	15° 06'35.3"N 73° 54'58.6"E to 15° 08'16.0"N 73° 55'30.2"E	9 - 10	75
21	08-12-09	Off Cabo de Rama	15° 08'16.0"N 73° 55'30.2"E to 15° 07'03.9"N 73° 55'42.6"E	7 - 9	65
22	08-12-09	Off Cabo de Rama	15° 07'12.9"N 73° 55'32.4"E to 15° 07'20.5"N 73° 55'13.4"E	7 - 9	135
23	18-12-09	Off Canacona	15° 01'21.5"N 73° 59'17.0"E to 15° 01'33"N 73° 59'02.1"E	10 - 11	90
24	18-12-09	Off Canacona	15° 02'02.6"N 73° 59'03.1"E to 15° 01'54"N 73° 59'05.8"E	7 - 8	75
25	18-12-09	Off Canacona	15° 02'53.0"N 73° 58'26.2"E to 15° 04'09"N 73° 57'10.2"E	14 - 15	70
26	09-01-10	Off Betul	15° 08'20"N 73° 56'26.5"E to 15° 07'47"N 73° 56'09.4"E	12 - 13	80
27	09-01-10	Off Betul	15° 07'47"N 73° 56'09.4"E to 15° 08'21.6"N 73° 56'28.5"E	12 - 13	85
28	09-01-10	Off Betul	15° 08'21.6"N 73° 56'28.5"E to 15° 08'53.7"N 73° 56'41.1"E	12 - 13	80
29	23-01-10	Off Cabo de Rama	15° 04'47.7"N 73° 55'48.5"E to 15° 04'53.7"N 73° 55'42.8"E	15 - 16	110
30	23-01-10	Off Cabo de Rama	15° 05'04.4"N 73° 55'28.6"E to 15° 04'59.4"N73° 54'44.4"E	14 -16	160
31	26-02-10	Off Sal estuary	15°08’20.0”N, 73°56’29.8”E – to 15°07’38.8”N, 73°56’00.7”E	6 - 8	60
32	26-02-10	Off Betul	15°10’57.0”N, 73°52’58.0”E to 15°14’25.6”N, 73°51’42.6”E	23 - 25	250
33	26-02-10	Off Betul	15°14’23.0”N, 73°51’50.0”E to 15°14’27.4”N, 73°51’44.4”E	22- 23	165
34	18-03-10	Off Betul	15°07’25.0”N, 73°54’08.8”E To 15°06’10.6”N, 73°54’55.0”E	16 - 17	115

35	18-03-10	Off Cabo de Rama	15°06’02.8”N, 73°54’48.8”E to 15°05’35.6”N, 73°55’11.9”E	19 - 20	105
36	18-03-10	Off Cabo de Rama	15°05’04.4”N, 73°55’28.6”E to 15°04’59.4”N, 73°54’44.4”E	14 - 15	140
37	18-03-10	Off Cabo de Rama	15°04’59.4”N, 73°54’44.4”E to 15°05’14.4”N, 73°54’28.6”E	15 - 16	120
38	30-03-10	Off Cabo de Rama	15°04’03.0”N, 73°57’32.0”E to 15°03’00.3”N, 73°58’25.7”E	16 - 17	75
39	30-03-10	Off Canacona	15°03’00.3”N, 73°58’25.7”E to 15°03’00.3”N, 73°58’25.7”E	8 - 10	90
40	30-03-10	Off Canacona	15°03’00.3”N, 73°58’39.0”E to 15°02’50.9”N, 73°58’56.4”E	10 - 11	120
41	30-03-10	Off Canacona	15°02’26.3”N, 73°59’02.3”E to 15°04’02.0”N, 73°57’26.7”E	14 - 15	100
42	11-04-10	Off Cabo de Rama	15°03’00.0”N, 73°58’39.0”E to 15°04’06.7”N, 73°58’07.0”E	8 - 10	85
43	11-04-10	Off Cabo de Rama	15°04’06.7”N, 73°58’07.0”E to 15°03’20.7”N, 73°57’58.7”E	9 -10	160
44	11-04-10	Off Agonda beach	15°03’20.7”N, 73°57’58.7”E to 15°03’20.6”N, 73°57’58.4”E	10 - 11	120
45	11-04-10	Off Agonda beach	15°03’42.1”N, 73°58’43.7”E to 15°03’42.0”N, 73°57’51.6”E	12 - 14	60
46	28-04-10	Off Agonda beach	15°02’58.7”N, 73°58’41.1”E to 15°02’13.0”N, 73°59’09.5”E	10 - 11	50
47	28-04-10	Off Agonda beach	15°03’23.5”N, 73°57’59.6”E to 15°03’20.4”N, 73°58’58.3”E	9 - 10	110
48	28-04-10	Off Agonda beach	15°02’13.3”N, 73°59’09.5”E to 15°02’56.5”N, 73°58’36.0”E	11 - 12	120
49	28-04-10	Off Canacona	15°01’43.0”N, 73°59’09.5”E to 15°02’56.0”N, 73°58’33.0”E	9 - 10	110
50	14-05-10	Off Betul	15°10’57.0”N, 73°52’58.0”E to 15°14’25.6”N, 73°51’42.6”E	17 - 18	110
51	14-05-10	Off Betul	15°14’23.0”N, 73°51’50.0”E to 15°14’27.4”N, 73°51’44.4”E	19 - 20	90
52	17-08-10	Off Betul	15°08’17.0”N, 73°56’27.9”E to 15°07’46.5”N, 73°55’54.2”E	12 - 13	30

53	17-08-10	Off Cabo de Rama	15°05’04.4”N, 73°55’28.6”E to 15°04’59.4”N, 73°54’44.4”E	13 - 14	35
54	23-09-10	Off Sal estuary	15°07’46.6”N, 73°56’42.0”E to 15°08’30.3”N, 73°56’39.1”E	9 -10	50
55	23-09-10	Off Colva	15°10’57.0”N, 73°52’58.0”E to 15°14’25.6”N, 73°51’42.6”E	22 - 23	150
56	23-09-10	Off Colva	15°14’23.0”N, 73°51’50.0”E to 15°14’27.4”N, 73°51’44.4”E	20 -22	165
57	23-09-10	Off Betul	15°07’25.0”N, 73°54’08.8”E to 15°06’10.6”N, 73°54’55.0”E	16 - 17	115
58	23-09-10	Off Sal estuary	15°08’56.0”N, 73°56’42.7”E to 15°08’35.6”N, 73°56’11.9”E	10 - 11	95
59	23-09-10	Off Betul	15°08’27.0”N, 73°56’27.0”E to 15°08’56.4”N, 73°56’39.3”E	6 - 8	25
60	30- 12 -10	Off Sal estuary	15°09’09.0”N, 73°56’36.0”E to 15°11’39.0”N, 73°55’56.7”E	6 - 8	90
61	30- 12 -10	Off Sal estuary	15°11’37.0”N, 73°55’54.0”E to 15°08’47.0”N, 73°56’38.3”E	16 - 18	75
62	30- 12 -10	Off Betul	15°08’47.0”N, 73°56’38.3”E to 15°08’51.0”N, 73°56’34.0”E	7 - 8	120
63	18 - 0 - 11	Off Benaulim	15°12’19.0”N, 73°55’43.0”E to 15°14’56.0”N, 73°55’00.0”E	7 - 8	95
64	18 - 0 - 11	Off Benaulim	15°14’54.3”N, 73°54’59.0”E to 15°11’55.0”N, 73°55’46.0”E	11 - 12	90
65	18 - 0 - 11	Off Benaulim	15°11’55.0”N, 73°55’49.0”E to 15°14’36.3”N, 73°55’04.0”E	6 - 8	105
66	29 - 01-11	Off Colva beach	15°12’34.0”N, 73°52’58.0”E to 15°14’25.6”N, 73°51’42.6”E	12 - 14	65
67	29 - 01-11	Off Colva beach	15°16’23.0”N, 73°51’50.0”E to 15°14’27.4”N, 73°51’44.4”E	10 - 12	60
68	29 - 01-11	Off Betul	15°07’25.0”N, 73°54’08.8”E to 15°06’10.6”N, 73°54’55.0”E	15 - 16	75
69	15- 02 -11	Off Benaulim	15°15’41.0”N, 73°54’01.0”E to 15°15’59.0”N, 73°54’32.1”E	7 - 8	112
70	15- 02 -11	Off Colva beach	15°16’27.0”N, 73°53’20.0”E to 15°15’37.4”N, 73°53’29.0”E	11 - 12	105

71	15- 02 -11	Off Colva beach	15°14’24.0”N, 73°53’29.2”E to 15°13’14.0”N, 73°53’12.0”E	15 - 16	110
72	15- 02 -11	Off Colva beach	15°15’37.0”N, 73°55’54.0”E to 15°16’25.0”N, 73°56’38.3”E	6 - 8	80
73	11 -03 -11	Off Canacona	15°03’00.3”N, 73°58’25.7”E to 15°03’00.3”N, 73°58’25.7”E	12 - 13	70
74	11 -03 -11	Off Canacona	15°03’00.3”N, 73°58’39.0”E to 15°02’50.9”N, 73°58’56.4”E	13 -14	65
75	11 -03 -11	Off Canacona	15°02’26.3”N, 73°59’02.3”E to 15°04’02.0”N, 73°57’26.7”E	13 -14	80
76	12- 04 -11	Off Cabo de Rama	15°03’00.0”N, 73°58’39.0”E to 15°04’06.7”N, 73°58’07.0”E	11 - 12	120
77	12- 04 -11	Off Agonda beach	15°03’42.1”N, 73°58’43.7”E to 15°03’42.0”N, 73°57’51.6”E	9 - 10	150
78	12- 04 -11	Off Sal estuary	15°08’20.0”N, 73°56’29.8”E to 15°07’38.8”N, 73°56’00.7”E	8 - 9	60
79	10 - 05-11	Off Sal estuary	15°08’20.0”N, 73°56’29.8”E to 15°07’38.8”N, 73°56’00.7”E	8 – 10	120
80	10 - 05-11	Off Betul	15°10’57.0”N, 73°52’58.0”E to 15°14’25.6”N, 73°51’42.6”E	10 - 12	60
81	10 - 05-11	Off Betul	15°14’23.0”N, 73°51’50.0”E to 15°14’27.4”N, 73°51’44.4”E	12 - 14	70
82	18- 09 -11	Off Canacona	15°03’00.3”N, 73°58’19.0”E to 15°02’50.9”N, 73°58’36.4”E	14-15	45
83	18- 09 -11	Off Canacona	15°02’26.3”N, 73°59’02.3”E to 15°04’02.0”N, 73°57’26.7”E	20-22	70
84	18- 09 -11	Off Canacona	15°03’00.0”N, 73°58’39.0”E to 15°04’06.7”N, 73°58’07.0”E	18-20	75
85	18- 09 -11	Off Cabo de Rama	15°03’42.1”N, 73°58’43.7”E to 15°03’42.0”N, 73°57’51.6”E	23-25	60
86	18- 09 -11	Off Agonda beach	15°03’42.1”N, 73°58’43.7”E to 15°03’42.0”N, 73°57’51.6”E	12 - 14	85
87	20- 11 -11	Off Colva	15°10’55.0”N, 73°52’59.0”E to 15°14’26.6”N, 73°51’44.6”E	20 - 21	65
88	20- 11 -11	Off Colva	15°14’24.0”N, 73°51’50.0”E to 15°14’27.4”N, 73°51’44.4”E	20 -22	100

89	20- 11 -11	Off Betul	15°07’25.0”N, 73°54’07.6”E to 15°06’10.6”N, 73°54’55.0”E	16 - 17	90
90	14-12 - 11	Off Canacona	15°00’23.0”N, 73°54’50.0”E to 15°01’27.4”N, 73°54’44.4”E	10 - 12	180
91	14-12 - 11	Off Agonda	15°04’53.0”N, 73°52’50.0”E to 15°02’47.4”N, 73°54’40.4”E	18 - 20	180
92	14-12 - 11	Off Cabe de Rama	15°05’11.0”N, 73°57’00.0”E to 15°07’27.4”N, 73°51’10.4”E	17 - 20	195
93	14-12 - 11	Off Cabo de Rama	15°03’00.0”N, 73°58’39.0”E to 15°04’06.7”N, 73°58’07.0”E	11 - 12	120
94	28-12 - 11	Off Sal estuary	15°08’20.0”N, 73°56’29.8”E to 15°07’38.8”N, 73°56’00.7”E	7 - 9	105
95	28-12 - 11	Off Sal estuary	15°08’20.0”N, 73°56’29.8”E to 15°07’38.8”N, 73°56’00.7”E	9 – 10	85
96	28-12 - 11	Off Betul	15°10’57.0”N, 73°52’58.0”E to 15°14’25.6”N, 73°51’42.6”E	10 - 12	70

minute details were recorded by Camera lucida diagrams using an Olympus SZX-DA 3M01330 microscope.

Subsequently, the samples were identified using conventional taxonomic methods involving phenotypic analysis including morphology, colour, texture patterns, meristic counts and morphological measurements down to the nearest 0.01 cm using vernier callipers. The above identification was aided by published taxonomic literature for the respective faunal groups: fin fishes (Day, 1878; Lindberg, 1973; Fischer and Whitehead, 1974; Fischer and Bianchi, 1984; Talwar and Kacker, 1984; Talwar and Jhingran, 1991); prawns (George, 1980; Kurian and Sebastian, 1986; Chan, 1998); stomatopods (Manning, 1998); brachyuran crabs (Alcock, 1895, 1896, 1899a, 1900; Leene, 1938; Chhapgar, 1957; Sakai, 1976; Sethuramalingam and Khan, 1991; Wee and Ng, 1995; Jeyabaskaran *et al.*, 2002); anomuran crabs (Khan, 1992); molluscs (Silas *et al.*, 1983; Roper *et al.*, 1984; Mookherjee, 1985; Rao and Rao, 1993; Wilson, 1994; Apte, 1998; Rajagopal *et al.*, 1998); echinoderms (Clark and Rowe, 1971); sea snakes (Rasmussen, 2001). In addition, internet websites such as Fishbase (Froese and Pauly, 2012), Sealifebase (Palomares and Pauly, 2012), and Hardy's internet guide to Marine Gastropods (Hardy, 2012) were referred for species identification.

2.4. Morphometric analysis

Morphometric analysis involved measurement of morphological parameters of the biological specimens and subsequent comparison with published data (Froese and Pauly, 2012; Palomares and Pauly, 2012). The above data was employed to aid the explanation pertaining to temporal variations in the occurrence of demersal fish and faunal associations.

2.5. Sample preservation

Representative specimens of fin fishes, molluscs and other faunal groups were preserved using 5 % formalin, whereas crustaceans were preserved in 5 % buffered formalin (buffered with hexamethylene tetramine to prevent fragmentation of appendages). These are stored in pre-labelled transparent plastic bottles and deposited as reference vouchers at the Marine Biology laboratory, Department of Marine Sciences, Goa University.

2.6. Stomach content analysis

Morphological parameters (Standard Length, Total Length) and weights of individual specimens were measured prior to dissection of the specimens. The entire gut was removed from the fish, weighed (wet weight) using electronic weighing balance (Sartorius, CP 225 with accuracy ± 0.01 mg) and preserved in 70 % alcohol. Further, analysis of stomach contents of fishes was carried out following the Gravimetric method (Hyslop, 1980). Based on the state of relative distension of the stomach, the intensity of feeding was classified into three categories as fully filled, ½ filled, and empty (Manojkumar, 2008). Gut contents digested beyond visual recognition and fishes with averted stomachs caused by decompression were not included in the analysis. Stomach contents were identified down to the lowest possible taxa and their frequency of occurrence was recorded.

2.7. Data compilation and processing

2.7.1. Faunal composition

All taxa encountered during the present study were divided into 4 broad taxonomic groups namely Finfishes, Crustaceans, Molluscs, and Other fauna, and graphically represented on pie-charts to elucidate the faunal composition of each of the above mentioned groups. Subsequently, a list of the above taxa was tabulated along with the status of reporting from the study area.

2.7.2. Faunal abundance and weight

Raw data i.e. abundance and / or weight of constituent species from five sub-samples of each trawl haul were summed up (equation 1).

$$X = x_1 + x_2 + x_3 + x_4 + x_5 \text{..} (1).$$

where 'x' denotes abundance / weight of a taxon in a sub-sample.

The above data was standardized to 60–minute trawl in view of the variability in trawling duration throughout the study and subsequently extrapolated to the total trawl. Thereafter, the data was segregated into the principal faunal groups namely fin fish, crustaceans, molluscs and, other fauna, and their sub-groups to determine their contribution to the total trawl catch and plotted on pie-charts. In addition, the monthly trends in abundance and weight of the principal faunal groups and their sub-groups were computed and graphically plotted to study the temporal variations. The abundance is expressed as number per hour (N/h), and weight as kilogram per hour (Kg/h). Comparisons of abundance and weight of faunal groups by month and season were analyzed by two-way Analysis of Variance (ANOVA).

2.7.3. Spatio-temporal variation

Standardized abundance and weight data were plotted using months as a variables using Microsoft Excel, 2007 version. To study the spatio-temporal variation of demersal fauna and habitat selection of sciaenids off Goa, the trawl catch data were segregated into two distinct habitats. The habitats near the sandy beaches were identified as "sandy habitat", those near the rocky shores or surrounded by submerged rocks were identified as "rocky habitat". Out of 165 trawls, 88 trawls were operated in the sandy habitat and the remaining 77 were taken in the vicinity of rocky habitat. Further, species wise abundance data for the respective habitats were segregated, normalized and plotted using the Surfer-5 software to study the habitat selection. Subsequently, colour contour maps based on faunal abundance were plotted using Surfer–6 software to study spatial variations.

2.7.4. Cluster analysis

Data collected from stomach content analysis were converted into a lower triangular matrix using the Bray–Curtis similarity coefficient (Bray and Curtis, 1957) and subjected to Dendrogram plotting and nMDS using the Plymouth Routines In Multivariate Ecological Research (PRIMER) version 5 computer program (Clarke and Gorley, 2001).

2.7.5. Dietary attributes

Vacuity index is the number of empty stomachs expressed as a percentage of the total number of stomachs examined (Hajisamae *et al.*, 2003).

Stomach content data was compiled and Index of Relative Importance "I_{RI}" (Pinkas *et al.*, 1971) was computed to evaluate the importance of each prey item.

$I_{\mathrm{RI}} = (\%\, N_i + \%\, W_i) \times \%\, FO_i$ .... (2)

Where N_i, W_i and FO_i represent percentage of number, weight and frequency of occurrence of prey "i", respectively.

In case of sciaenids due to the occurrence of planktonic prey items only % FO was used to avoid the error of volume to weight conversion as suggested by Baker *et al.* (2013).

Percentage FO is the number of stomachs in which particular food item was present and expressed as a percentage of the total number of non-empty stomachs.

Index of diet breadth "B" of a species was computed using Levin's standardized index (Krebs, 1989; Labropoulou and Papadopoulou-Smith, 1999) to establish the level of specialization of each examined species and to identify whether it is a generalized or specialized feeder. This index ranges from 0 to 1; low values (< 0.5) indicate a diet dominated by a few prey items or specialized consumer and higher values (> 0.5) indicate generalized consumer.

$$B_i = [(\Sigma_j p_{ij}^2)^{-1} - 1]\,(n-1)^{-1} \quad \ldots\ldots (3)$$

Where, B_i is Levin's standardized index for predator "i", p_{ij} is the proportion of the diet of predator "i" that is made up of prey "j", "n" is the number of prey items.

Dietary similarity index "S" (Linton *et al.*, 1981) was computed to evaluate the extent of diet overlap between the commonly observed species.

$$S = 100\,(1 - \tfrac{1}{2}\,\Sigma\,|P_{xi} - P_{yi}|) \quad \ldots\ldots (4)$$

Where, P_{xi} and P_{yi} are the proportions of the diets of the species examined 'x' and 'y' respectively, of prey 'i'.

Trophic level of the species was computed following Christensen and Pauly (1992) to assess the position of the examined species in the food web.

$$TL_i = 1 + \sum_{j=1}^{n} (DC_{ij} \cdot TL_j) \quad \ldots\ldots (5)$$

Where, TL_i is the trophic level of the species "i", DC_{ij} is the proportion of the prey species "j" in the diet of "i", TL_j is the trophic level of the prey species.

Chapter 3.

Species composition and spatio-temporal variations of demersal fauna of Goa

3.1. Introduction

Coastal ecosystems support wide array of species and their complexity in terms of species diversity and species interactions are much emphasized in the tropical seas (Venkataraman and Wafar, 2005). The prevalence of a wide range of abiotic factors, local geographic features coupled with diverse habitat offer scope to sustain high species diversity (Ansari *et al.*, 1995).

In the demersal environment, high diversity leads to the formation of myriad assemblages, which interact among themselves forming larger communities. Among the demersal environments, near shore trawling areas are of particularly greater concern as they are subjected to indiscriminate removal of non-target species, including rare and non-commercial ones, caught incidentally by bottom trawlers (Kumar and Deepthi, 2006; Padate *et al.*, 2009). Recent literature indicates the growing importance of rare species in biodiversity research (Fenchel and Uiblein, 2010) mainly because rare species are represented by relatively few individuals, and have a rather narrow / patchy geographical distribution (Padate *et al.*, 2010a) and are characteristic constituents of distinct habitat type and assemblages.

Observations on demersal fisheries of Goa coast reveal that these rare species are commonly caught as by-catch by trawlers and discarded back to the sea (Padate *et al.*, 2009; personal observation). Rampant removal of non-commercial and rare species leads to loss of biodiversity, thus making it inevitable to create a database on regional diversity of demersal fauna (Ray and Grassle, 1991).

The community structure concept focuses upon the interactions among species and their environments including trophic networks (Pianka, 1973; Cody, 1974) and enables better understanding, not only of the species, but also the associated biological processes that regulate the community. These studies comprise (a) qualitative analyses involving species composition and their ecological categorization, and (b) quantitative analyses pertaining to faunal abundance, weight, diversity and spatio-temporal variations among these parameters.

In view of this, a comprehensive review of literature was carried out to explore various aspects of the demersal marine community structure in coastal ecosystems across various bio-regions of the world.

3.2. Literature review

Published literature pertaining to the demersal marine fish communities indicate that extensive studies have been carried out in the major bay-estuarine and coastal ecosystems (Elliot *et al.,* 2007). A majority of these studies have been carried out in the Indo–Western Pacific regions (Wallace *et al.*, 1984; Blaber *et al.*, 1985, 1989, 1994, 1995; Blaber and Milton, 1990; Chong *et al.*, 1990; Potter *et al.*, 1990; Robertson and Duke, 1990; Watson *et al.*, 1990; Chittima and Wannakiat, 1992; Federizon, 1992; Ansari *et al.,* 1995, 2003; Harrison and Whitfield, 1995; Martin *et al.*, 1995; Bianchi, 1996; Laroche *et al.*, 1997; Alias, 2003; Campos, 2003; Hajisamae *et al.*, 2003; Harrison, 2003; Srinath *et al.*, 2003; Lugendo *et al.*, 2007; Chen *et al.*, 2009; Hajisamae, 2009; Yemane *et al.,* 2010). The above studies were focused at describing the community structure of demersal fishes of both pristine and highly impacted coastal habitats through spatio-temporal and trophic analyses of the constituent fish populations. In addition, a few of these studies (Martin *et al.*, 1995; Ansari *et al.*, 2003; Lugendo *et al.*, 2007) attempted to elucidate the role of environmental factors on the community structure and suggested that environmental anomalies play vital role in the composition of biotic communities.

Studies from Europe and the Mediterranean region (Claridge *et al.*, 1986; Pomfret *et al.*, 1991; Potter *et al.*, 1997; Elliot and Dewailly, 1995; Marshall and Elliot, 1998; Koutrakis *et al.*, 2000; Mathieson *et al.*, 2000; Gordo and Cabral, 2001; Lobry *et al.*, 2003; Prista *et al.*, 2003; Labropoulou and Papaconstantinou, 2005; Akin *et al.*, 2005; Selleslagh and Amara, 2008) on the demersal faunal assemblages of temperate estuaries and boreal shelf waters and revealed that salinity, temperature and depth played a major role in structuring species assemblages of these environments.

Albaret *et al.* (2004), Guillard *et al.* (2004) and Simier *et al.* (2006) intensively studied the spatio-temporal variability in fish diversity and distribution within the Gambia estuary (Atlantic coast of Africa) in relation to environmental variables and suggested the use of estuaries as a major habitat for fish communities.

It is imperative that these studies focused mostly on demersal ichthyofauna, thus creating lacunae in understanding the role of invertebrate components. In contrast, only few studies (De Ben *et al.*, 1990; Maes *et al.*, 1998; Ungaro *et al.*, 1999; Akin *et al.*, 2003; Chesoh *et al.*, 2009) attempted to describe both demersal fin fish and invertebrate communities. De Ben *et al.* (1990) reported spatio-temporal variations in fin fish and crustacean distribution and abundance from the Yaquina Bay, Oregon (USA) and attributed the same to variations in salinity and temperature. Ungaro *et al.* (1999) attempted to describe the fin fish, crustacean and cephalopod assemblages along the South Adriatic coast of the Mediterranean Sea and revealed a strong association between fin fish distribution and depth, whereas the influence of depth on invertebrate was comparatively lower.

Studies pertaining to the diversity of coastal macrofauna from the estuarine and shelf waters of Goa (Rao and Dorairaj, 1968; Talwar, 1973; Prabhu and Dhawan, 1974; George, 1980; Parulekar *et al.*, 1980; Ansari *et al.*, 1995) were focussed on reporting commercial species, thereby creating lacunae on occurrence and distribution of rare and non-commercial species from this region. Recent studies (Padate *et al.*, 2009; Padate *et al.*, 2010a, 2010b) documented one species new to science and few rare species from Goa coast. Additionally, other studies from this region focused upon the taxonomy of various fauna including gastropods (Kumbhar and Rivonker, 2012), mud crabs (Padate *et al.*, 2013a) and puffer fishes (Padate *et al.*, 2013b). Padate (2011) reported 55 new records from the Goa coast. Above studies indicate that the documentation of demersal fauna from the Goa coast is preliminary and necessitates further update through more intensive studies.

Hence, the establishment of a comprehensive database on the demersal marine fauna was pertinent in order to provide a platform towards improved understanding of the coastal biodiversity of Goa. The present study primarily attempts to provide baseline information on the species composition of coastal macrofauna through intensive sampling and subsequent creation of an inventory about all the components of the demersal community. Further, the study makes an attempt to explain the spatio-temporal variations in the occurrence of demersal fauna along the Goa coast.

3.3. Results

3.3.1. Species composition

Studies on species composition revealed altogether 184 taxa belonging to seven major faunal groups (Figure 3.1). Among these, the teleosts (119 taxa) dominated, followed by crustaceans (27), molluscs (22), elasmobranchs (09), echinoderms (04), sea snakes (02) and cnidarians (01). Among these, 180 taxa were identified down to the species level (Table 3.1).

Figure 3.1. Species diversity of demersal fauna

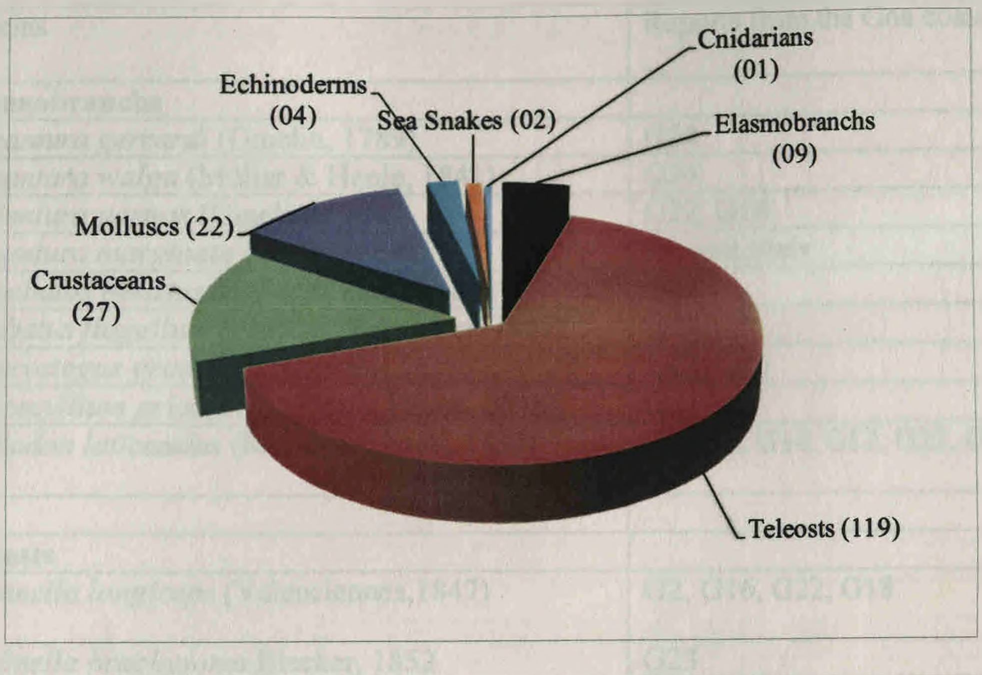


Table 3.1. List of demersal marine taxa observed during the present study

Sl. No.	Species	Reports from the Goa coast
A.	**Elasmobranchs**	
1	*Himantura gerrardi* (Gmelin, 1789)	G24
2	*Himantura walga* (Müller & Henle, 1841)	G24
3	*Himantura uarnak* (Gmelin, 1789)	G22, G16
4	*Himantura marginata* (Blyth, 1860)	Present study
5	*Rhinobatos obtusus* Müller & Henle, 1841	G24
6	*Aetobatus flagellum* (Bloch & Schneider, 1801)	G24
7	*Glaucostegus granulatus* (Cuvier, 1829)	G22, G16
8	*Chiloscyllium griseum* (Müller & Henle, 1838)	G2
9	*Scoliodon laticaudus* (Müller & Henle, 1838)	G2, G4, G14, G17, G22, G16
B.	**Teleosts**	
1	*Sardinella longiceps* (Valenciennes,1847)	G2, G16, G22, G18
2	*Sardinella brachysoma* Bleeker, 1852	G23
3	*Sardinella gibbosa* (Bleeker, 1849)	G2, G23
4	*Sardinella fimbriata* (Valenciennes, 1847)	G2, G16, G18
5	*Escualosa thoracata* (Valenciennes, 1847)	G2, G16, G18
6	*Nematalosa nasus* (Bloch, 1795)	G2, G16, G18
7	*Dussumieria acuta* (Valenciennes, 1847)	G4, G14, G17, G22
8	*Opisthopterus tardoore* (Cuvier, 1829)	G4, G14, G16, G17, G18
9	*Pellona ditchela* Valenciennes, 1847	G2, G4, G14, G17
10	*Ilisha elongata* (Anonymous [Bennette], 1830)	G2, G14
11	*Thryssa malabarica* (Bloch, 1795)	G2, G3
12	*Thryssa mystax* (Bloch & Schneider, 1801)	G24
13	*Thryssa hamiltoni* Gray, 1835	G2
14	*Thryssa purava* (Hamilton, 1822)	G2, G16
15	*Thryssa setirostris* (Broussonet, 1782)	G24
16	*Thryssa dussumieri* (Valenciennes, 1848)	G2, G16
17	*Stolephorus commersonnii* (Lacepède, 1803)	G16, G21
18	*Stolephorus baganensis* Hardenberg, 1933	G2
19	*Hyporhamphus limbatus* (Valenciennes, 1847)	Present study
20	*Mugil cephalus* Linnaeus, 1758	G18
21	*Siganus canaliculatus* (Park, 1797)	G2, G16
22	*Signaus vermiculatus* (Valenciennes, 1835)	G23
23	*Ambassis gymnocephalus* (Lacepède, 1802)	G2, G3, G16
24	*Ostorhinchus fasciatus* (White, 1790)	G24
25	*Archamia bleekeri* (Günther, 1859)	G24
26	*Alectis indica* (Rüppell, 1830)	G2, G22
27	*Alepes djedaba* (Forsskål, 1775)	G2, G22
28	*Atropus atropos* (Bloch & Schneider, 1801)	G2, G14, G17, G22
29	*Caranx ignobilis* (Forsskål, 1775)	G22
30	*Caranx sexfasciatus* Quoy & Gaimard, 1825	G2, G23
31	*Decapterus russelli* (Rüppell, 1830)	G22

32	*Megalaspis cordyla* (Linnaeus, 1758)	G2, G14, G16, G17, G22
33	*Parastromateus niger* (Bloch, 1795)	G2, G4, G16, G22
34	*Scomberoides commersonnianus* (Lacepède, 1801)	G24
35	*Scomberoides tol* (Cuvier, 1832)	G2, G23
36	*Drepane punctata* (Linnaeus, 1758)	G2, G16, G22
37	*Drepane longimana* (Linnaeus, 1758)	G24
38	*Gerres filamentosus* (Cuvier, 1829)	G2, G16
39	*Gerres limbatus* Cuvier, 1830	G16
40	*Lactarius lactarius* (Bloch & Schneider, 1801)	G1, G2, G4, G14, G17, G22
41	*Gazza minuta* (Bloch, 1795)	G24
42	*Photopectoralis bindus* (Valenciennes, 1835)	G4, G14, G17, G22
43	*Nuchequula blochii* (Valenciennes, 1835)	G2, G16
44	*Leiognathus brevirostris* (Valenciennes, 1835)	G24
45	*Leiognathus daura* (Cuvier, 1829)	G2, G16
46	*Leiognathus berbis* (Valenciennes, 1835)	G2
47	*Eubleekeria splendens* (Cuvier, 1829)	G2, G4, G14, G17
48	*Secutor insidiator* (Bloch, 1787)	G2, G4, G16, G22
49	*Secutor ruconius* (Hamilton, 1822)	G2
50	*Lutjanus lutjanus* Bloch, 1790	G2, G14, G16
51	*Upeneus tragula* Richardson, 1846	Present study
52	*Nemipterus japonicus* (Bloch, 1791)	G2, G16, G18, G22
53	*Nemipterus bipunctatus* (Valenciennes, 1830)	Present study
54	*Pempheris molucca* Cuvier, 1829	G24
55	*Priacanthus hamrur* (Forsskal, 1775)	G2
56	*Filimanus heptadactyla* (Cuvier, 1829)	G2, G16, G22
57	*Daysciaena albida* (Cuvier, 1830)	G2, G14, G17
58	*Dendrophysa russelii* (Cuvier, 1829)	G24
59	*Johnius borneensis* (Bleeker, 1851)	G2, G14, G16
60	*Johnius coitor* (Hamilton, 1822)	Present study
61	*Johnius elongatus* LalMohan, 1976	G2, G14, G16
62	*Johnius carutta* Bloch, 1793	Present study
63	*Johnius dussumieri* (Cuvier, 1830)	G2
64	*Johnius belangerii* (Cuvier, 1830)	G2
65	*Johnius amblycephalus* (Bleeker, 1855)	Present study
66	*Kathala axillaris* (Cuvier, 1830)	G2
67	*Otolithes cuvieri* Trewavas, 1974	G2, G14, G16, G18
68	*Otolithes ruber* (Bloch & Schneider, 1801)	G2, G4, G14, G17, G18
69	*Pennahia anea* (Bloch, 1793)	G2, G14, G17
70	*Nibea maculate* (Bloch & Schneider, 1801)	G2, G23
71	*Epinephelus diacanthus* (Valenciennes, 1828)	G2, G22,G16
72	*Sillago sihama* (Forskål, 1775)	G2, G14, G17, G18, G16
73	*Pomadasys hasta* (Bloch, 1790)	G1, G2, G3, G16
74	*Pomadasys furcatus* (Bloch & Schneider, 1801)	G24
75	*Pomadasys maculatus* (Bloch, 1793)	G2, G22, G16
76	*Plectorhinchus gibbosus* (Lacepède, 1802)	G24
77	*Terapon jarbua* (Forskål, 1775)	G2, G16, G22
78	*Terapon theraps* Cuvier, 1829	G2, G16
79	*Terapon puta* Cuvier, 1829	G2, G16

80	*Scomberomorus guttatus* (Bloch & Schneider, 1801)	G2, G16, G22
81	*Rastrelliger kanagurta* (Cuvier, 1816)	G2, G16, G18, G22
82	*Trichiurus lepturus* Linnaeus, 1758	G2, G14, G17, G22
83	*Sphyraena putnamae* Jordan & Seale, 1905	G22
84	*Sphyraena obtusata* Cuvier, 1829	G16, G22
85	*Pampus argenteus* (Euphrasen, 1788)	G2, G4, G14, G16, G17
86	*Pampus chinensis* (Euphrasen, 1788)	G2, G4, G14, G16, G17
87	*Odontamblyopus rubicundus* (Hamilton, 1822)	G2
88	*Yongeichthys criniger* (Valenciennes, 1837)	G24
89	*Parachaeturichthys polynema* (Bleeker, 1853)	G24
90	*Callionymus japonicus* Houttuyn, 1782	G24
91	*Callionymus sagitta* Pallas, 1770	G24
92	*Grammoplites scaber* (Linnaeus, 1758)	G2, G16
93	*Minous monodactylus* (Bloch & Schneider, 1801)	G2
94	*Cynoglossus dubius* Day, 1873	G2, G14, G17
95	*Cynoglossus puncticeps* (Richardson, 1846)	G2
96	*Cynoglossus macrostomus* Norman, 1928	G2, G14, G17
97	*Paraplagusia bilineata* (Bloch, 1785)	G2
98	*Paraplagusia blochii* (Bleeker, 1851)	G2
99	*Brachirus orientalis* (Bloch & Schneider, 1801)	Present study
100	*Synaptura albomaculata* Kaup, 1858	G24
101	*Synaptura commersonnii* (Lacepède, 1802)	G4, G16
102	*Solea ovata* Richardson, 1846	G2, G16
103	*Pseudorhombus triocellatus* (Bloch & Schneider, 1801)	G2, G16
104	*Pseudorhombus arsius* (Hamilton, 1822)	G2, G14, G17
105	*Triacanthus biaculeatus* (Bloch, 1786)	G24
106	*Lagocephalus spadiceus* (Richardson, 1845)	G2
107	*Chelonodon patoca* (Hamilton, 1822)	G2
108	*Odonus niger* (Rüppell, 1836)	Present study
109	*Acreichthys hajam* (Bleeker, 1951)	Present study
110	*Bregmaceros mcclellandi* Thompson, 1840	G16
111	*Arius maculatus* (Thunberg, 1792)	G2, G14, G17
112	*Arius dussumieri* Valenciennes, 1840	G2
113	*Plotosus lineatus* (Thunberg, 1787)	G14, G16, G17
114	*Pisodonophis cancrivorus* (Richardson, 1848)	G2
115	*Muraenesox cinereus* (Forskål, 1775)	G2, G22
116	*Uroconger lepturus* Richardson, 1845	G2
117	*Gymnothorax thyrsoideus* (Bleeker, 1852)	Present study
118	*Saurida tumbil* (Bloch, 1795)	G2, G14, G16, G17
119	*Trachinocephalus myops* (Forster, 1801)	G24
C.	**Crustaceans**	
1	*Penaeus* (*Penaeus*) *monodon* Fabricius, 1798	G4, G5, G16, G21
2	*Penaeus* (*Fenneropenaeus*) *indicus* (H. Milne Edwards,1837)	G4, G5, G21, G16
3	*Penaeus* (*Marsupenaeus*) *japonicus* Bate, 1888	G11, G21

4	*Metapenaeus dobsoni* (Miers, 1878)	G4, G5, G16, G21,G9
5	*Metapenaeus affinis* (H. Milne Edwards, 1837)	G4, G5, G16, G21,G9
6	*Parapenaeopsis stylifera* (H. Milne Edwards, 1837)	G4, G5, G16, G21,G9
7	*Parapenaeopsis maxillipedo* (Alcock, 1905)	G24
8	*Exhippolysmata ensirostris* (Kemp, 1914)	G16
9	*Alpheus euphrosyne euphrosyne* de Man, 1897	G6
10	*Panulirus polyphagus* (Herbst, 1793)	G16
11	*Diogenes miles* (Fabricius, 1787)	G24
12	*Diogenes alias* McLaughlin and Holthuis, 2001[5,‡]	Present study
13	*Dorippe astuta* (Fabricius, 1793)	G13, G6
14	*Calappa lophos* (Herbst, 1785)	G24
15	*Ashtoret lunaris* (Forskål, 1775)	G13, G6
16	*Leucosia craniolaris* (Linnaeus, 1764)	G13
17	*Doclea rissonii* Leach, 1815	G13
18	*Portunus* (*Portunus*) *sanguinolentus* (Herbst, 1783)	G6, G13, G16, G22
19	*Portunus* (*Portunus*) *pelagicus* (Linnaeus, 1758)	G6, G13, G16, G22
20	*Scylla serrata* (Forskål, 1775)	G13, G16
21	*Charybdis* (*Charybdis*) *lucifera* (Fabricius, 1798)	G13
22	*Charybdis* (*Charybdis*) *feriata* (Linnaeus, 1758)	G13, G22
23	*Charybdis* (*Charybdis*) *variegata* (Fabricius, 1798)	G24
24	*Charybdis* (*Goniohellenus*) *vadorum* (Alcock, 1899)	G13
25	*Etisodes epistomus*	Present study
26	*Dotilla* sp.	??
27	*Miyakella nepa* (Latreille, 1828)	??
D.	**Molluscs**	
1	*Paphia textile* (Gmelin, 1791)	G6, G10
2	*Solen truncatus* Wood, 1815	G6
3	*Turritella duplicata* (Linnaeus, 1758)	G15
4	*Turritella turritella* (Lamarck, 1822)	G15
5	*Bufonaria* (*Bufonaria*) *spinosa* (Link, 1807)	??
6	*Gyrineum natator* (Röding, 1798)	G8
7	*Murex tribulus* Linnaeus, 1758	G15
8	*Purpura bufo* Lamarck, 1822	G15
9	*Babylonia spirata* (Linnaeus, 1758)	G15
10	*Olivancillaria gibbosa* (Born, 1778)	G15
11	*Cantharus spiralis* (Gray, 1839)	G15
12	*Tibia* (*Tibia*) *curta* Sowerby, 1842	G15
13	*Pugilina cochlidium* (Linnaeus, 1758)	G15
14	*Turricula javana* (Linnaeus, 1767)	G15
15	*Trochus radiates* Gmelin, 1791	G15
16	*Thias lacera* (Born, 1778)	G12
17	*Turbo* sp.	??
18	*Trigonostoma scalariformis* Lamarck, 1822	Present study
19	*Uroteuthis* (*Photololigo*) *duvauceli* (Orbigny, 1835)	G22, G16

20	*Sepiella inermis* (Van Hasselt, 1835)	G24
21	*Cistopus indicus* (Orbigny, 1840)	G24
22	*Octopus* sp.	
E.	**Echinoderms**	
1.	*Astropecten indicus* Döderlein, 1889	G6
2.	*Temnopleurus toreumaticus* (Leske, 1778)	G6
3.	*Temnopleurus decipiens* (De Meijere)	Present study
4.	*Stomopneustes variolaris* Lamarck, 1816	Present study
F.	**Sea snakes**	
1.	*Enhydrina schistosa* (Daudin, 1803)	G19, G20
2.	*Lapemis curtus* (Shaw, 1802)	G19, G20
G.	**Jellyfish**	
1.	*Aurelia aurita* (Linnaeus, 1758)	??

G1– Rao and Dorairaj (1968)

G2 – Talwar (1973)

G3 – Tilak (1973)

G4 – Prabhu and Dhawan (1974)

G5 – George (1980)

G6 – Parulekar *et al.* (1980)

G7 – Poss (1986)

G8 – Mookherjee (1985)

G9 – Achuthankutty and Parulekar (1986)

G10 – Rao *et al.* (1992)

G11– Achuthankutty and Nair (1993)

G12– Rao and Rao (1993)

G13 – Chatterji (1994)

G14 – Ansari *et al.* (1995)

G15 – Apte (1998)

G16 – Alvares (2002)

G17 – Ansari *et al.* (2003)

G18 – Ansari (2004)

G19 – Lobo *et al.* (2004)

G20 – Lobo (2005)

G21– Ansari *et al.* (2006)

G22 – Ansari (2008)

G23 – Froese and Pauly (2012)

G24 – Padate (2011)

??- literature not available

3.3.2. New records for the study area

Out of the 184 species collected during the present study, sixteen were recorded for the first time from the region (Table 3.2). These include one sea urchin namely *Temnopleurus decipiens* that has been recorded for the first time from Indian waters. In addition, another sea urchin (*Stomopneustes variolaris*), two teleosts (*Acreichthys hajam*, *Johnius coitor*), one hermit crab (*Diogenes alias*) and one gastropod (*Trigonostoma scalarifomis*) are new records for the entire west coast of India. Additionally, ten teleosts are new records for Goa coast (Table 3.2).

3.3.3. Quantitative analysis

3.3.3a.Total catch

The quantitative analysis of trawl catch data revealed that crustaceans were the major faunal group in terms of both abundance (52 %; Figure 3.2a) and weight (45 %; Figure 3.2b). The teleosts were the second largest group in terms of faunal abundance (40 %; Figure 3.2a) and weight (42 %; Figure 3.2b). Molluscs and echinoderms constituted only 3 % of faunal abundance, and contributed only 4 % to the total faunal weight. Elasmobranchs and miscellaneous groups (sea snakes and cnidarians) contributed only 1 % to the total abundance.

3.3.4. Temporal variations

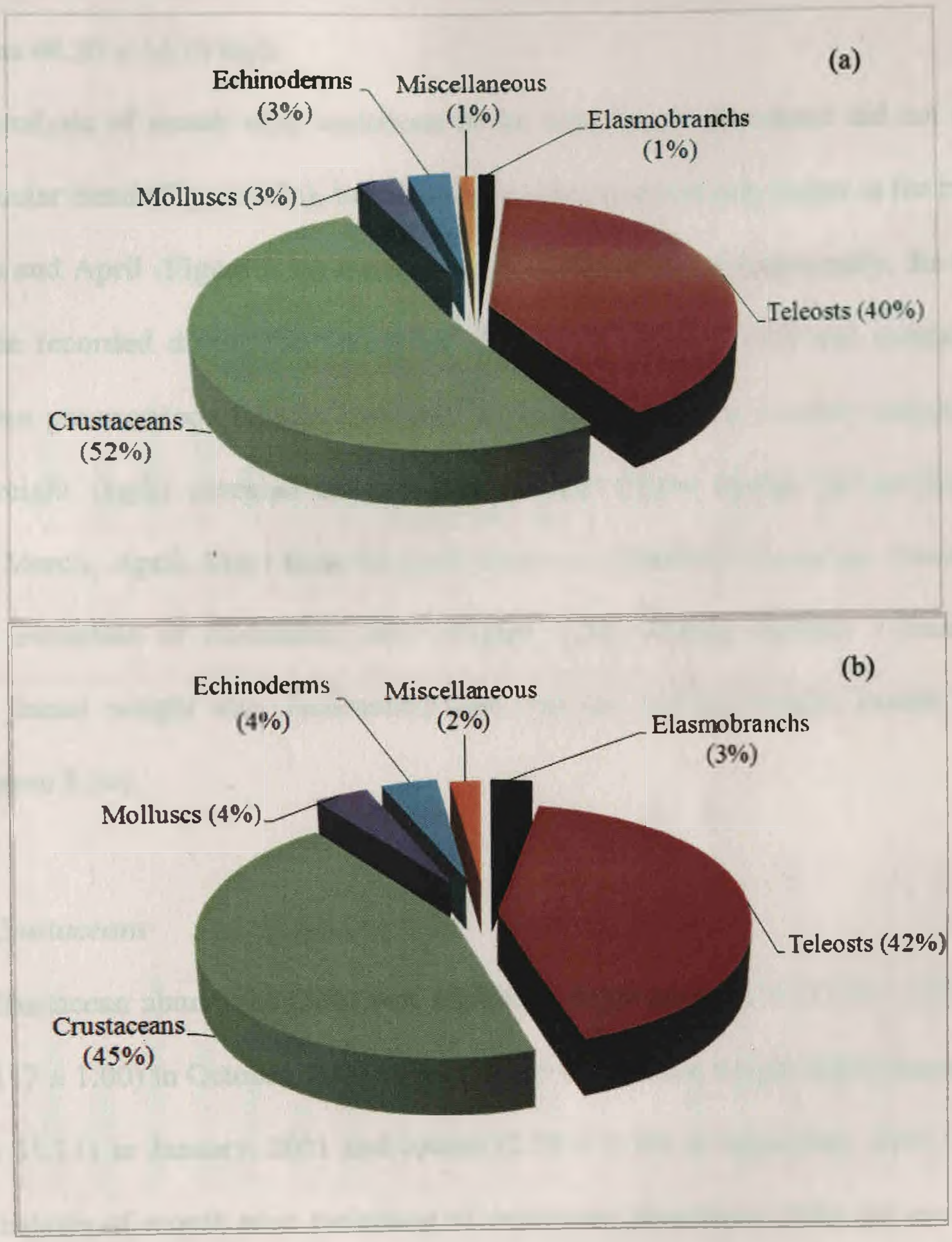
3.3.4a. Total fauna

Analysis of temporal variations of faunal abundance (N/h) revealed maximum faunal abundance in September, 2010 (N/h = 3518 ± 1790) and minimum in November, 2010 (N/h = 616 ± 88). The average abundance recorded during the entire study period was 1514 ± 673 N/h. Analysis of month wise variations of the total faunal weight (Kg/h)

Table 3.2. New records of demersal marine species along Goa coast

Sr. No.	**Species**	**Known Habitat**
I	**New record for the Indian coasts**	
1	*Temnopleurus decipiens* (De Meijere)	Sandy/Muddy/Coral reef
II	**New to West coast of India**	
1	*Stomopneustes variolaris* (Lamarck, 1816)	Rocky
2	*Acreichthys hajam* (Bleeker, 1851)	Coral reef
3	*Trigonostoma scalarifomis* (Lamarck, 1822)	Sandy bottom
4	*Diogenes alias* McLaughlin and Holthuis, 2001	Sandy/Muddy/Coral reef
5	*Johnius coitor* (Hamilton, 1822)	Muddy/Estuary
	New to Goa coast	
1	*Leiognathus brevirostris* (Valenciennes, 1835)	Sandy/Rocky
2	*Upeneus tragula* Richardson 1846	Coral reef
3	*Nemipterus bipunctatus* (Valenciennes, 1830)	Rocky/Coral reef
4	*Johnius amblycephalus* (Bleeker, 1855)	Muddy soft bottom
5	*Johnius carutta* Bloch, 1793	Muddy/Estuary
6	*Brachirus orientalis* (Bloch & Schneider, 1801	Coral reef/Sandy bottom
7	*Himantura marginata* (Blyth, 1860)	Sandy reef
8	*Odonus niger* (Rüppell, 1836)	Coral reef
9	*Diodon hystrix* Linnaeus, 1758	Coral reef
10	*Gymnothorax pseudothyrsoideus* (Bleeker 1853)	Coral reef/Muddy bottom

Figure 3.2. Group-wise proportions of (a) faunal abundance and (b) weight of demersal assemblage



revealed the highest value in November, 2011 (115 ± 0 kg/h) and lowest in September 2010 (17.30 ± 2.10 kg/h). The overall average weight recorded during the entire study period was 69.30 ± 14.10 kg/h.

Analysis of month wise variations in the total faunal abundance did not reveal any particular trend (Figure 3.3a), but abundance was comparatively higher in the months of March and April (Figure 3.3a) throughout the study period. Exceptionally, the faunal abundance recorded during the December, 2009 and January, 2010 was substantially higher than pre-monsoon months (February to May). Analysis of monthly variations of faunal weight (kg/h) revealed comparatively higher values during the pre-monsoon months (March, April, May) than the post monsoon (October, November, December), with the exception of November, 2011 (Figure 3.3b). During October – December, monthly faunal weight was considerably less than the average weight, except during 2011 (Figure 3.3a).

3.3.4b. Crustaceans

Crustacean abundance (N/h) was highest in September, 2010 (2710 ± 1371) and lowest (117 ± 1.00) in October, 2009 (Figure 3.4a). Crustacean weight (kg/h) was highest (54.33 ± 31.11) in January, 2011 and lowest (2.50 ± 0.70) in September, 2010 (Figure 3.4b). Analysis of month wise variations of crustacean abundance (N/h) did not reveal any particular trend. Crustacean abundance was comparatively higher during March and April of all the sampling years (Figure 3.4a), and low during October, 2009 and November, 2010. On the other hand, crustacean abundance was comparatively low in February throughout the study period. Analysis of month wise variations of crustacean weight (kg/h) revealed comparatively higher values during January – May, as compared to September, October, and November (Figure 3.4b).

Figure 3.3. Month wise variations of total fauna: (a) total abundance and (b) total weight

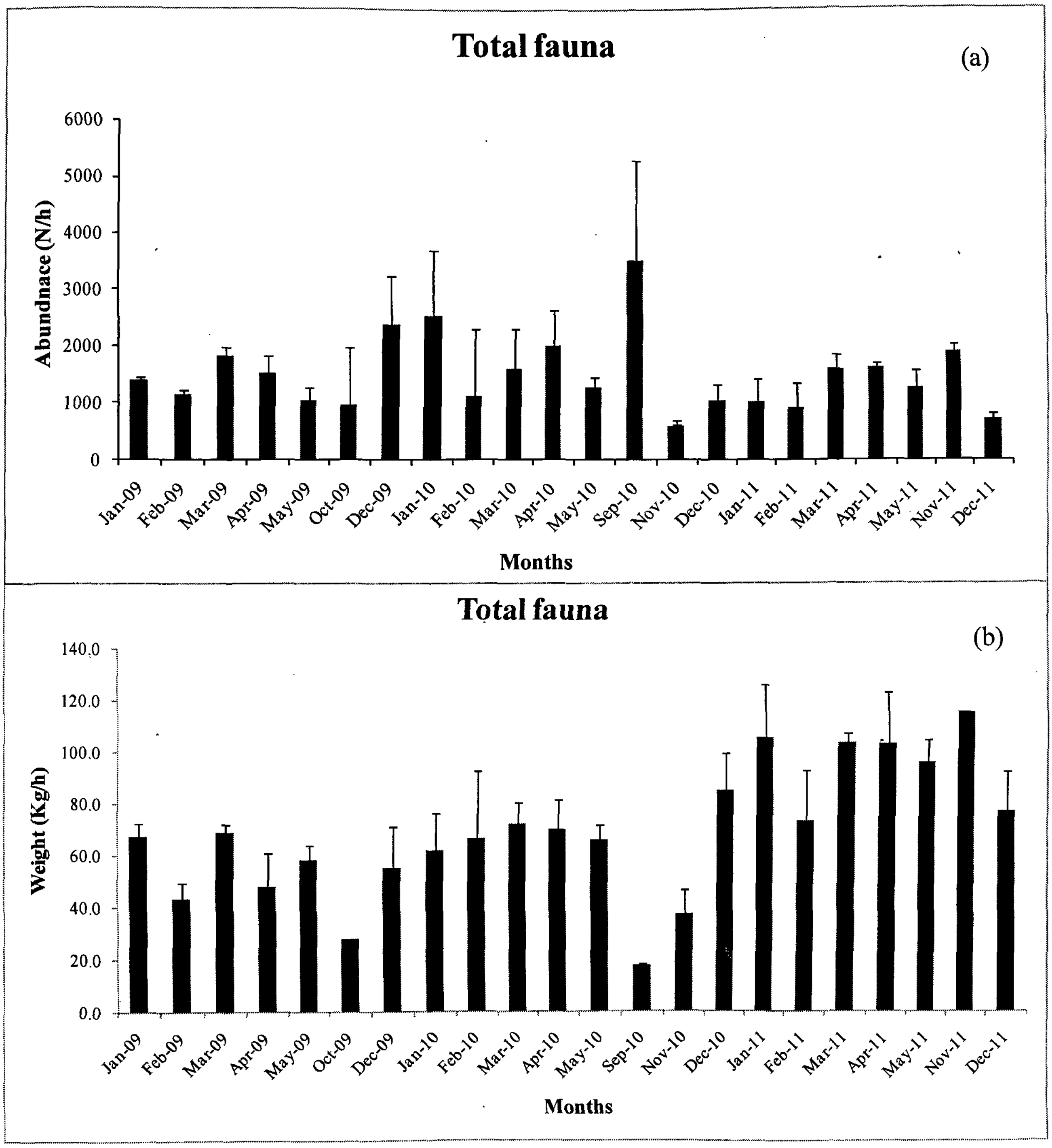
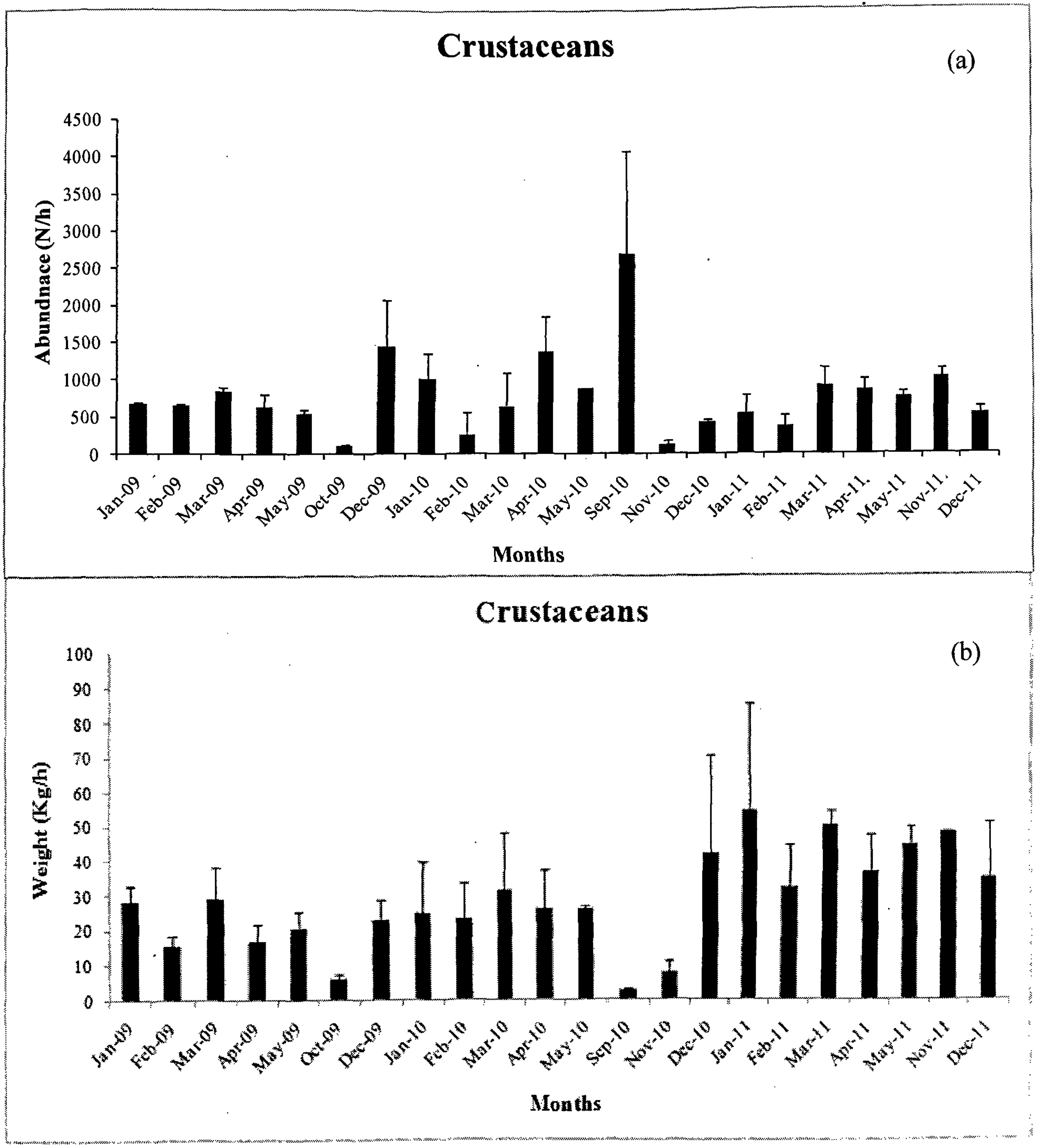


Figure 3.4. Month wise variations of (a) total abundance and (b) total weight of crustaceans



Crustaceans were divided into three groups namely prawns, stomatopods and crabs for quantitative analysis. Among these, the prawns dominated the crustacean catches in terms of both abundance and weight, followed by stomatopods and crabs (Figure 3.5a, b). The other groups (non-portunid brachyura, anomura and non-penaeid prawns) occurred rarely and in very less quantities due to which these were excluded from the analysis.

Analysis of temporal variations revealed that prawn abundance was higher during the months of April and May throughout the study period (Figure 3.5a). In addition, prawns dominated the crustacean catch in October, 2009. Stomatopod abundance was higher during the months of December and January of each sampling year compared to April. They were absent in the catches during October, 2009 and November, 2010 (Figure 3.5a). Crabs occurred regularly in the trawl catches but their quantity was very low as compared to prawns and stomatopods, except in November and December, 2010, when their abundance exceeded that of prawns (Figure 3.5a).

Analysis of temporal variations of faunal weight revealed that stomatopods and prawns contributed more or less equally throughout the study period (Figure 3.5b). Prawns dominated the crustacean catches during April, whereas, stomatopods contributed in relatively higher proportions in February.

3.3.4c. Teleosts

The highest abundance of teleosts (1504 ± 1043 N/h) was recorded in January, 2010 and lowest (136 ± 78 N/h) in December, 2011 (Figure 3.6a). Teleost abundance was comparatively higher during January – March throughout the study period. However, in 2011, their abundance was higher in November. On the other hand, teleost abundance was consistently low in May as compared to other periods (Figure 3.6a).

Figure 3.5. Month wise variations of percentage contribution of various crustacean groups: (a) abundance and (b) weight

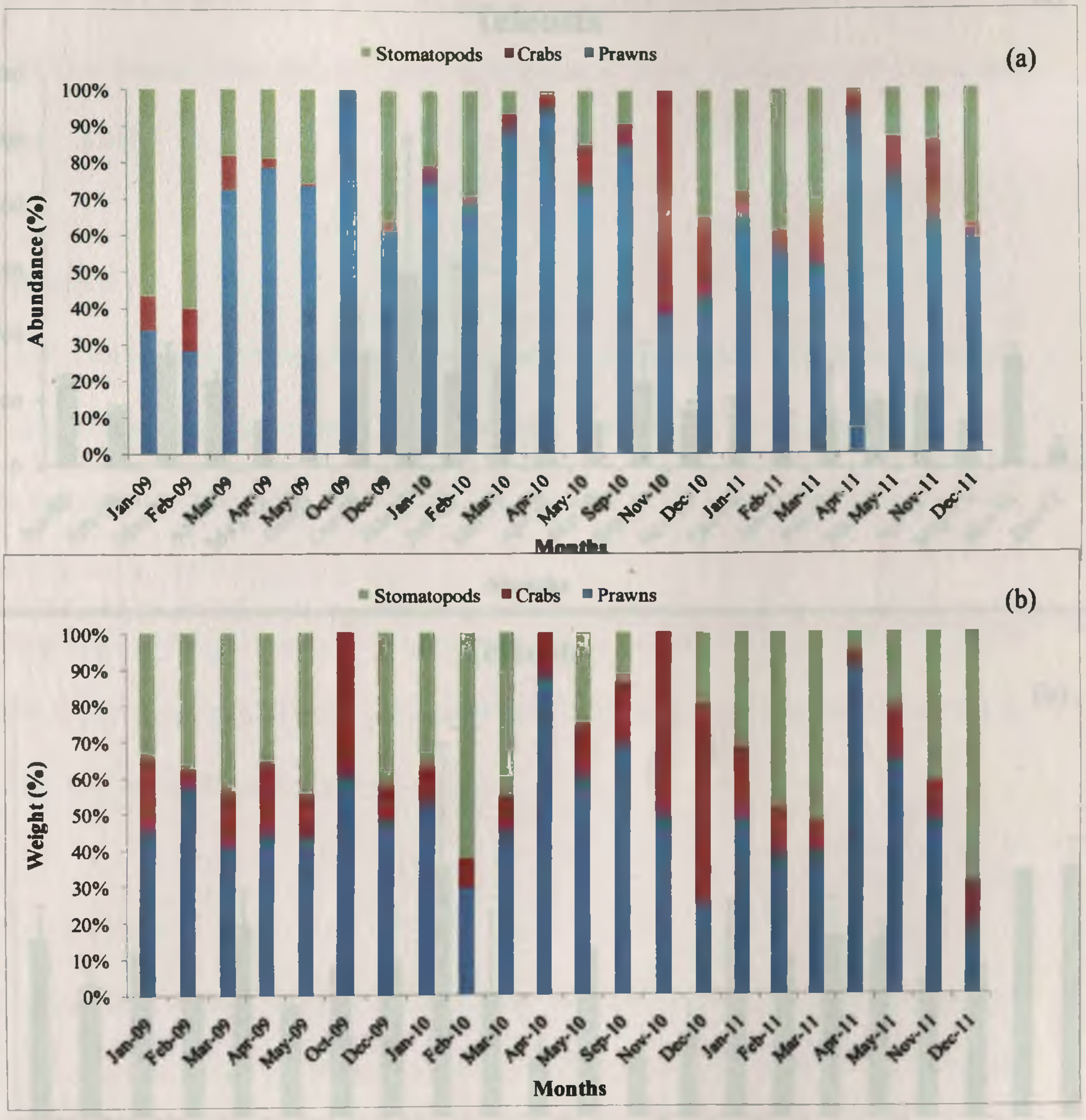
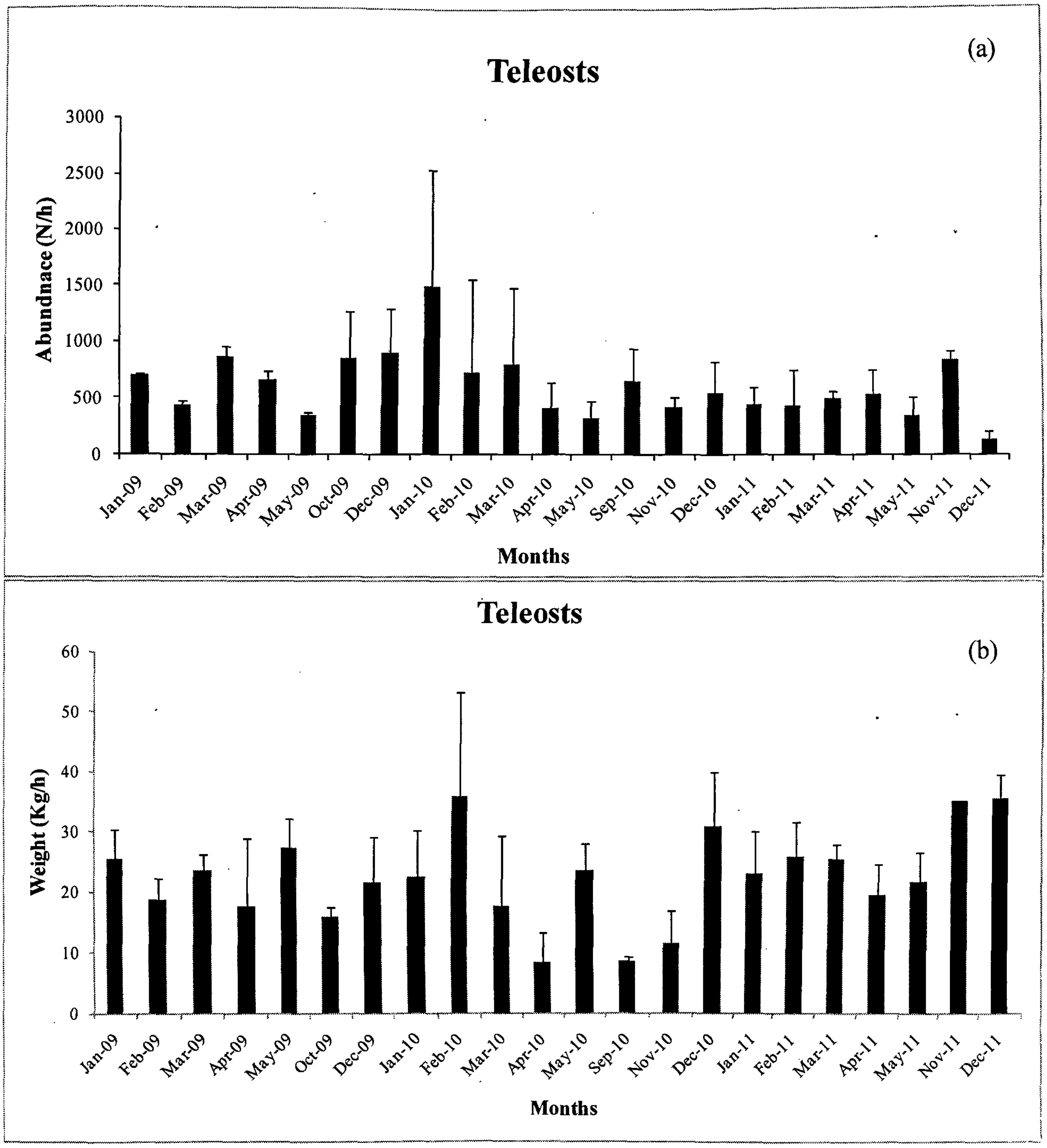


Figure 3.6. Month wise variations of (a) total abundance and (b) total weight of teleosts



Analysis of teleost weight data revealed the highest weight (35.83 ± 17.45 kg/h) in February, 2010 and lowest (8.38 ± 4.89 kg/h) in April, 2010 (Figure 3.6b). Month wise variations revealed that weight was comparatively higher during January – March. In addition, higher values were also recorded in December, 2010, November and December, 2011 (Figure 3.6b).

3.3.4d. Molluscs

Molluscan catch observed during the study period mainly comprised of squids, cuttlefish, bivalves and gastropods. The maximum abundance of molluscs (135 ± 102 N/h) was recorded in February, 2010. They were absent in the trawl catches during May, 2010 and February, 2011 (Figure 3.7a).

Analysis of weight revealed highest weight of molluscs (13.20 ± 4.24 kg/h) in November, 2010 (Figure 3.7b). During December, 2011, weight of molluscs could not be recorded as they were discarded as a by-catch.

3.3.4e. Echinoderms

Echinoderm catch observed during the present study period comprised sea urchins and sea stars. The maximum abundance of echinoderms (189 ± 176 N/h) and weight (12.70 ± 8.70 kg/h) was recorded during April, 2011 (Figure 3.8a, b). It was further observed that echinoderms occurred only during the pre-monsoon months (March, April and May) during the study period (Figure 3.8a, b).

3.3.5. Spatial variations

The present study area is located near the Betul fishing jetty, which is marked by complex habitats such as sandy shore, rocky habitat and estuary. Hence, to facilitate the

Figure 3.7. Month wise variations of (a) total abundance and (b) total weight of molluscs

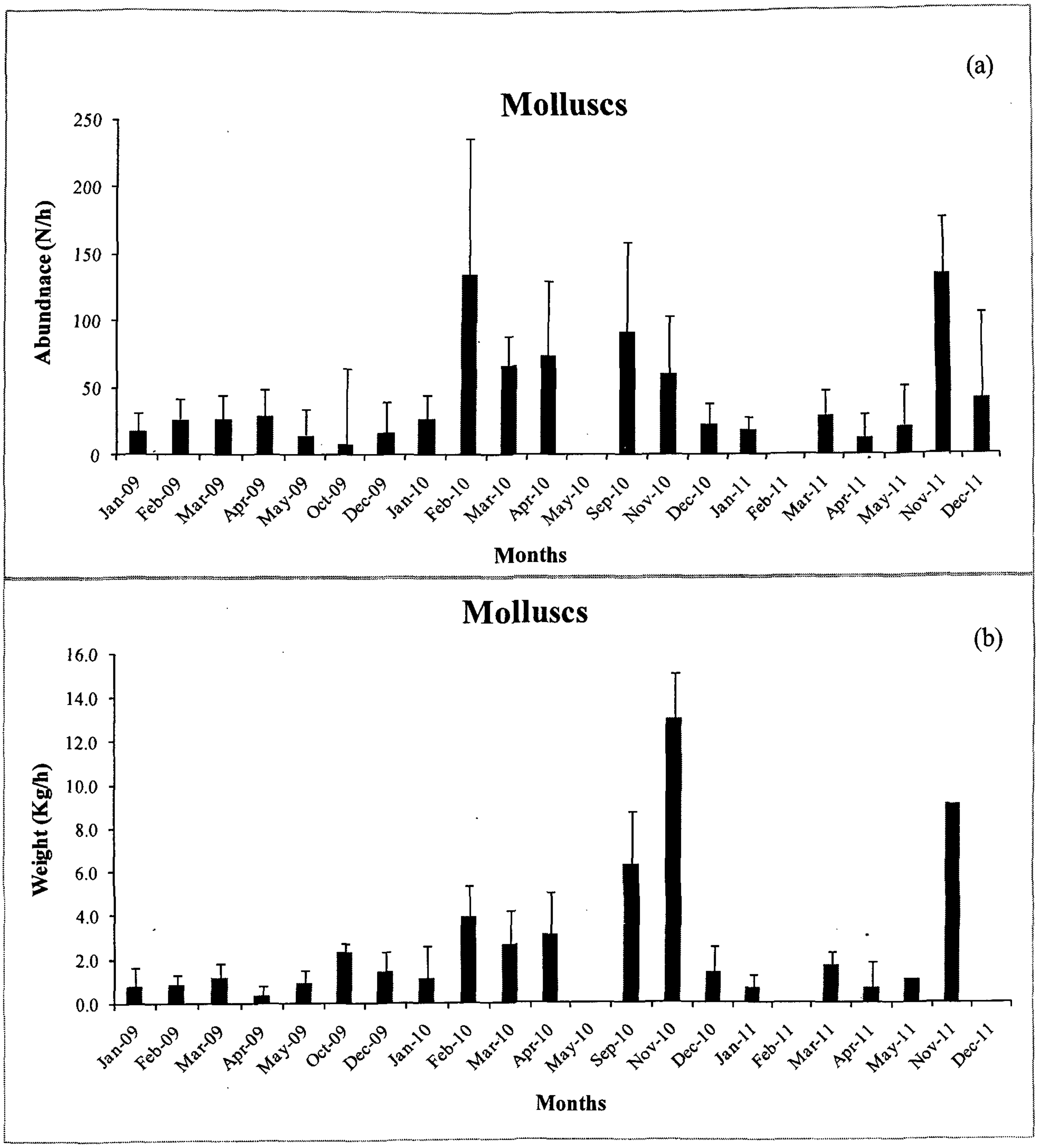
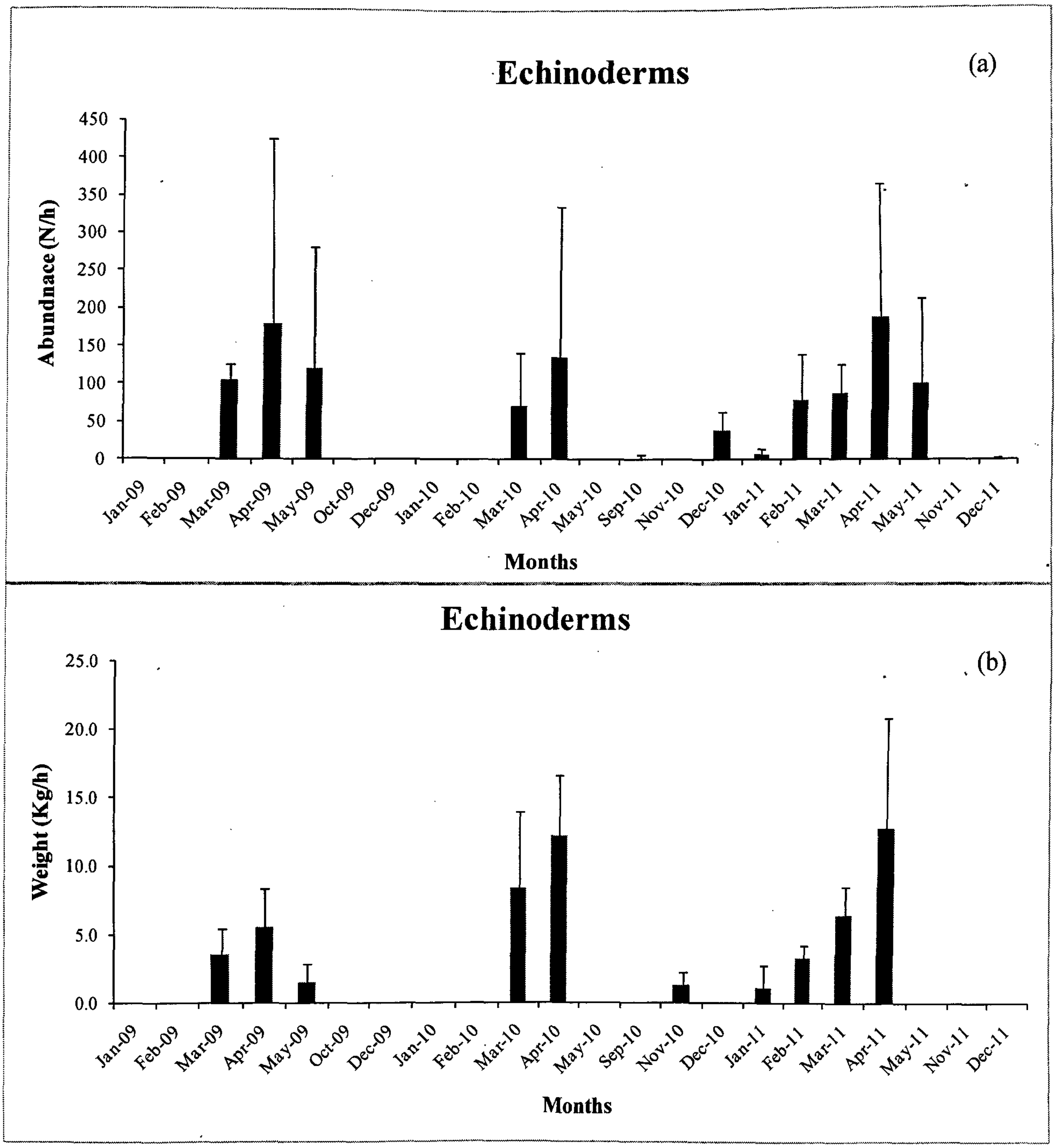


Figure 3.8. Month wise variations of (a) total abundance and (b) total weight of echinoderms



analysis of spatial variations, the regions located north and south of the Sal estuary were considered as sandy and rocky habitats, respectively. Stations near the mouth of the Sal estuary were considered as estuarine habitat.

Analysis of spatial variations of total fauna revealed high abundance in the sandy as well as the rocky habitats (Figure 3.9a). Further, analysis of spatial variations was carried out with respect to seasons (post-monsoon and pre-monsoon). This exercise revealed that during the post-monsoon, the faunal abundance was higher near the estuarine mouth area and rocky habitats (Figure 3.9b). On the other hand, during the pre-monsoon, the faunal abundance was comparable in the sandy and rocky habitats (Figure 3.9c).

Prawn abundance was observed to be higher at the estuary mouth and rocky habitats during the post-monsoon season (Figure 3.10a) whereas, during the pre-monsoon it was higher south of Cabo de Rama and near sandy habitat (Figure 3.10b). Similarly, stomatopod abundance was higher in the rocky patches off Cabo de Rama and Agonda during the post-monsoon (Figure 3.10c), whereas during the pre-monsoon, the abundance was higher mostly along the sandy habitats (Figure 3.10d). It was further observed that during the pre-monsoon, stomatopods were nearly absent from the catches taken along the rocky habitats off Cabo de Rama.

Teleost abundance was higher near the estuarine mouth and sandy habitat during the post-monsoon (Figure 3.11a) whereas, during the pre-monsoon it was higher in the rocky habitats off Cabo de Rama (Figure 3.11b). Similarly, echinoderms also showed significant spatial variation along the sandy and rocky habitats with regards to seasons. It was observed that during the post-monsoon, echinoderms occurred mostly in sandy habitats with very low mean abundance (Figure 3.12a). During the pre-monsoon, the

Figure 3.9. Spatial variations of faunal abundance during the study period: (a) Total abundance, (b) post-monsoon, (c) pre-monsoon

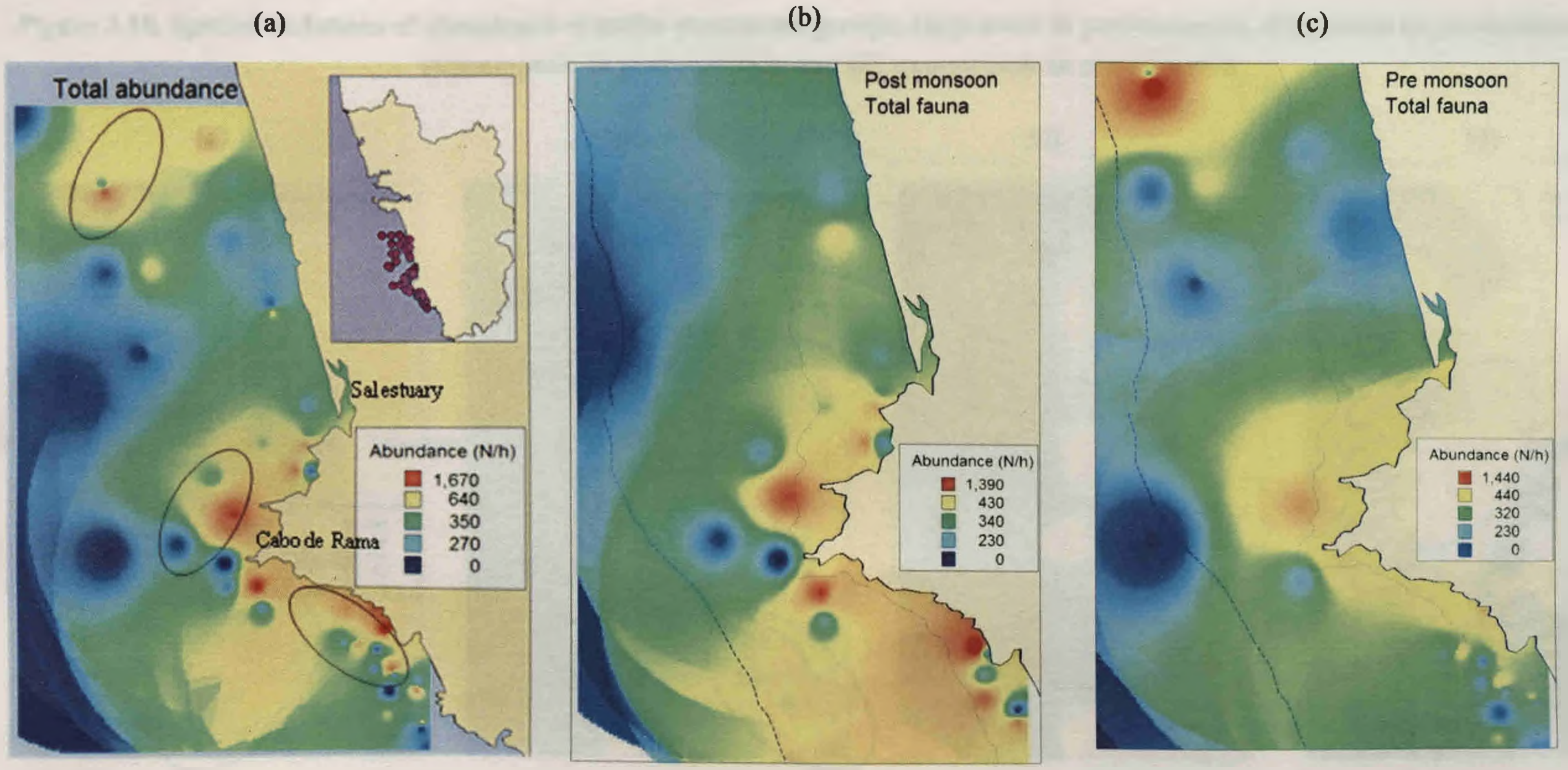


Figure 3.10. Spatial variations of abundance of major crustacean groups: (a) prawns in post-monsoon, (b) prawns in pre-monsoon, (c) stomatopods in post-monsoon and (d) stomatopods in pre-monsoon

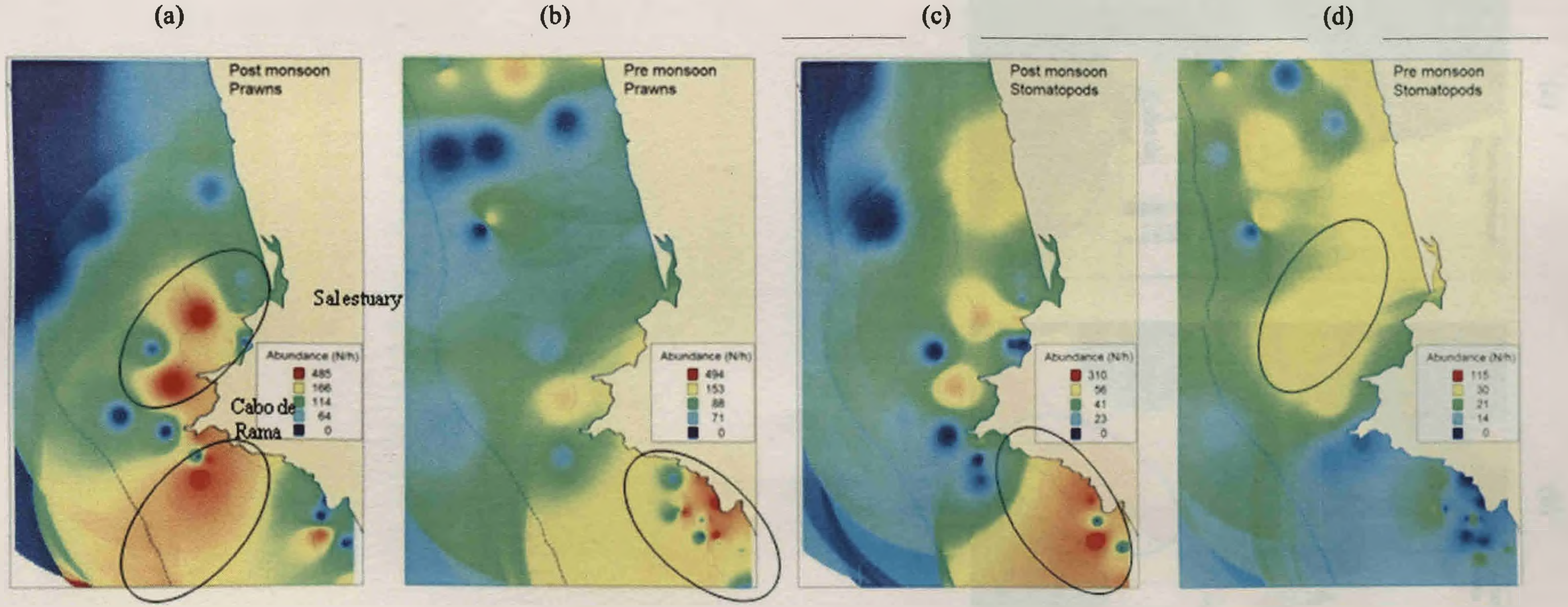


Figure 3.11. Spatial variations of abundance of teleosts: (a) post-monsoon and (b) pre-monsoon

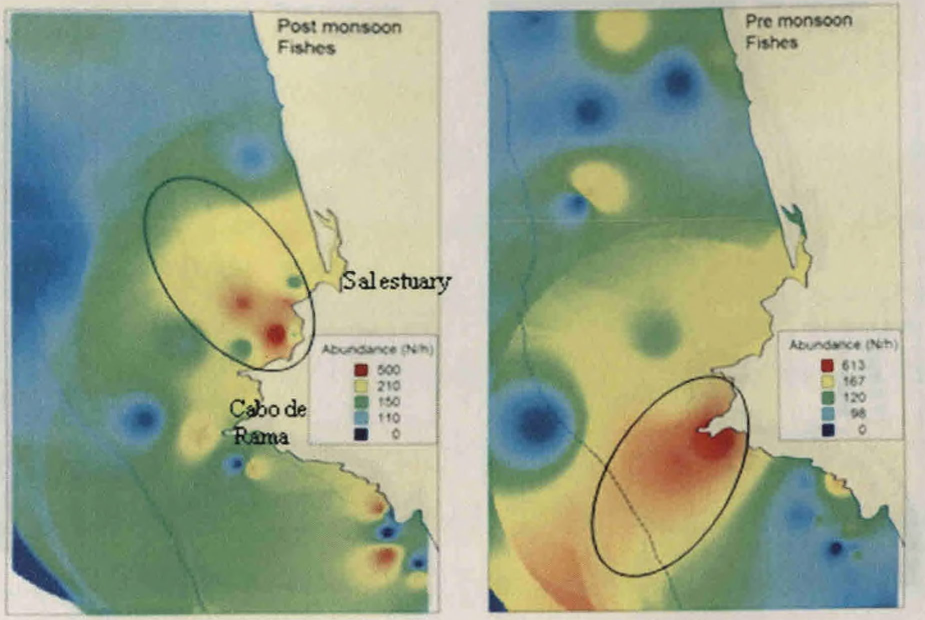
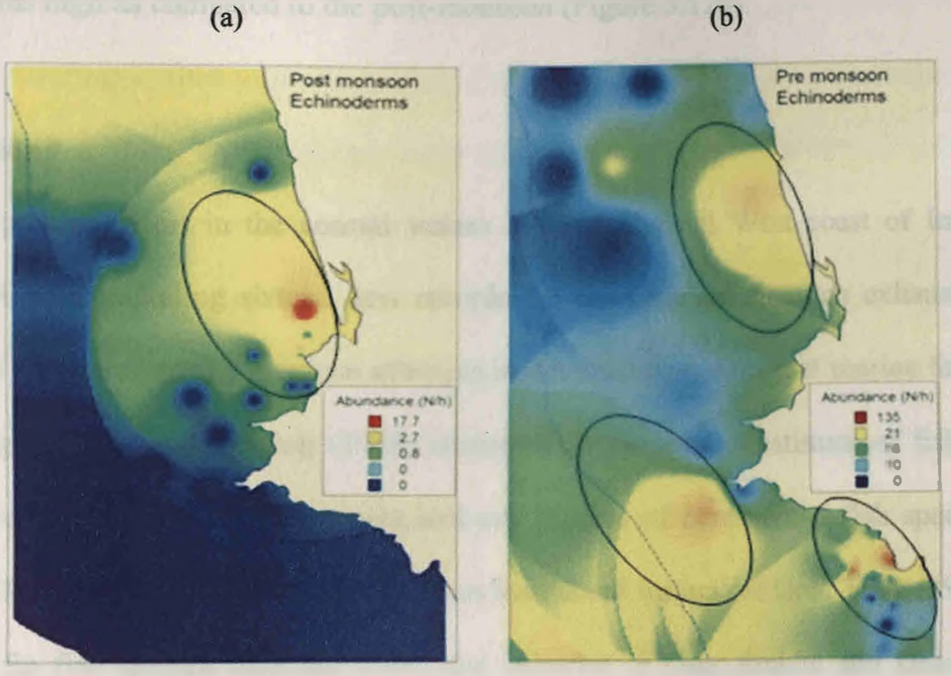

(a) (b)

Figure 3.12. Spatial variations of abundance of echinoderms: (a) post-monsoon and (b) pre-monsoon



echinoderms were observed in both the sandy and the rocky habitats, and their mean abundance was high as compared to the post-monsoon (Figure 3.12b).

3.4. Discussion

The present effort in the coastal waters of Goa, Central West coast of India, revealed 184 taxa including sixteen new records for the Goa coast, much exhaustive inventory as compared to the previous attempts in documenting demersal marine fauna from this region. Rao and Dorairaj (1968) attempted to provide an estimate of fishery yield off Goa and listed only four genera and one species of commercial fish species. Talwar (1973) reported 168 fin fish species from the littoral waters off Goa. Tilak (1973) reported 51 fin fish species from the rivers and estuaries of Goa. Prabhu and Dhawan (1974) reported 47 commercially important taxa (10 elasmobranchs, 28 teleosts, 03 stomatopods and 06 prawns) of demersal marine fauna from the 20 and 40 metres depth regions off Goa coast along with catch rates of few important fishery items. George (1980) provided brief taxonomic descriptions of 17 species of penaeid prawns from the Goa coast. Parulekar *et al.* (1980) reported 78 epifaunal marine taxa from the Goan estuaries along with their distribution patterns, biomass production and trophic relations. Ansari *et al.* (1995, 2003) reported two elasmobranchs and 57 teleosts from the Mandovi–Zuari estuarine complex and the adjacent bays along with seasonal variations in their abundance, distribution, diversity and effect of environmental factors. Lobo (2005) reported eight species of sea snakes from the coastal waters of Goa. It is apparent from the above that major focus was laid upon reporting only commercially exploited species.

Recently, Padate (2011) updated information on demersal marine species composition off Goa coast with 204 species, including 55 new reports from this region. It is imperative that not much attention was paid to the rare species as these constitute trash fish and are discarded by the commercial trawlers. In view of this, the present study envisaged developing a more rigorous, scientific database through continuous monitoring of diverse habitats (mangrove estuaries, coral reefs, rocky and sandy habitats), greater sampling effort with a focus on rare species.

The near shore waters off Goa are known for patchy coral reef habitats (Rodrigues *et al.*, 1998) that are located in the vicinity of the fishing grounds. The observations made in the present study also revealed twenty eight reef associated species in the near shore trawl catches. Such observations highlight that these coastal regions provide congenial habitats for a wide array of marine as well as coastal estuarine species (Kulkarni *et al.*, 2003).

Quantitative analysis of trawl catch data suggested that crustaceans were the dominant faunal group as the bottom trawlers targeted mainly penaeid prawns. It is worth mentioning that although the bottom trawl is employed mainly to harvest penaeid prawns, their contribution was only 35 and 24 % of the total faunal abundance and weight, respectively. These findings are in concurrence with the global trends (Watson *et al.*, 2006), which indicate significant reduction in prawn catches i.e. 52.65 % during 1970's to 17.86 % during the 1990's. The overall decline in prawn catches may be attributed to long-term intensive targeted exploitation using trawl nets with small cod end mesh size, thus leading to recruitment over-fishing as reported along the Goan coast (Ansari *et al.*, 2006). The dominance of other groups such as fin fish, other crustaceans (stomatopods and crabs), molluscs and other fauna in the trawl catches during the present study emphasizes the non-selective nature of the fishing gear (Kumar and Deepthi, 2006). Most of the above fauna, except a few commercially important species, are non-targeted species those are caught incidentally (Watson *et al.*, 2006). Global estimates of trawl by-catch indicated a two-fold increase from 1970's (46.84 %) to the 1990's (89.30 %), primarily due to the increasing use of bottom trawlers (Watson *et al.*, 2006).

Analysis of temporal variations of total faunal abundance and weight revealed that the total abundance and weight were slightly higher during March and April as compared to October–December, with a few exceptions. These observations suggested that prevalence of calm conditions, constant salinity and temperature during the pre-monsoon offer a relatively favourable environment to the demersal fauna. Krishna Kumari *et al.* (2002) suggested that the pre-monsoon season is generally characterized by higher temperature, salinity conditions in the near shore and estuarine waters coupled with increased productivity. On the other hand, very high faunal abundance and low faunal weight observed during September, 2010 is mainly due to the capture of large number of juveniles of penaeid prawns (*Metapenaeus dobsoni* and *M. affinis*).

Analysis of the crustacean catches revealed that the three major penaeid prawns namely *M. dobsoni*, *M. affinis* and *Parapenaeopsis stylifera* generally dominated the trawl catches during the present study. All the above species are residents of the near shore waters of Goa, whose juveniles are known to migrate into the adjacent estuaries (Achuthankutty and Parulekar, 1986). Crustacean abundance did not show any consistent trends in abundance during the study period owing to multiple breeding periodicities of various crustacean species (Achuthankutty and Parulekar, 1986). However, crustacean weight was comparatively higher during the pre-monsoon as compared to the post-monsoon months. This could be attributed to large proportions of *P. stylifera* adults, which are known to breed during pre-monsoon (Achuthankutty and Parulekar, 1986).

Further assessment of the individual crustacean groups (including prawns, crabs and stomatopods) revealed an inverse relation between penaeid prawns and *Miyakella nepa* throughout the present study, probably suggest disproportionate partitioning of resources between these groups. For example, in the month of April, prawns dominated the crustacean catch in absence of stomatopods. However, more detailed studies involving long-term dietary analyses of these groups are required to substantiate this relationship.

The portunid crabs comprised both juveniles as well as gravid females throughout the study period thus indicating that these are coastal resident species. However, the low abundance of portunid crabs is suggestive of the inability of the demersal trawl to exploit these resources owing to uneven bathymetry of the fishing grounds (Wagle and Kunte, 1999).

Quantitative analysis of teleosts suggested that although they were represented by greater number of species than the other faunal groups, their abundance was less as compared to crustaceans. Analysis of temporal variations suggested a lack of particular trend as this data represented trends of a wide array of estuarine and marine species with varied life history cycles and equally distinct occurrence periodicities and migration patterns. Teleost weight was slightly higher during the pre-monsoon than the post-monsoon except during 2011 (December and November). Further detailed studies on commonly occurring fin fishes would provide much better understanding regarding their seasonal variations.

Molluscan catch during the study period comprised mainly squids, cuttlefish, bivalves and gastropods. Among these, squids (*Photololigo duvauceli*) and several gastropods occurred regularly in the trawl catch. Analysis of temporal variations suggested that molluscan abundance and weight were higher during the post-monsoon months as compared to the pre-monsoon. This is mainly due to capture of large quantities of the squid *P. duvauceli* during November–December. Roper *et al.* (1984) reported that this spawns off the southwest coast of India during September-October.

The echinoderm catches during the present study were mostly restricted to the pre-monsoon months and the higher catches from March to May are probably due to their spawning aggregations in the coastal waters, whereas lower abundance during the other periods suggests migration to deeper waters to avoid strong onshore wave surges (Freeman *et al.*, 2001; Kitazawa *et al.*, 2007).

Analysis of spatial variations suggested that demersal fauna might undertake short distance migrations between different habitats. High faunal abundance in both sandy and rocky habitats suggested that demersal fauna utilize both habitats during different stages of their respective life cycles. Higher faunal abundance near the estuarine mouth during the post-monsoon is attributed to the high productivity in the bay-estuarine ecosystems which enhances the role of nursery grounds (Ansari *et al.*, 1995). Similarly, higher abundance near the sandy and rocky habitats during the pre-monsoon suggested the occurrence of permanent coastal residents as well as quasi-resident and opportunistic species due to calm conditions and ample food availability (Padate, 2011).

Analysis of spatial variations of crustaceans suggested that prawns and stomatopods are permanent resident of coastal waters as evident from their higher abundances during both the seasons. Further, alternate dominance of prawns and stomatopods in the sandy and rocky habitats indicated the existence of niche overlap between these two groups. Therefore, it was assumed that the dominant stomatopod community replaced the prawns from the sandy habitat during pre-monsoon and vice-versa.

High abundance of teleosts near the estuarine mouth during the post-monsoon is attributed to high biological productivity due to nutrient influx from river and upwelling during that season (Madhupratap *et al.*, 2001). On the other hand, high abundance of teleosts in the rocky habitats during the pre-monsoon may be attributed to abundant prey availability, particularly prawns, which occurred in high abundance along the rocky habitat (Figure 3.10b). In addition, higher numbers of juveniles observed in trawl catches from the sandy habitats as compared to the rocky habitats, suggested that the juvenile populations forage on smaller benthic invertebrates along the sandy habitats and subsequently the adults move to the rocky habitats where they consume larger prey items (Manojkumar, 2008; Abdurahiman *et al.*, 2010). Echinoderms occurred in the trawl catches mostly during the pre-monsoon, except in 2010, when small quantities of sea stars were also captured in November, 2010. This could be because of near shore trawlers limiting themselves to lesser depths during all the seasons (< 25 m), whereas echinoderms being exclusively marine, might migrate to deeper waters during post-monsoon because of the high turbidity and salinity variations (Freeman *et al.*, 2001).

The complex scenario involving the loss of coastal biodiversity through overfishing and habitat alteration coupled with substantial reduction in the marine fish catches necessitates urgent remedial actions for the conservation of the coastal resources. This involves data collection, formulation of legislative structures and implementing preventive measures to conserve the coastal biodiversity. In view of this, the present study has attempted large-scale data collection and holistic analysis of the demersal marine community structure to facilitate understanding of the intricate issues pertaining to the ecology of demersal fauna.

It is imperative from the present study that sizeable information coupled with reporting of new records has enabled to create a stronger database for this region. Hence, it is mandatory to carry out continuous monitoring of these coastal habitats to generate a much better inventory for future reference and efficient management of these resources.

The inferences drawn in the above study are the outcome of a three-year long spatial and temporal assessment of the demersal resources of the coastal waters of Goa.

However, future studies of greater magnitude involving intensive perennial surveys in the region with greater emphasis on eco-biological aspects (size classes, feeding, reproduction and migration) would facilitate a better understanding of the demersal marine fish community structure of Goa.

Chapter 4.

New record of the sea urchin *Temnopleurus decipiens* from Indian waters

4.1. Introduction

Sea urchins (Echinodermata: Echinoidea) inhabit sea grass beds, coral reefs (Nybakken and Bertness, 2005), intertidal regions (Lawrence, 2006), and feed on benthic invertebrates and algae (Norderhaug and Christie, 2009). Among the various families of echinoids that inhabit the Indo-West Pacific, the Temnopleuridae comprise of fourteen genera and twenty five species (Kroh and Mooi, 2011; Kroh, 2012) that are known for their comparatively wide distribution (Clark and Rowe, 1971). Among the temnopleurid genera, *Temnopleurus* (L. Agassiz, 1841) which comprises of seven extant and one fossil species, is the most abundant (Mortensen, 1943; Smith, 2005; Schultz, 2006; Kroh *et al.*, 2011) and its distribution ranges from the east coast of Africa and Madagascar to Japan, Hawaii and Australia (Clark, 1912; Mortensen, 1943; Clark and Rowe, 1971; Schultz, 2006). Published literature on temnopleurid sea urchins (Mortensen, 1943; Clark and Rowe, 1971) suggests that the structure of apical system and peristome, arrangement of pore pairs and sutural pits are the most important criteria for species identification. Information available for Indian waters (Bell, 1888, 1889, 1902; Koehler and Vaney, 1914; Sane and Chhapgar, 1962; Clark and Rowe, 1971; Schultz, 2006; Sastry, 2007) reveal the occurrence of only three temnopleurid species namely *Temnopleurus toreumaticus* (Leske, 1778), *T. reevesii* (Gray, 1855) and *T. apodus* (A. Agassiz & H. L Clark, 1906).

The present paper describes a new record of *Temnopleurus decipiens* (de Meijere, 1904) for the Indian region from Goa, along the west coast of India. This description is complimented by a comparative analysis of morphological characters present in *T. decipiens* and *T. toreumaticus* with their extant congeners using test characters (N = 22; sensu Coppard and Campbell, 2006). Further, two additional morphological characters namely "spine length with respect to the test diameter" and "colour banding on spine" are used to differentiate the seven extant species of *Temnopleurus*.

4.2. Taxonomic identification

Sea urchin specimens were examined under a stereomicroscope (Olympus SZX9, Olympus, Japan) and morphological characters were recorded. Altogether, thirty seven sea urchins were identified down to the family level using morphological features such as test texture, arrangement of ambulacral pore pairs and structure of the Aristotle's lantern (Mortensen, 1943; Clarke and Rowe, 1971; Coppard *et al.*, 2005; Smith, 2005). Subsequently, species identification was carried out using external characters such as test colour, shape, arrangement of ambulacral pore pairs, sutural pits near the peristome, form of apical system and periproct, position of anal opening and presence of a suranal plate. Morphological parameters namely Horizontal Test Diameter (HTD); Vertical Test Diameter (VTD); Peristome Diameter (PSD); Apical Disc Diameter (AD); Periproct Diameter (PPD); Genital Plate Width (GPW); Genital Plate Height (GPH); Gonopore Diameter (GD) (sensu Coppard and Campbell, 2006) and spine length were measured using electronic calipers (Absolute Digimatic) with an accuracy of 0.01 mm. The apical system, as well as ambulacral and inter-ambulacral plates, was examined for identification and differentiation of the species (Mortensen, 1943; Clarke and Rowe, 1971; Schultz, 2006). Further, seven morphological ratios were derived from these morphometric parameters following Coppard and Campbell (2006). All the photographs were taken using Nikon D60 Digital SLR camera.

4.3. Systematics

Class ECHINOIDEA Leske, 1778

Subclass EUECHINOIDEA Bronn, 1860

Superorder CAMARODONTA Jackson, 1912

Order TEMNOPLEUROIDA Mortensen, 1942

Infraorder TEMNOPLEURIDEA Kroh & Smith, 2010

Family TEMNOPLEURIDAE A. Agassiz, 1872

4.3.1. Family Temnopleuridae A. Agassiz, 1872

DIAGNOSIS – Test well sculptured, usually with distinct pits, troughs or pores at the angles of the sutures at least in juveniles, and usually throughout life. Primary tubercles imperforate, with or without crenulation; those in ambulacral and inter-ambulacral zones similar in size. Pore-pairs forming a simple adradial band which does not expand adorally. Apical disc dicyclic, peristome much larger than apical disc; buccal notches obsolete; Aristotle's lantern of the camarodont type. Periproct subcircular with smooth edges (periproctal plates not indenting apical ring); ambulacra trigeminate, with echinid-style compounding (Smith, 2005).

4.3.2. Genus *Temnopleurus* L. Agassiz, 1841

DIAGNOSIS – Test profile hemispherical to sub-conical, rather thick-shelled with conspicuous crenulations, size often exceeding 40 mm HTD. Ambulacral plating trigeminate, pore-pairs arranged in near-vertical arcs forming a single adradial band; each compound plate comprises a single primary tubercle located closer to the pore zone and smaller perradial tubercles scattered randomly across the plate. Inter-ambulacral plates with a central primary tubercle, smaller secondary and military tubercles scattered randomly over the remainder of the plate. Conspicuous pits and troughs present at the angle of sutures, usually with horizontal extensions; primary tubercles imperforate and distinctly crenulated. Peristome with ten buccal plates and ten buccal tube-feet, buccal notches very feeble. Periproct subcircular, usually with eccentric opening and some larger periproctal plates. Genital plates with tubercles forming a ring around the periproct (Mortensen, 1943; Clarke and Rowe, 1971; Smith, 2005).

Observation of sea urchins collected during the present study revealed two forms of the genus *Temnopleurus* that prompted us to look into the systematics of both these forms. A review of published literature (Leske, 1778; de Meijere, 1904; Mortensen, 1943; Clark and Rowe, 1971; Smith, 2005; Schultz, 2006) resulted in the identification of two species *Temnopleurus decipiens* (de Meijere, 1904) and *T. toreumaticus* (Leske, 1778) in Indian waters.

4.3.3. *Temnopleurus decipiens* (de Meijere, 1904)

Genocidaris decipiens de Meijere, 1904, "Siboga" Ech. p.76. Taf. XVI, 264-266. (Type locality – Labuan Badjo, Flores and Saleh Bay, Indonesia).

MATERIAL EXAMINED

Off Betul fishing jetty, Goa, west coast of India, 15°04'N, 73°55'E, 17–20 m depth, 17 specimens, test diameter ranging from 5.4 to 21.30 mm.

Representative specimens are preserved in 70 % ethanol and have been deposited as voucher samples at the Marine Biology laboratory, Department of Marine Sciences, Goa University.

DESCRIPTION

Test small, dome-shaped (hemispherical), well sculptured with convex aboral surface; flattened oral surface with sunken peristome (Figure 4.1A). HTD ranges from 5.42 to 21.30 mm (μ = 14.60 ± 4.78 mm) and VTD from 2.74 to 12.92 mm (μ = 8.22 ± 3.15 mm); test width about twice its height (μ VTD/HTD ratio = 0.56:1). Test comprises of five pairs of alternately placed ambulacral and inter-ambulacral plates, inter-ambulacral plates are placed at about the level of ambulacral plates (Figure 4.1C). Colouration of the naked test light green to grey (Figure 4.1C).

Ambulacral plates compound trigeminate, their pore-pairs bear numerous tube feet (in living specimens) that are arranged in a straight line forming a single adradial band. The single primary tubercle of each ambulacral plate is close to the pore zone, surrounded by randomly scattered smaller secondary tubercles; tubercles imperforate and distinctly crenulated.

Inter-ambulacral plates cover a slightly larger area of the test than the corresponding ambulacra. Each inter-ambulacral plate has a central primary tubercle surrounded by smaller secondary and miliary tubercles that cover the remainder of the plate (Figure 4.2A). Primary tubercles imperforate and distinctly crenulated. Wedge-shaped pits are located at the angle of the suture, and are arranged in a zig-zag manner along the middle of the inter-ambulacrum; lateral extensions of the pits separate the inter-ambulacral plates and reach the pore-pair zone (Figure 4.2B); sutural pits near the peristome also conspicuous (Figure 4.2C).

Peristome large (PSD 35.18 ± 3.33 % of HTD), roughly circular in outline with very feeble buccal notches; covered with soft skin, comprised of five pairs of buccal plates with buccal tube feet emanating from them. Aristotle's lantern of the camarodont

Figure 4.1 Oral view of (A) *Temnopleurus decipiens*, (B) *Temnopleurus toreumaticus*, and aboral view of (C) *Temnopleurus decipiens*, (D) *Temnopleurus toreumaticus*

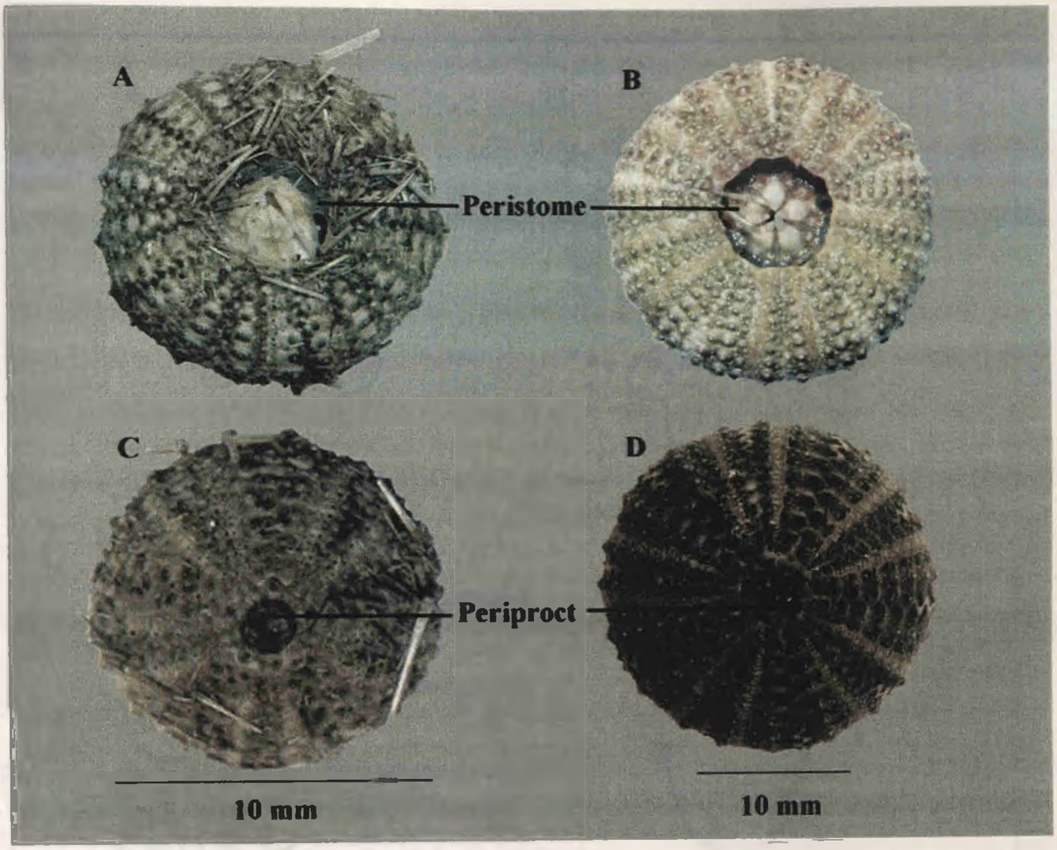
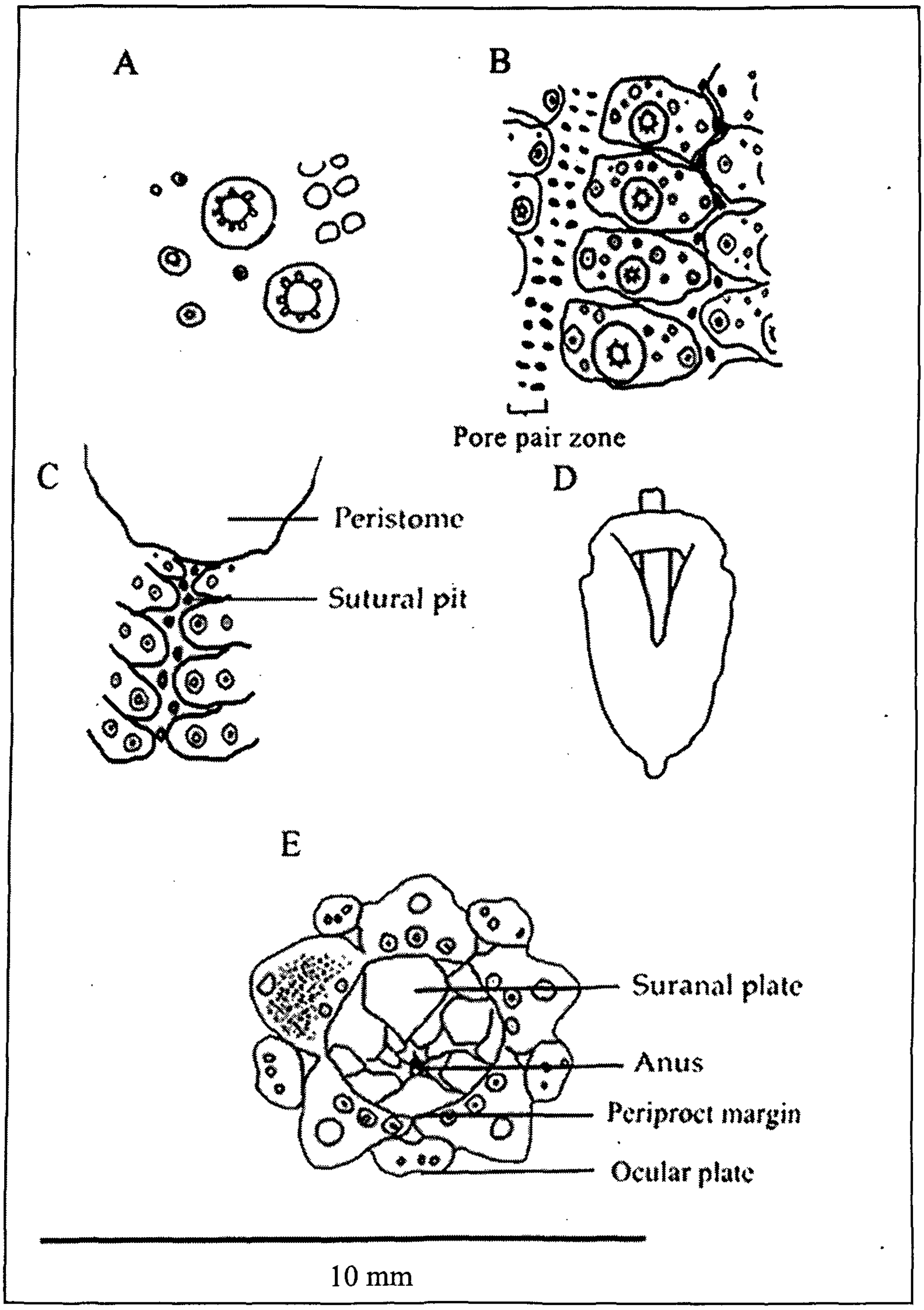


Figure 4.2. ***Temnopleurus decipiens*** **(A) Primary tubercle (B) Inter-ambulacrum (C) Sutural pit near-peristome (D) Pyramid of Aristotle's lantern (E) Apical system**



type (i.e., with a paired rod-like epiphysis bridging across the upper end of pyramid (Figure 4.2D).

Apical system dicyclic, relatively large, but smaller than the peristome (AD 25.14 ± 3.96 % of HTD). Apical system with four equal-sized genital plates and one larger genital plate with madreporite. Inner part of each genital plate with small tubercles, outer part naked. The number of tubercles was found to vary with the size of the specimens: 1–2 tubercles in specimens < 5 mm, whereas 3–4 tubercles in larger specimens. Genital plate wider than long (mean GPH : GPW = 0.87:1). Gonopore roughly circular, approximately one-third of genital plate size (GD 32.57 ± 7.40 % of GPH) and located at the centre of each genital plate. Ocular plates oval-shaped, placed at the junction of two adjacent genital plates, do not reach the periproct margin; covered with 3–4 small tubercles. Conspicuous triangular pit present at the junction of the ocular plate with its two adjacent genital plates. Periproct roughly circular in outline, approximately one-seventh of maximum test diameter (PPD 13.89 ± 2.17 % of HTD), composed of brown plates; anal opening eccentric, located opposite genital plate 'I'. Suranal plate conspicuous, located opposite the anus, covering approximately half the periproct (Figure 4.2E).

Spines thin, total length not exceeding maximum test diameter (SL 61.80 ± 11.74 % of HTD), their surface covered with fine longitudinal ridges. Spine colouration white with alternating reddish or purple bands (Figure 4.3A).

HABITAT AND DISTRIBUTION

Temnopleurus decipiens has been reported from the Philippines, the eastern Indian Ocean (Clark and Rowe, 1971; Marsh and Morrison, 2004), the South China sea (Lane *et al.*, 2000) and Western Australia (Marsh and Morrison, 2004; Figure 4.4). Lane

Figure 4.3. Banding on spines of (A) *Temnopleurus decipiens* and (B) *Temnopleurus toreumaticus*

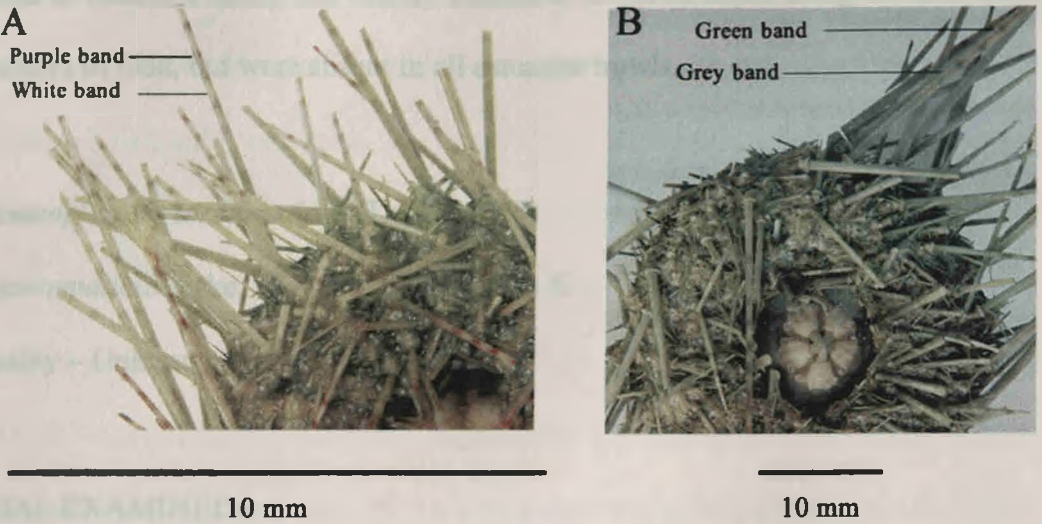
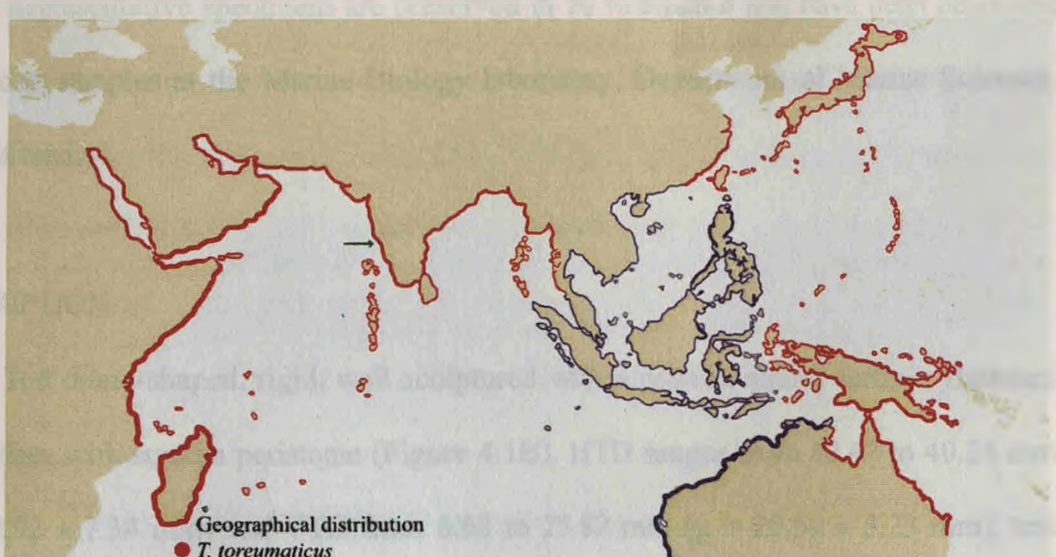


Figure 4.4. Geographical distribution of *T. decipiens* and *T. toreumaticus*



et al. (2000) reported this species from depths of 18–40 m around the coastal shelf waters of southern China. The present specimens of *T. decipiens* (as well as *T. toreumaticus*) were found to inhabit a sandy and muddy bottom at 15–20 m depth along the near shore coastal waters of Goa, but were absent in all estuarine trawls.

4.3.4. *Temnopleurus toreumaticus* (Leske, 1778)

Cidaris toreumatica Leske, 1778, p. 155-156, Tab X.

(type locality – Unknown)

MATERIAL EXAMINED

Off Betul fishing jetty, Goa, west coast of India, 15°04'N, 73°55'E, 8-20 m depth, 20 specimens, test diameter ranges from 12.47 to 40.24 mm.

Representative specimens are preserved in 70 % ethanol and have been deposited as voucher samples at the Marine Biology laboratory, Department of Marine Sciences, Goa University.

DESCRIPTION

Test dome-shaped, rigid, well sculptured with a convex aboral surface; flattened oral surface with sunken peristome (Figure 4.1B). HTD ranges from 12.47 to 40.24 mm (μ = 33.92 ± 7.34 mm) and VTD from 6.68 to 25.82 mm (μ = 20.59 ± 5.23 mm); test width about twice its height (μ VTD/HTD ratio = 0.61:1). Test comprised of five pairs of alternately placed ambulacral and inter-ambulacral plates, inter-ambulacral plates placed at about the level of the ambulacral plates (Figure 4.1D). The naked test displays an olive green to dark grey colour (Figure 4.1D).

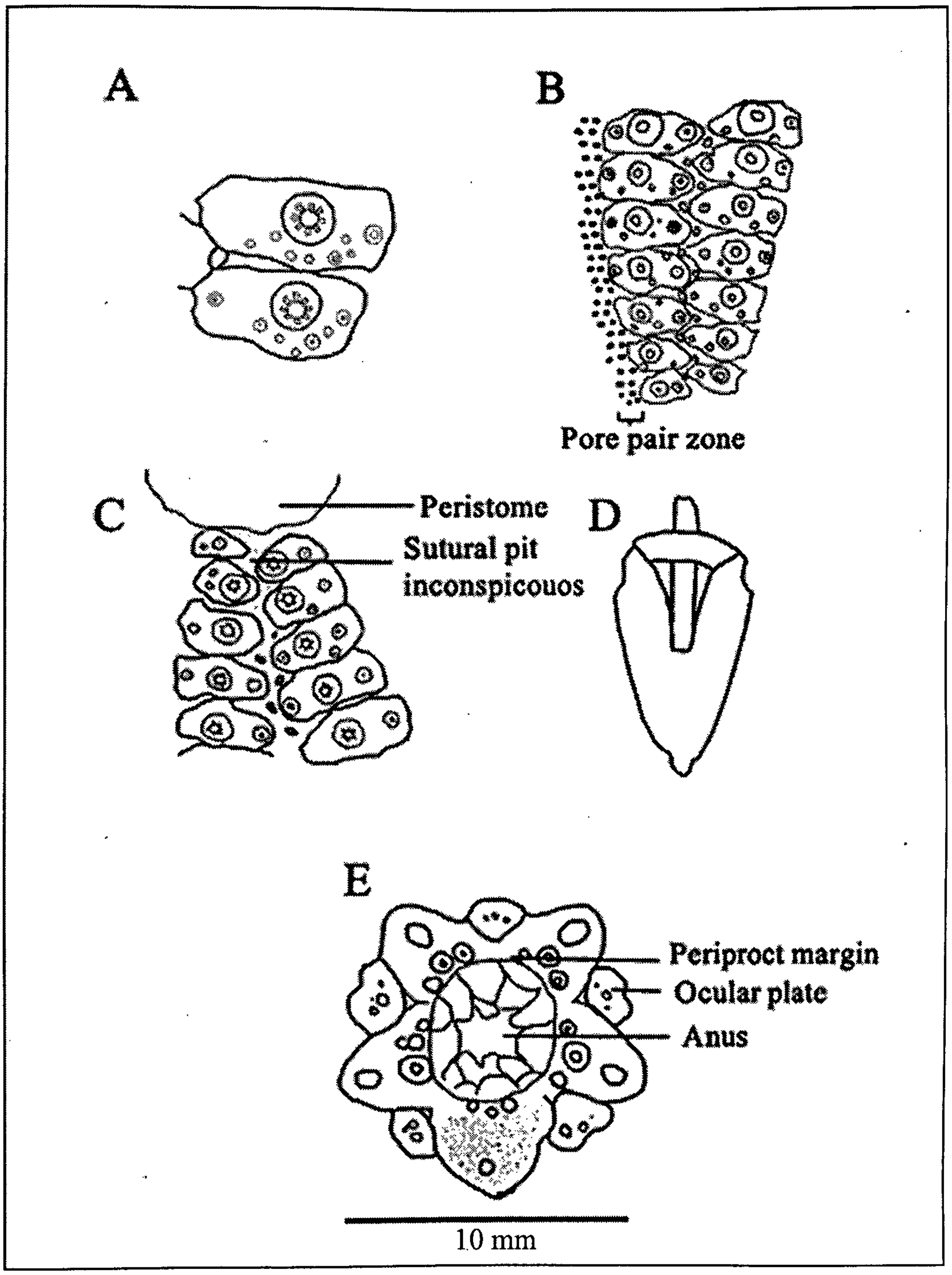
Ambulacral plates compound trigeminate, their pore-pairs bear numerous tube feet (in living specimens) and are arranged in slightly vertical arcs forming a single adradial band. The single primary tubercle of each ambulacral plate is close to the pore zone and is surrounded by randomly scattered smaller secondary tubercles; tubercles imperforate and distinctly crenulated.

Inter-ambulacral plates cover a slightly larger area of the test than the corresponding ambulacra. Each interambulacral plate has a central primary tubercle surrounded by smaller secondary and miliary tubercles that cover the remainder of the plate (Figure 4.5A). Primary tubercles imperforate and distinctly crenulated. Wedge-shaped pits are located at the angle of the suture, and are arranged in a zig-zag manner along the middle of the inter-ambulacrum; lateral extensions of the pits separate the inter-ambulacral plates and reach the pore-pair zone (Figure 4.5B). In specimens larger than 25 mm HTD, these pits extend horizontally over the entire surface of the plate. However, sutural pits near the peristome are inconspicuous (Figure 4.5C).

The peristome is large (PSD 34.26 ± 1.87 % of HTD) and roughly circular in outline with very feeble buccal notches. It is covered with soft skin and comprised of five pairs of buccal plates with buccal tube feet emanating from them. The Aristotle's lantern is of the camarodont type (i.e., with a paired rod-like epiphysis bridging across the upper end of the pyramid (Figure 4.5D).

The apical system is dicyclic and smaller than the peristome (AD 19.86 ± 2.02 % of HTD), with four equal-sized genital plates and one larger genital plate with madreporite. Inner part of each genital plate with small tubercles, outer part naked. The number of tubercles was found to vary with the size of the specimen: 1–2 tubercles in specimens < 12 mm, whereas 3–5 tubercles in larger specimens.

Figure 4.5. ***Temnopleurus toreumaticus*** **(A) Primary tubercle (B) Inter-ambulacrum (C) Sutural pit near-peristome (D) Pyramid of Aristotle's lantern (E) Apical system**



The genital plate is wider than long (mean GPH: GPW – 0.82:1). The gonopores are roughly circular and approximately one-third of the genital plate's size (GD 35.21 ± 5.98 % of GPH). They are located at the centre of each genital plate. Ocular plates are oval-shaped and are placed at the junction of two adjacent genital plates, but do not reach the periproct margin. The ocular plates are covered with 3–4 small tubercles. A small depression is present at the junction of the ocular plate with its two adjacent genital plates. The periproct is roughly circular in outline, one-tenth of maximum test diameter (PPD 11.40 ± 1.58 % of HTD) and is composed of dark brown plates. The anal opening is located near the centre of the periproct; a suranal plate is absent (Figure 4.5E).

Spines are thick, with a total length not exceeding maximum test diameter (SL 61.80 ± 11.74 % of HTD). Their surface is covered with fine longitudinal ridges. Spine colouration is grey with alternating greenish or brownish bands (Figure 4.3B).

HABITAT AND DISTRIBUTION

Temnopleurus toreumaticus is a fairly widespread species known to occur in East Africa, Madagascar, the Persian Gulf, the Red Sea and on the east coast of Australia (Clark and Rowe, 1971; Figure 4.4). In Japan, this species is found from northern Honshu to southern Kyushu (Mortensen, 1943; Schultz, 2006). Kitazava *et al.* (2007) studied the habitats of this sea urchin species in Shirikiwa Bay, Japan and indicated that *T. toreumaticus* inhabits the inter-tidal and sub-tidal zones of muddy beaches and can also be found near rocky patches with rich assemblages of algae. Published reports for Indian waters (Ramsay, 1885; Clark and Rowe, 1971) suggest that this species is widely distributed and inhabits sandy and muddy substrata between 5–40 m depth.

4.4. Brief description of other species of genus *Temnopleurus*

4.4.1. *Temnopleurus michaelseni* (Döderlein, 1914)

Maximum test diameter 25 mm. Suranal plate distinct and rounded; anal opening eccentric in the periproct. Ambulacral pore pairs arranged in a straight series. Deep sutural furrow continuous along the entire length of the sutures. Grooves in ambulacra and inter-ambulacra are deeply depressed and separated. Primary spines short, less than half the test diameter, coloured reddish brown at the base changing to greenish at the tip (Mortensen, 1943; Schultz, 2006).

HABITAT AND DISTRIBUTION

Littoral zone down to 16 m depth along the western and southern coasts of Australia (Schultz, 2006).

4.4.2. *Temnopleurus alexandri* (Bell, 1884)

Maximum test diameter 80 mm. Genital plate with some larger tubercles at the inner edge, absence of distinct suranal plate and anal opening near the centre of the periproct. Pore pairs arranged in oblique arcs. Each inter-ambulacral plate contains up to seven primary tubercles arranged in horizontal series. Sutural pits deep at the oral side. Spines short, pointed, less than the half the test diameter, coloured greenish at the base, distally more purplish (Mortensen, 1943; Schultz, 2006).

HABITAT AND DISTRIBUTION

Littoral zone down to 50 m depth (Schultz, 2006) from the eastern Indian Ocean to the coasts of Australia (Clark and Rowe, 1971).

4.4.3. *Temnopleurus hardwickii* (Gray, 1855)

Test rather strong with a maximum diameter of 46 mm. Apical system inflated; genital plate with numerous tubercles. Periproct large without distinct suranal plate; anus opening near the centre of the periproct. Pore pairs arranged in a straight vertical series. Sutural pits and furrows deep, continuous over the oral side. Spines short, less than one-fourth of the test diameter, with dark brown colour at base and light brown at the distal end (Mortensen, 1943; Schultz, 2006).

HABITAT AND DISTRIBUTION

Coastal waters from 5 to 35 m depth off Japan, Korean peninsula and northern China (Schultz, 2006).

4.4.4. *Temnopleurus reevesii* (Gray, 1855)

Test fragile, hemispherical, test diameter 30–45 mm. Apical system with ocular plate 'I' inserted. Anal opening strongly eccentric in the periproct with distinct suranal plate. Pore pairs arranged in a straight vertical series. Sutural pits small, furrows shallow, continuous at the oral side as well. Spines short, about half the diameter of the test, with brownish to light greyish tinge (Clark, 1912; Mortensen, 1943; Schultz, 2006).

HABITAT AND DISTRIBUTION

Coastal waters from 36 to 200 m depth (Clark, 1912) in East Africa, Madagascar, the eastern Indian Ocean, the Philippines, Malaysia, China and Japan (Clark and Rowe, 1971; Schultz, 2006).

4.4.5. *Temnopleurus apodus* (A. Agassiz & H. L. Clark, 1906)

Small-sized species with a maximum test diameter of 7 mm. Pore pairs arranged in slightly vertical arcs. Apical system distinctly larger than peristome. Only five buccal plates present on peristome, madreporic pores few (12–14) in number. Suranal plate covers more than half the periproct, anal opening very eccentric. Primary spines slender and long, nearly equal to test diameter (Clark, 1912; Mortensen, 1943).

HABITAT AND DISTRIBUTION

Coastal waters from 100 to 325 m depth off Hawaii (Clark, 1912), in the South China Sea (Lane *et al.*, 2000) and on the east coast of India (Sastry, 2007).

4.5. Comparative diagnosis

Our analysis of twenty seven morphological characters revealed significant differences between *T. decipiens* (N = 17) and *T. toreumaticus* (N = 20) with respect to the position of the anus, the presence of a suranal plate, the presence of sutural pits near the peristome and the arrangement of ambulacral pore pairs. In addition, subtle morphological differences were observed with respect to the diameter of the apical system, the ratio of spine length to maximum test diameter and the colour banding on spines (Table 4.1). An attempt was made to compare our observations with the original description by de Meijere (1904) to provide a better picture of the taxonomy of these two species.

4.6. Comparison with the original description

De Meijere (1904) first described *T. decipiens* (originally as a *Genocidaris decipiens*) from sandy, coral and muddy bottom habitats down to 40 m depth from the

Table 4.1. Comparison of morphological characters of *Temnopleurus decipiens* and *Temnopleurus toreumaticus*

Morphological characters	***T. decipiens* (N = 17)**	***T. toreumaticus* (N = 20)**
Test structure		
Test colour	Olive green to light green	Olive-green to grey
Test shape	Hemispherical	Hemispherical
Arrangement of ambulacral pore pairs	Straight series	Slightly vertical arcs
Sutural pits near peristome	Conspicuous	Inconspicuous
Form of apical system	Dicyclic	Dicyclic
Form of periproct	Large circular, brown plates	Circular, black plates
Position of anal opening	Eccentric	Subcentral
Suranal plate	Present	Absent
Colour of spine	Purple white bands	Brown green bands
Meristic counts		
Number of median series tubercles on interambulacra	1	1
Number of tubercles present on the genital plate	1–3	3–5
Morphometric measurements		
Mean horizontal test diameter(HTD) (mm)	14.60 ± 4.78	33.92 ± 7.34
Mean vertical test diameter (VTD) (mm)	8.22 ± 3.15	20.59 ± 5.23
Mean peristome diameter (PD) (mm)	5.06 ± 1.59	11.57 ± 2.45
Mean apical disc diameter (AD) (mm)	3.53 ± 0.92	6.64 ± 1.31
Mean periproct diameter (PPD) (mm)	1.99 ± 0.67	3.77 ± 0.63
Mean genital plate width (GPW) (mm)	1.25 ± 0.38	2.37 ± 0.51
Mean genital plate height (GPH) (mm)	1.06 ± 0.30	1.92 ± 0.33
Mean gonopore diameter (GD) (mm)	0.35 ± 0.13	0.68 ± 0.19
Mean spine length	10.63 ± 4.90	21.75 ± 4.70
Morphometric ratios		
VTD (% of HTD)	55.15 ± 4.76	60.38 ± 6.17
% of spine length to the HTD	73.00 ± 11.61	62.00 ±11.74
Peristome (% of HTD)	35.15 ± 3.33	34.26 ± 1.87
Apical system (% of HTD)	25.14 ± 3.96	19.86 ± 2.02
Periproct (% of HTD)	13.90 ± 2.17	11.40 ± 1.58
Diameter of gonopore (% GPH)	32.56 ± 7.40	35.20 ± 5.98
Height to width ratio of the genital plate	0.86:1 ± 0.11	0.78:1 ± 0.09

Labuan Badjo, Flores and Saleh Bay, Indonesia. The specimens collected in the waters off Goa were found to resemble de Meijere's description with regard to the morphological characters "presence of a distinct suranal plate", "eccentric anal opening" and "zig-zag arrangement of sutural pits". However, they differed from the original description by the pattern of the ocular plate arrangement, such that "none of the ocular plates placed near the periproctorial margin reach the periproct" (Figure 4.2E). Another marked difference was the large test size (21.3 mm HTD) as compared to the original description (7.0 mm HTD).

4.7. Comparative analysis of genus *Temnopleurus*

The distinctiveness of *T. decipiens* was asserted based on a comparison with our observations on *T. toreumaticus* and published descriptions of the other five congeners (Clark, 1912; Mortensen, 1943; Clark and Rowe, 1971; Schultz, 2006). Among the twenty seven morphological characters used in the taxonomic identification of species of genus *Temnopleurus*, seven parameters (i.e., anal position, presence of suranal plate, sutural pits near peristome, pore pair arrangement, number of buccal plate in the peristome, colouration of the primary spine and length of the spine with respect to test diameter) were used for our comparative analysis (Table 4.2).

This analysis revealed that *T. decipiens* shares the character "eccentric anus" and "presence of suranal plate" with *T. apodus, T. reevesii* and *T. michaelseni* as opposed to "sub-centric anus" and "absence of distinct suranal plate" in *T. toreumaticus, T. hardwickii* and *T. alexandri*. In addition, *T. decipiens* possessed "conspicuous sutural pits near peristome", a character shared only with *T. reevesii.* Pore pair arrangement was found to be in "straight vertical series" among *T. decipiens, T. reevesii, T. hardwickii* and *T. michaelseni,* whereas the same was observed to be "arced" in *T. toreumaticus, T.*

Table 4.2. Comparison of morphological characteristics of all seven extant species of the genus *Temnopleurus*

Morphological characters	Position of the anus	Suranal plate	Sutural pits near peristome	Pore pair arrangement	Number . of buccal plates	Banding on spines	Relative length of spine toHTD	Ref.
T. toreumaticus	Subcentral	Absent	Inconspicuous	Arced	10	Red or brown	>½ HTD	1,2
T. hardwickii	Subcentral	Absent	Inconspicuous	Straight series	10	Absent	<½ HTD	1,2
T. alexandri	Subcentral	Absent	Inconspicuous	Arced	10	Absent	<½ HTD	1,2
T. decipiens	Eccentric	Present	Conspicuous	Straight series	10	Purple or red	>½ HTD	1,3
T. apodus	Eccentric	Present	Inconspicuous	Arced	5	Absent	>½ HTD	1,4
T. reevesii	Eccentric	Present	Conspicuous	Straight series	10	Absent	<½ HTD	1,2
T. michaelseni	Eccentric	Present	Inconspicuous	Straight series	10	Absent	<½ HTD	1,2

[1]Mortensen, 1943 [2]Schultz, 2006 [3]de Meijere, 1904 [4]Clark, 1912

alexandri and *T .apodus*. In *T. apodus*, it was observed that it possessed "peristome smaller than apical system" and "five buccal plates", whereas, the other species possessed "peristome larger than apical system" and "ten buccal plates". A comparison of another major character namely spine colouration revealed "purple to red" bands in *T. decipiens* and "brown to red" bands in *T. toreumaticus.* However, the other five species showed lack of colour bands on the spines. In addition, spine length in these species (*T. decipiens, T. toreumaticus* and *T. apodus*) was found to be "greater than half the test diameter" in contrast with "less than half the test diameter" in the other four species.

4.8. Revised key to the extant species of the genus *Temnopleurus*

1. Anus located near the centre of the periproct (subcentral), suranal plate absent...2
- Anus located away from the centre (eccentric), distinct suranal plate present........4

2. 3–4 primary tubercles present on each inter-ambulacral plate 3
- 7–8 primary tubercles present on each inter-ambulacral plate......*T. alexandri* (Bell, 1884)

3. Primary spines long, equal to half of horizontal test diameter, banded with reddish or brown colour bands, pore pairs arranged in arcs.....*T. toreumaticus* (Leske, 1778)
- Primary spines short, length is less than one-fourth of the horizontal test diameter, spines never banded, pore pairs arranged in a straight vertical series...............*T. hardwickii* (Gray, 1855)

4. Peristome larger than apical system, contains ten buccal plates with ten buccal tube feet...5
- Peristome smaller than apical system, contains five buccal plates with five buccal tube feet...*T. apodus* (Agassiz and Clark, 1907)

5. Primary spines short, less than half of the test diameter, not banded 6
- Primary spines long equal to two-third of the test diameter, banded with dark purple or red-coloured bands...........................*T. decipiens* (de Meijere, 1904)

6. Sutural pits deep, horizontal furrows deep and elongate, sutural pits at the oral side inconspicuous.....................................*T. michaelseni* (Döderlein, 1914)
- Sutural pits shallow, horizontal furrows shallow and not elongated, sutural pits at the oral side conspicuous ....*T. reevesii* (Gray, 1855)

4.9. Discussion

Temnopleurus is a well-studied echinoid genus distributed across the Indo-West Pacific region (Clark, 1912; Mortensen, 1943; Clark and Rowe, 1971; Schultz, 2006). This genus is comprised of seven extant and one fossil species. Four of the extant species (*T. decipiens, T. reevesii, T. apodus* and *T. michaelseni*) possessing an eccentric anus and a large suranal plate were initially included under sub-genus *Toreumatica* (sensu Coppard *et al.*, 2005). Recently, the sub-genus *Toreumatica* has been accepted as the genus *Temnopleurus* (Kroh, 2012). Among these, *T. decipiens* is one of the least studied species in respect of its bio-geographical distribution (Clark and Rowe, 1971) due to limited occurrence. The present study records the occurrence of *T. decipiens* for the first time from the Indian coast. The present finding assumes significance as it not only updates information about a rare echinoid species but also extends its known geographical range to the central Indian Ocean. Our observation reveals the occurrence of two species of the genus *Temnopleurus* (*T. decipiens* and *T. toreumaticus*) in the near shore waters of Goa.

Review of published literature (Mortensen, 1943; Clark and Rowe, 1971; Coppard *et al.*, 2005; Smith, 2005; Schultz, 2006) suggests morphological differences between these species in respect of position of the anus within the periproct and the presence of a suranal plate. However, there were discernibly marked differences in respect of sutural pits near the peristome and two morphometric ratios, % of AD to HTD and ratio of spine length to HTD (Table 4.1). Further, comparison of *T. decipiens* with its original description by de Meijere (1904) revealed that the present specimens differed from the type specimen with respect to size, and the position of ocular plate with respect to periproct margin. Therefore, our observations suggest that the size of *T. decipiens* ranges from 5 to 21 mm, and the position of the ocular plate with respect to periproct margin vary within the species.

A comparative analysis of the extant species of the genus *Temnopleurus* (Clark, 1912; Mortensen, 1943; Clark and Rowe, 1971; Coppard *et al.*, 2005; Smith, 2005; Schultz, 2006) was carried out using seven morphological parameters (Table 4.2). This analysis suggested that apart from the structure of periproct, arrangement of sutural pits and ambulacral pore-pairs, the number of tubercles on the plate also varies between the species of genus *Temnopleurus*. In this context, a revised taxonomic key to all the extant species of the genus *Temnopleurus* is provided with two additional characters: the primary tubercle count and relative spine length, to differentiate between the congeners. However, the fossil species *Temnopleurus latidunensis* Clegg, 1933 was not taken into consideration for taxonomic comparison as the description lacked details of the structure of the periproct and the spines (Kroh *et al.*, 2011).

In summary, the present study reveals the first record of *T. decipiens* from the Indian waters, and an attempt has been made to compare its morphology with its congeners. Further, molecular studies pertaining to the nucleic acid homology would decipher phylogenetic and intra-species variability among this group.

Chapter 5.

Biological aspects and catch trends of elasmobranchs

5.1. Introduction

Traditionally, the elasmobranch fisheries of the Goan coast consisted of catches taken with beach seines (inshore), gill nets and hook-and-line (offshore). Mechanization of fishing vessels (1963) led to exploitation of bulk of the elasmobranchs as by-catch of bottom trawlers operating in the near shore and offshore waters off Goa. Published literature (Raje *et al.*, 2007) suggests that 38 species including twenty six species of sharks, 9 species of rays and 3 species of skates have contributed to the elasmobranch fishery of Goa during 1969–2004 (CMFRI, 1979; Kurup *et al.*, 1987; Srinath *et al.*, 2006) with an average annual landing of 461.78 mt per annum. Amongst the commercially exploited elasmobranchs, *Scoliodon laticaudus* (Müller and Henle, 1838) and *Sphyrna zygaena* (Linnaeus, 1758) attract lucrative markets for dried products (Hanfee, 1997), however only large sized batoids are locally consumed. Large-scale discarding of elasmobranch juveniles by trawlers might be the reason for the inaccurate estimation of species abundance and diversity.

Elasmobranchs being top predators play a major role in regulating the population size and dynamics of lower trophic level (LTL) fishes (Wetherbee and Cortés, 2004; Séret *et al.*, 2010). Targeted fishing for elasmobranchs due to high demand for their meat, fins, liver and other products has resulted in increased global landings to the tune of 760,000 mt per annum (Stevens *et al.*, 2000). Further, intrinsic biological traits such as slow growth rate, low fecundity (Holden, 1974; Jennings *et al.*, 1998; Ebert *et al.*, 2008), high fishing mortality coupled with juvenile discard push some species to depletion, while endangering others (Stevens *et al.*, 2000). Although elasmobranchs have been traditionally exploited, the present rate of elasmobranch exploitation seems to be highly unsustainable as there are serious concerns owing to drastically declining populations (Séret *et al.*, 2010).

In response to global concerns over dwindling stocks of elasmobranchs as a result of overexploitation, studies pertaining to the biological traits of elasmobranchs (Cortés, 2000; Ebert *et al.*, 2008; Abdurahiman *et al.*, 2010), their population dynamics (Walker and Heessen, 1996; Walker and Hislop, 1998), status of exploitation (Compagno, 1990; Bonfil, 1994) and its effects on their stocks (Stevens *et al.*, 2000; Stobutzki *et al.*, 2002) have received attention of fisheries researchers recently (Stevens *et al.*, 2000).

Against this background, attempts have been made to provide baseline information on species composition, spatio-temporal variations in occurrence, size class and diet of dominant elasmobranch species collected from the fishing grounds of Goa. Further, an attempt has also been made to provide a better insight into the status of exploitation and utilization of these resources based on elasmobranch landings of Goa during 1969–2004.

5.2. Methodology

5.2.1. Auxiliary data collection

Sea Surface Temperature (SST) data was obtained from Group for High Resolution Sea Surface Temperature (GHRSST) Level 4 (AVHRR) Advanced Very High Resolution Radiometer, Path Finder, available at POET.PODAAC website.

5.2.2. Diet analysis

A total of 165 guts belonging only to three species *Scoliodon laticaudus, Chiloscyllium griseum* and *Himantura walga* were analyzed for their feeding habits. Other species were not subjected to this exercise due to insufficient number of specimens.

Further, only *S. laticaudus* was selected to assess ontogenic shift in the diet as both juvenile and adult specimens were available. These samples were categorized into three different size groups namely small (10 – 25 cm, juveniles), medium (26 – 40 cm, sub adults), large (41 – 57 cm, adults) and the percent Index of Relative Importance (I_{RI}) for each prey item for the all size groups was calculated.

5.2.3. Collection and analysis of Fishery data

Marine fish landing data of Goa for the periods 1969–2004 (CMFRI) and 2006–2010 (Department of Fisheries, Government of Goa, 2011) were obtained and an assessment of trends in elasmobranch fisheries of Goa was carried out. Subsequently, the elasmobranch trends during 1969–2004 were compared with trends of other higher trophic level (HTL) fishes and lower trophic level (LTL) fishes during the same period.

5.3. Results

5.3.1. Environmental variables

Sea Surface Temperature (SST) range during the entire study period was 26.02 – 31.03 °C with a mean value of 28.86 ± 1.14 °C.

5.3.2. Biological aspects

Species composition

A total of 9 elasmobranch species (Table 5.1) were observed in the inshore trawl catches. Among these, only three namely *C. griseum, H. walga* and *S. laticaudus* were found to occur in 16, 15 and 10 % of the trawl hauls, respectively (Table 5.1) indicating a sizeable contribution of these species to the total elasmobranch catch. However, the

Table 5.1. Species composition, occurrence and size range of elasmobranch species examined during the present study

Sr. No.	Species	N	Frequency of occurrence (%)	Size range (cm)	L_m (cm)*	Juveniles (n)	Adults (n)
1.	*Chiloscyllium griseum* (Müller & Henle, 1838)	62	16.00	11 – 58[1]	30.6 – 55.0[1]	31	31
2.	*Scoliodon laticaudus* (Müller & Henle, 1838)	108	15.00	15 - 57[1]	32.6 – 58.4[1]	84	24
3.	*Himantura walga* (Müller & Henle, 1841)	63	10.00	5 - 37[2]	19.8 – 35.4[2]	45	18
4.	*Aetobatus flagellum* (Bloch & Schneider, 1801)	10	0.05	20 - 105[2]	29.9 – 53.7[2]	06	04
5.	*Himantura gerrardi* (Gmelin, 1789)	07	0.03	9 - 28[2]	73.8 – 132.4[2]	07	00
6.	*Glaucostegus granulatus* (Cuvier, 1829)	06	0.03	9 – 25[1]	99.3 – 128.2[1]	06	00
7.	*Rhinobatus obtusus* Müller & Henle, 1841	05	0.04	20 – 30[1]	37.5 – 67.3[1]	03	02
8.	*Himantura uarnak* (Gmelin, 1789)	03	0.02	22 – 35[2]	73.8 – 132.4[2]	03	00
9.	*Himantura marginata* (Blyth, 1860)	01	0.01	35[2]	68.2 - 124[2]	01	00

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[1] total length [2] disc width

contribution of the other six species was negligible (<0.05 %; Table 5.1) highlighting the rarity of their occurrence.

Quantitative analysis of trawl catch data collected during the present study revealed a meagre contribution from elasmobranchs (0.42 and 0.97 % by abundance and weight, respectively). Subsequently, the above data was assorted to represent 'pre-monsoon' and 'post-monsoon' seasons. The temporal trends revealed no marked differences between the seasons (Figure 5.1a, b). Annual landings of Goa (2006–2010; Department of Fisheries, Government of Goa; Figure 5.2.) indicated greater contribution from South Goa ($\alpha = 0.01$, $P = 0.00295$) (Table 5.2).

Size class and life stages

The observations on the size and their comparison with L_m values (Froese and Pauly, 2012) indicated that 72 % specimens were juveniles, whereas only 28 % were adults (Table 5.1). Species wise data indicated that *S. laticaudus, H. walga, Aetobatus flagellum* and *Rhinobatos obtusus* were dominated by juveniles, *C. griseum* was equally represented by juveniles and adults, and the other five species were represented exclusively by juveniles (Table 5.1).

5.3.3. Diet analysis

Among the 165 guts examined, 27.27, 26.06 and 46.67 % were empty, partially filled and gorged, respectively. The percentage of empty stomachs in *S. laticaudus*, *C. griseum* and *H. walga* was found to be 17, 31 and 31, respectively. Analysis of their stomach contents revealed 13 prey items (Table 5.3). The order of prey importance for all the observed specimens was teleosts (45.95 % I_{RI}) followed by crustaceans (40.19 % I_{RI}) and molluscs (13.83 % I_{RI}). The Indian Oil sardine, *Sardinella longiceps* was the most

Figure 5.1. Seasonal variations in elasmobranch abundance (a) and weight (b)

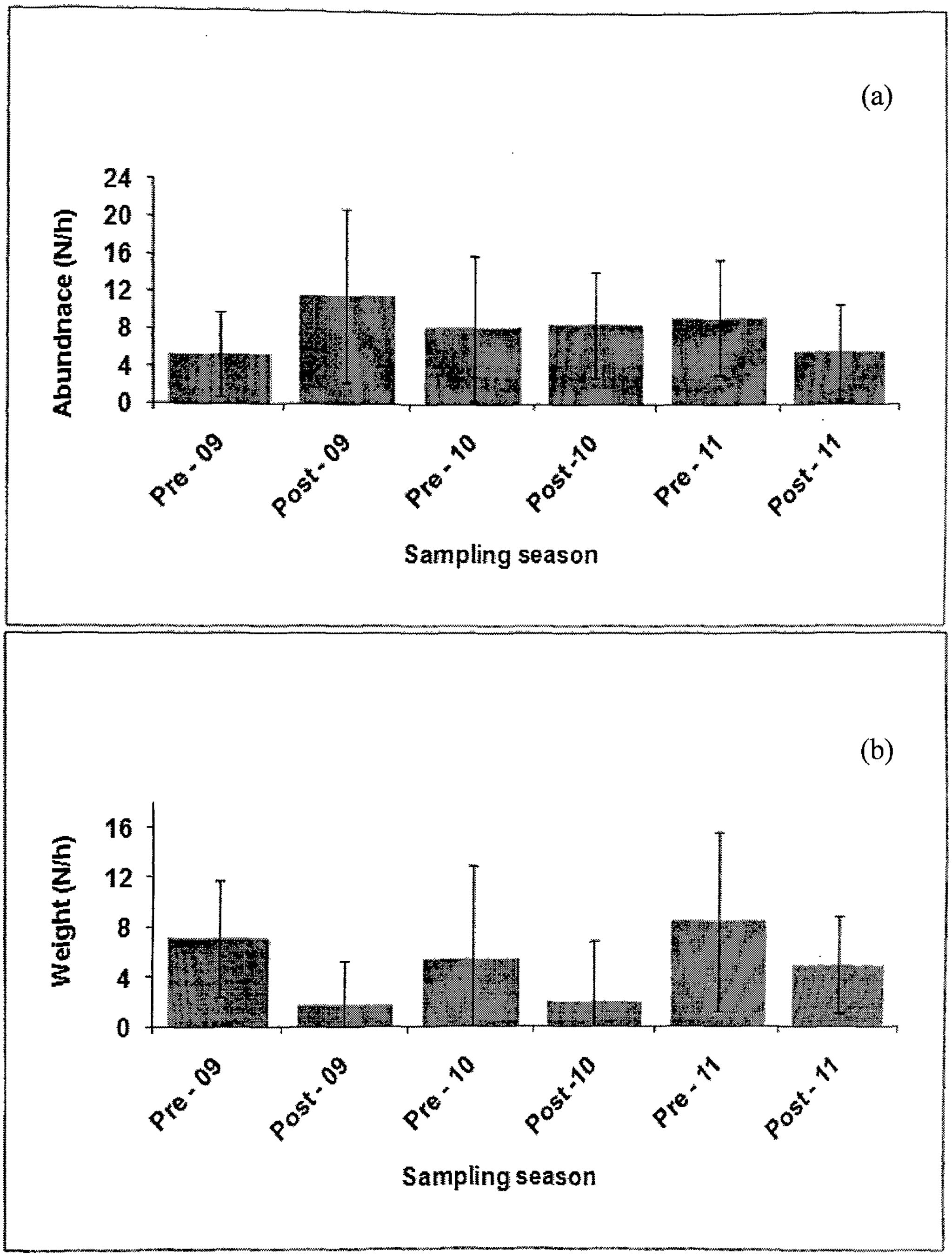


Figure 5.2. Elasmobranch landings along North Goa and South Goa during 2006-2010

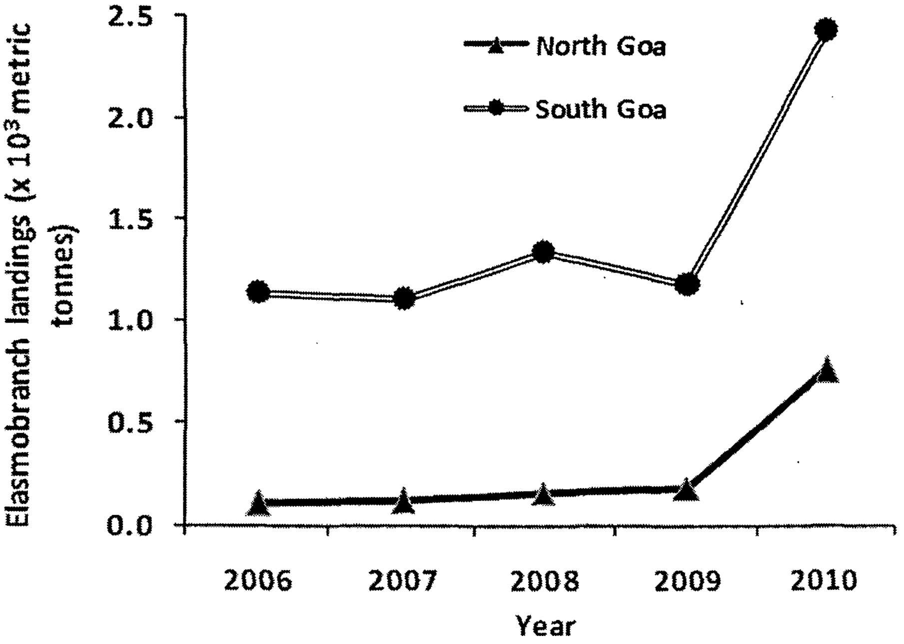


Table 5.2. Comparison between elasmobranch landings of South Goa and North Goa using one way ANOVA (α = 0.01)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3573648	1	3573648	17.7358	0.00295	11.25862
Within Groups	1611948	8	201493.5			
Total	5185596	9				

Table 5.3. Index of Relative Importance for individual prey items in elasmobranch diet

Sr. No.	Prey items (Faunal group-wise)	Index of Relative Importance (%)			
		Total Elasmobranchs (N=165)	*S. laticaudus* (N=71)	*C. griseum* (N=42)	*H. walga* (N=52)
I.	**Crustaceans**				
1.	*Penaeus monodon*	1.33	4.58	0.00	0.00
2.	*Parapenaeopsis stylifera*	2.90	16.11	0.00	0.00
3.	*Metapenaeus dobsoni*	3.49	9.86	12.85	0.00
4.	Mysis	2.74	1.40	0.00	4.81
5.	Unidentified prawn	12.51	11.08	0.00	23.65
6.	*Miyakea nepa*	17.22	15.82	0.00	15.73
7.					
II.	**Teleosts**				
1.	*Sardinella longiceps*	38.20	12.83	71.03	0.00
2.	*Stolephorus commersonnii*	2.83	3.90	10.47	0.00
3.	Unidentified clupeid	0.97	3.45	0.00	0.00
4.	*Trichiurus lepturus*	1.12	3.93	0.00	0.00
5.	Unidentified teleost	2.83	10.52	0.00	0.00
6.					
III.	**Molluscs**				
1.	*Uroteuthis duvauceli*	12.30	0.00	0.00	55.79
2.	*Sepiella inermis*	1.53	6.47	5.63	0.00

important prey item of the elasmobranchs (Table 5.3). Further, analysis of the stomach contents revealed that crustaceans (58.85 % I_{RI}), teleosts (81.50 % I_{RI}) and cephalopod molluscs (55.79 % I_{RI}) dominated the diets of *S. laticaudus, C. griseum* and *H. walga,* respectively (Table 5.3).

Gut content analysis of different size groups of *S. laticaudus* (Table 5.4) revealed that crustaceans (96.65 % I_{RI}) were the major prey item of small individuals (15–25 cm). Medium sized individuals fed on a mixed diet of crustaceans (60.05 % I_{RI}), teleosts (33.14 % I_{RI}) and molluscs (6.79 % I_{RI}). The diet of large individuals was dominated by teleosts (94.72 % I_{RI}), whereas crustaceans were absent.

Levins' diet breadth index (B) revealed that the all three elasmobranchs *H. walga* (0.76), *S. laticaudus* (0.67) and *C. griseum* (0.53) are generalized feeders which feed on multiple prey items. Further, estimation of diet overlap among these species indicated the highest overlap between *S. laticaudus* and *H. walga* (65.61 %), followed by *S. laticaudus* and *C. griseum* (34.00 %). There was no overlap (0 %) between *C. griseum* and *H. walga*. The trophic level of the elasmobranchs ranged between 3.75 (*C. griseum* and *S. laticaudus*) and 4.05 (*H. walga*).

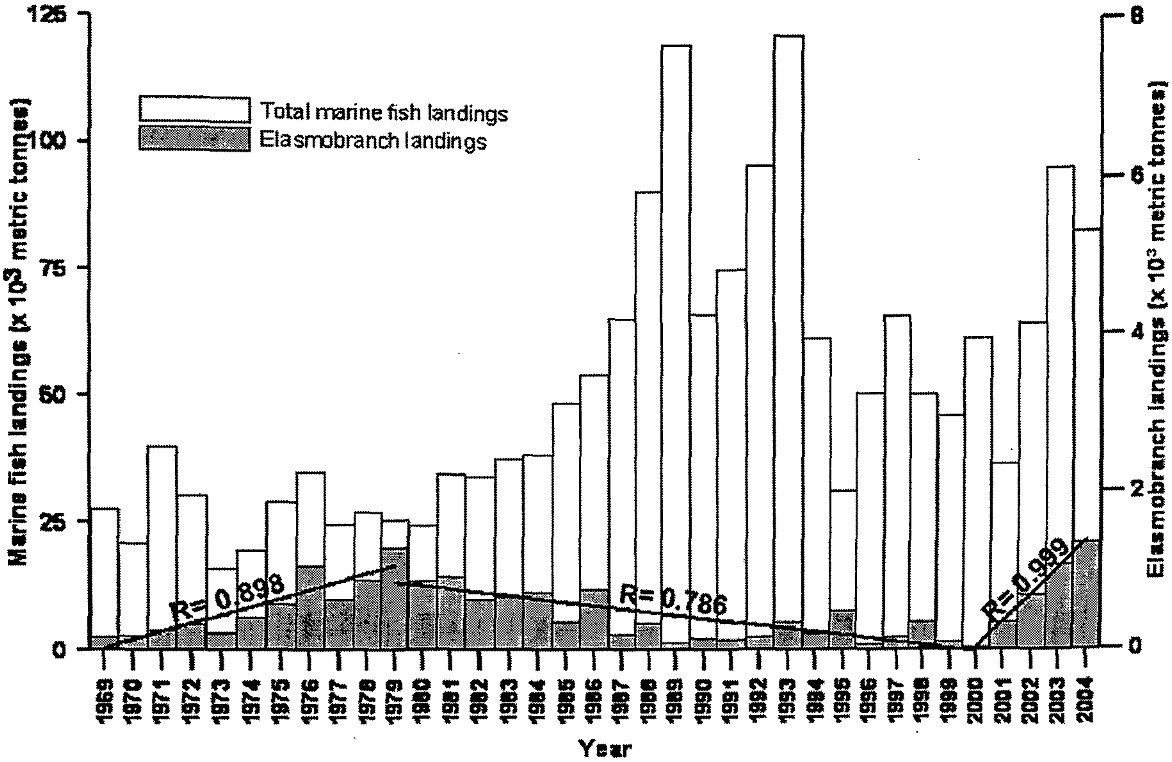
5.4. Catch trends (1969 – 2004)

Analysis of the elasmobranch annual catch landings of Goa during 1969–2004 indicated highly variable trends (461.78 ± 363.33 mt), and their contribution to the total marine fish landings of the region during this period ranged between 0.05 and 5.04 %. Elasmobranch landings during the above period did not show any particular trend (Figure 5.3). The initial post-mechanization period (1969) was marked with very low landings (138 mt), followed by a substantial increase up to 1280 mt in 1979 (R = 0.898) and significant reduction up to 29 mt in 2000 (R = 0.786). However, the production increased

Table 5.4. Diet matrix of *S. laticaudus* with prey items arranged in size groups indicating ontogenic shift

Sl. No.		Prey Items	Size Class		
			10 -25	**26-40**	**41-57**
I.		**Crustaceans**	**95.65**	**60.05**	**0.00**
	1	*Penaeus monodon*	0.00	12.78	0.00
	2	*Parapenaeopsis stylifera*	17.39	0.00	0.00
	3	*Metapenaeus dobsoni*	4.34	0.00	0.00
	4	Mysis	39.13	0.00	0.00
	5	Unidentified prawn	17.39	4.07	0.00
	6	*Miyakea nepa*	17.39	43.19	0.00
II.		**Teleosts**	**4.34**	**33.14**	**90.72**
	1	*Sardinella longiceps*	4.34	9.53	41.4
	2	*Stolephorus commersonnii*	0.00	0.00	11.59
	3	Unidentified clupeid	0.00	9.53	0.00
	4	*Trichiurus lepturus*	0.00	8.40	9.27
	5	*Unidentified teleost*	0.00	5.66	28.45
III.		**Molluscs**	**0.00**	**6.79**	**9.27**
	1	*Uroteuthis duvauceli*	0.00	0.00	0.00
	2	*Sepiella inermis*	0.00	6.79	9.27

Figure 5.3. Landings of elasmobranchs and total marine fish from of Goa during 1969–2004



discernibly up to 1353 mt in 2004 (R = 0.999). Comparison of the elasmobranch trends with the total annual marine landings of Goa revealed an inverse relationship (Figure 5.3).

Although, data on the elasmobranch fishery of Goa is available since 1969, assorted group-wise landings data for sharks, skates and rays is available only for the period 1981–2004. It is evident (Figure 5.4) that sharks were the major group and their landing trends influenced those of the total elasmobranchs during the above period. Rays occurred largely as incidental by-catch of bottom trawls and their contribution was negligible except during 2002–2004 (Figure 5.4).

Further investigation into the causes of reduction in elasmobranchs landings of Goa during 1969–2004 was done by comparing trends of their percentage contribution to the total marine fish landings with those of LTL and other HTL fishes. The graph (Figure 5.5) shows an inverse relationship between the trends of elasmobranchs and other HTL fishes, whereas it showed a direct relationship with LTL fishes. Hence, the data were split into two periods i.e. the initial period (1969–1979) with discernible increase in the contribution of elasmobranchs (Figure 5.6a) and the later period (1979–2004) with gradual reduction (Figure 5.6b). The initial upsurge in elasmobranch contribution (Figure 5.6a) was found to be significant (R = 0.932) and corresponded with significant increase in other HTL fishes (R = 0.953) and reduction in LTL fishes (R = 0.961). On the other hand, reduction in the contributions of both elasmobranchs and other HTL corresponded with insignificant increase in LTL percentage (Figure 5.6a).

Elasmobranch landings data collected from two principal jetties (Malim, North Goa and Betul, South Goa) indicated that two species namely *S. zygaena* and *S. laticaudus* formed the major bulk of the sharks landed at the respective jetties whereas, *C. griseum* was landed in meagre quantities along the entire region. It was further

T- 627

Figure 5.4. Catch trends of elasmobranchs including sharks, skates and rays for Goa coast (1981–2004)

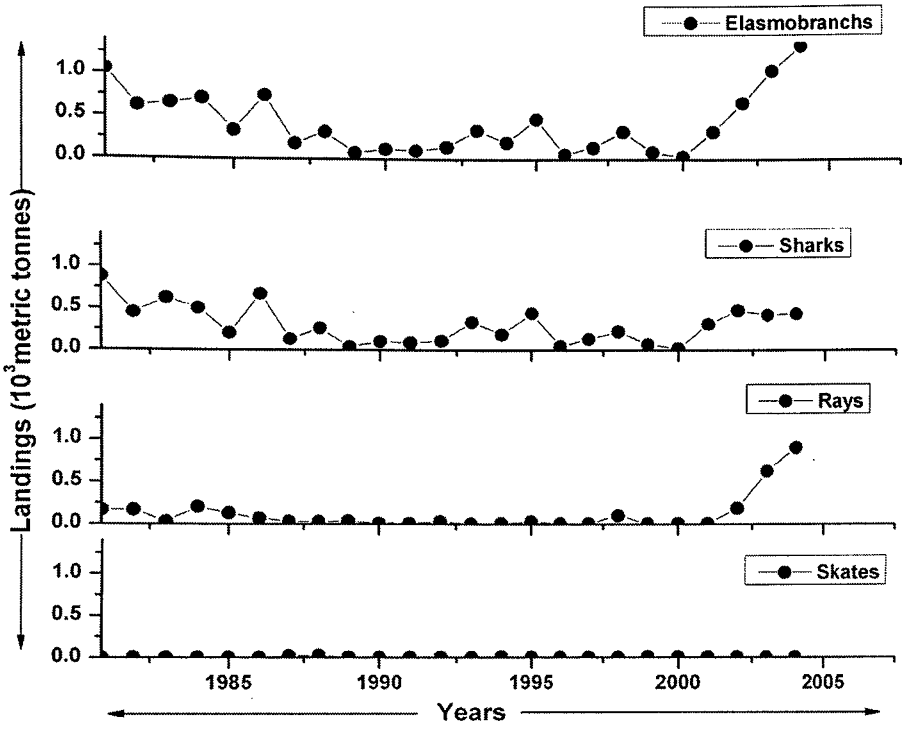


Figure 5.5. Trends of landings of elasmobranchs, other higher trophic level fishes and lower trophic level fishes from Goa during 1969–2004

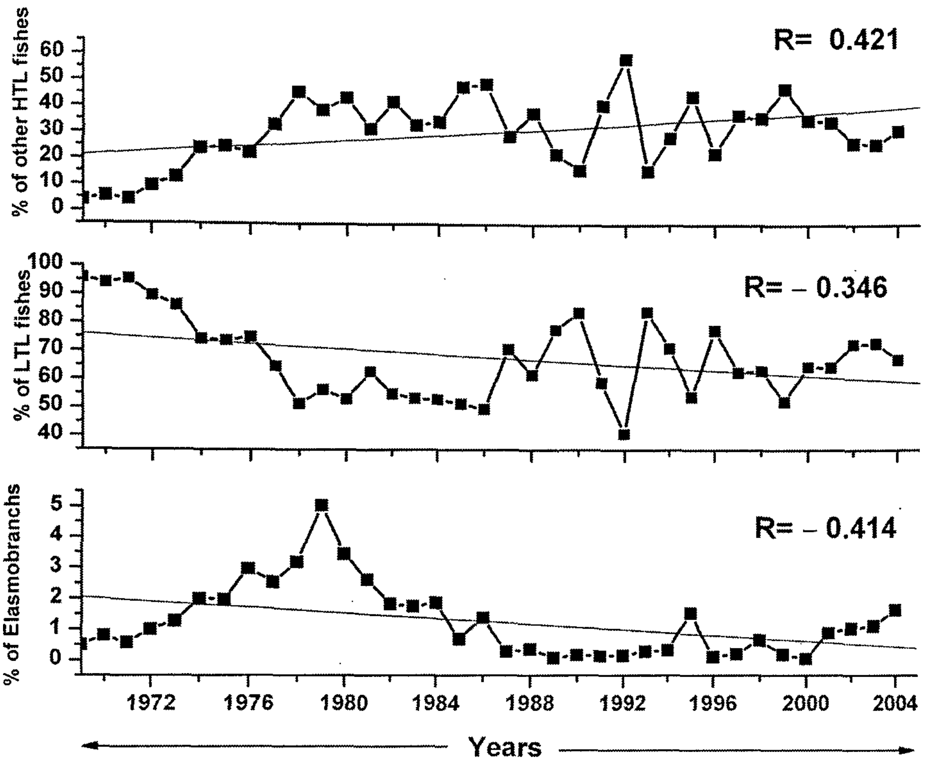
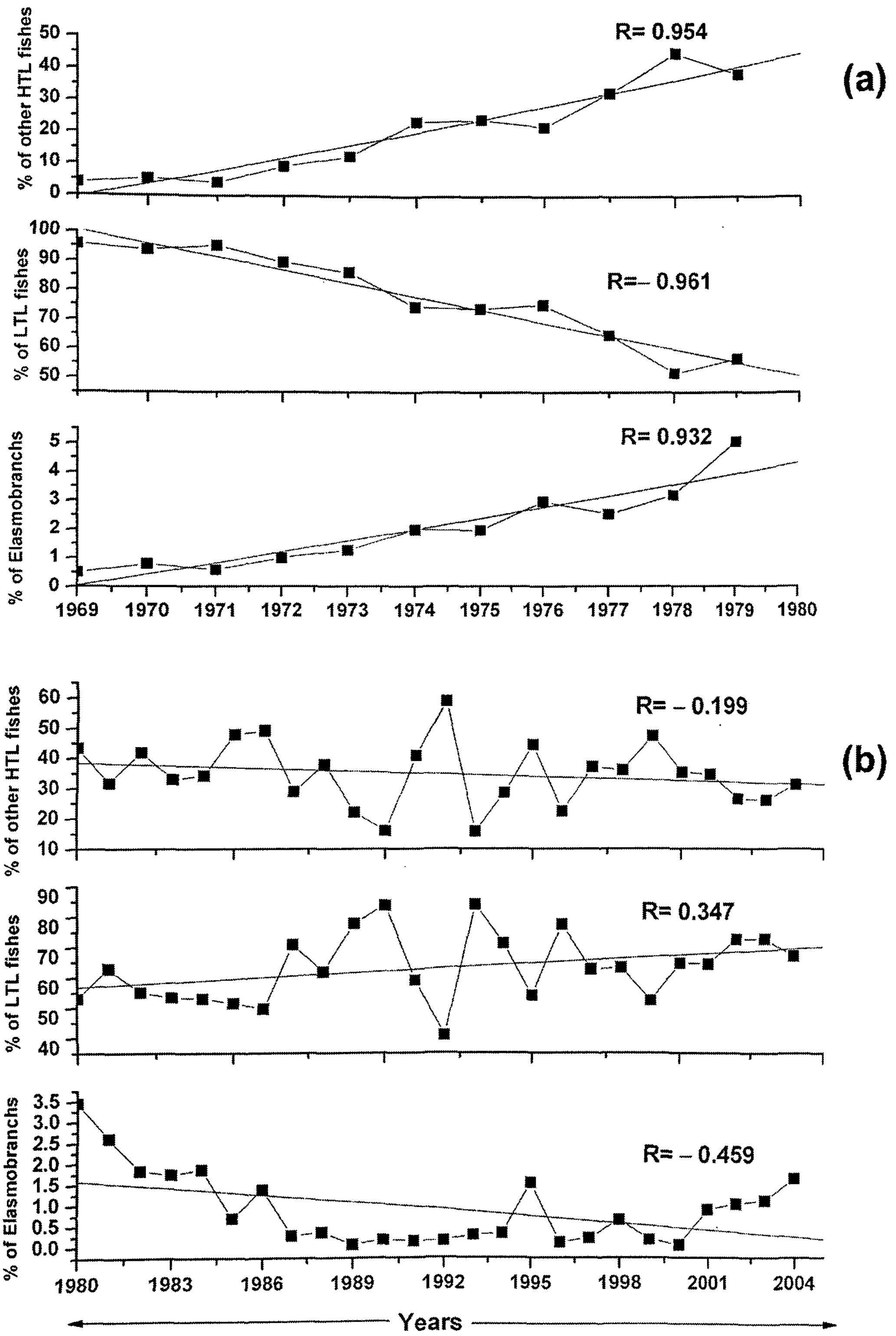


Figure 5.6. Trends of landings of elasmobranchs, other higher trophic level fishes and lower trophic level fishes from Goa (a) during 1969 – 1979 and (b) during 1980 – 2004



observed that the above species were mainly caught by bottom trawlers operating along the inshore waters between 20 and 80 m depths. In addition, large pelagic sharks (*Carcharhinus* spp.) weighing up to 250 kg were occasionally landed by large mechanized vessels operating hook and line at 50–80 m depths. However, in recent times legislative ban on hook-and-line fishing has probably reduced the landings of these sharks. At present, these fishes are rarely caught in purse seines.

5.5. Discussion

The present observations indicated that a total of 9 species represent Goan inshore fishing grounds. Among these, only three species namely *S. laticaudus, C. griseum* and *H. walga* were found to be more frequent in their occurrence. Published literature (Froese & Pauly, 2012) suggested that the above species were common inhabitants of estuarine and inshore shelf waters across the Indo-Western Pacific region. Further, the present study area along the west coast of India is highly productive (Madhupratap *et al.*, 2001) and supports wide array of prey items consisting of demersal teleosts and epibenthic invertebrates (Ansari *et al.*, 1995; Padate *et al.*, 2010a, 2010b). The observed frequency of occurrence of these fishes in trawl catches indicated that they were subjected to intensive fishing. The available data on the fishing effort suggested that there has been a considerable rise in the number of boats operating along the PFZ in this region (Padate *et al.*, 2009; Department of Fisheries, Government of Goa, 2011). It is mandatory to note that the other seven species were rare in abundance and occurred only in trawl catches operated in the vicinity of submerged rock reefs. It is apparent that these species preferred such habitats (Froese and Pauly, 2012) and stray individuals might have been incidentally trapped in the trawl net. The inherent biological traits such as slow growth and maturity, low fecundity and slow doubling time (Hoenig and Gruber, 1990; Stevens *et al.*, 2000; Frisk *et al.*, 2005; Froese and Pauly, 2012) might be the cause of their low abundance in the tropical coastal waters. The absence of the hammerhead shark *S. zygaena* in the inshore waters was noteworthy as it is one of the highest contributors to the elasmobranch fishery of the region. This implies that it inhabits coastal waters beyond 30 m depth.

Higher elasmobranch diversity observed in the present investigation as compared to earlier published literature (Prabhu and Dhawan, 1974; Ansari *et al.*, 1995) could be due to intensive sampling of various habitats (estuaries, mangroves, submerged rocky patches, coral reefs and near shore waters).

Quantitative analysis of the trawl catches revealed that the elasmobranchs contributed only 0.97 % by weight, which could be attributed to the capture of juveniles of these organisms. The inshore fishing grounds off Goa serve as the primary nursery areas for juveniles of elasmobranchs (Ansari *et al.*, 1995). Further, their reduced abundance suggests that bottom trawlers are mostly designed to trap demersal prawns, whereas elasmobranchs form an incidental catch due to their ecological niche (Stobutzki *et al.*, 2001). A comparative analysis of the present data with earlier reports (CMFRI, 1979; Kurup *et al.*, 1987; Srinath *et al.*, 2006) suggested that the elasmobranchs' contribution in recent years was distinctly less to the overall trawl catches. This could be due to increased fishing effort as evidenced by the number of trawlers operating in this area, which are responsible for indiscriminate removal of juveniles of these species. Simultaneously, the data generated by the CMFRI is mainly based on the landings from all fishing gears (trawlers, purse seines, long line and gill net).

Analysis of temporal variations using ANOVA did not reveal any significant differences between the seasons. It appears that all the three common elasmobranchs (*S. laticaudus, C. griseum* and *H. walga*) were residents of this region. In addition, their frequency of occurrence in the inshore and estuarine hauls suggested that they navigate regularly between these waters. Further, the lack of seasonal differences in their occurrence could be attributed to minor fluctuations in the water temperature ($\mu = 28.86 \pm 1.14$ °C). However, the observations made on the elasmobranch landings from north and south Goa showed marked differences. The northern part of the present study area is characterized by the presence of large estuaries, whereas the absence of a large estuary in the southern part highlights reduced fresh water intrusion in adjacent coastal region. This implies that owing to influence of fresh water influx and the transient nature of population during most of the year, the elasmobranchs landing was less in the northern region. On the other hand, less influx of fresh water in the southern region yield higher catches along the region. Published reports (Froese and Pauly, 2012) suggest that most of the presently recorded elasmobranchs undertake amphidromous migration.

Analysis of size class among the observed elasmobranchs indicated that juveniles dominated the population during most of the sampling duration, except December-January, suggesting that the inshore region functions as perennial nurseries for young-of-the-year and juveniles (Ansari *et al.*, 1995).

The analysis of the degree of fullness of gut content revealed low proportion of empty guts in *S. laticaudus* suggesting higher feeding intensity as compared to *C. griseum* and *H. walga*. Relatively high I_{RI} values for teleosts in the elasmobranch diet were influenced by I_{RI} data of *S. laticaudus* and *C. griseum*. The dominance of natantian decapods in the diet of *S. laticaudus* along with comparable proportion of teleosts suggested that it is a non-selective predator. It is essential to note that the inference drawn here could be biased as most of the analyzed samples were juveniles. Devadoss (1989) suggested that post-parturition, when the fishes are unable to move fast owing to limited strength, they feed on epibenthic fishes and invertebrates. On the other hand, high proportions of a single prey group (clupeoid fishes and cephalopod molluscs) observed in the case of *C. griseum* and *H. walga,* respectively suggested that these species are specialized feeders. Further, high proportions of crustaceans and pelagic teleosts in the diet of *S. laticaudus* and *C. griseum* suggested a bentho-pelagic mode of foraging, whereas the dominance of decapods and squids in the ray diet suggested that it is an epibenthic feeder. Elasmobranchs are known to adapt to various feeding strategies depending upon the type and degree of specialization in respect of habitat, prey items and morphology (Wilga *et al.*, 2007).

Gut content analysis of different size groups suggested that juveniles of *S. laticaudus* preferably fed on small crustaceans (Mysis and small sized *Miyakella nepa*), medium sized individuals fed on a mixed diet of large crustaceans (prawns and *M. nepa*) and variety of teleosts, whereas adults preferred teleosts. A similar observation made by Abdurahiman *et al.* (2010) indicated that juveniles mostly fed on epibenthic crustaceans and slow moving organisms whereas adults fed on benthic and pelagic teleosts. It is known that carnivorous fishes become more ichthyophagous with size and age (Renones *et al.*, 2002). This could be attributed to the differences in locomotion and ability to catch prey at different life stages (Devadoss, 1989) suggesting a tendency towards an ontogenic shift in the diet.

Diet breadth (*B*) analysis for the above three species suggested that they were generalist feeders, which consumed a wide array of prey items including penaeid prawns, stomatopods, clupeoid fishes and cephalopods. Published literature (Ellis *et al.*, 1996; Raje, 2003; Navia *et al.*, 2007; Gutteridge *et al.*, 2011) suggested that epibenthic crustaceans, cephalopod molluscs and teleosts were the common prey items of elasmobranchs worldwide.

Diet overlap between species is related to the degree of competition among organisms under conditions of limited resource availability (Odum, 1971). High percentage of diet overlap between *S. laticaudus* and *H. walga* suggested that both the species were generalist feeders of epibenthic crustaceans. However, despite occupying similar trophic levels, the low degree of diet overlap between *S. laticaudus* and *C. griseum* suggested that availability of wide array of prey items could have resulted in resource partitioning among these species (Burrell, 1992). Secondly, differences in mouth morphology, dentition and / or feeding behaviour may influence the degree of competition towards resource utilization (Scrimgeour and Winterbourn, 1987).

The meagre contribution of elasmobranchs to the total marine fish landings of Goa during 1969–2004 despite the increased fishing effort suggests the absence of an organized elasmobranch fishery off Goa. The reported figures could be inaccurate as elasmobranchs form incidental by-catch of bottom trawlers, purse seines and gill nets, and depending on their size, they are either utilized or discarded. An inverse relationship between the total marine fish landings and elasmobranch landings suggested that much of the fishing effort was concentrated towards the exploitation of LTL (sardines, mackerels, prawns) and other HTL fishes (tuna, perch-like fishes, flatfishes). The fishing effort in terms of mechanized vessels operating along the Goan shelf waters has increased from only four vessels in 1963 to 1152 in 2004 (Department of Fisheries, Government of Goa) suggesting that the expansion of marine fishery might have resulted in exploration of deeper waters (> 40 m depth), which support substantial stocks of HTL and LTL organisms.

Among the three groups listed by the CMFRI namely "sharks", "skates" and "rays", the former dominated the elasmobranch landings during the post-mechanization period. This is mainly due to the contribution of trawlers, purse seines and gill nets those harvested large quantities of *S. laticaudus* and *S. zygaena* at 30-50 m depths off Goa. On the other hand, relatively meagre catches of batoid fishes during the above period may be attributed to discarding of under-sized juveniles back into the sea, owing to lack of commercial value (personal observation). Secondly, there is no record of the discarded fraction of the elasmobranch by-catch that resulted in poorly documented batoid fish catches. Bonfil (1994) opined that lack of authentic information on biological aspects of elasmobranch by-catch across the globe stemmed out of inadequate recording of elasmobranch catches.

The decreasing trend of elasmobranchs and LTL fishes with a simultaneous increase in other HTL fishes during 1969–2004 suggested shift in the fishing effort. Statistically significant variations in trends of these resources during 1969–1979 suggested that although the quantum of fishing with traditional crafts and gears did not vary substantially, further expansion of the mechanized fishery during this period led to increased harvesting of HTL fishes from deeper waters (up to 80 m depth). The recent catch trends (1979–2004) displayed a decrease in elasmobranchs and other HTL fishes with a simultaneous increase in LTL fishes that resulted in decrease in the Marine Trophic Index along this region (Bhathal and Pauly, 2008).

Despite the increase in fishing effort in the shelf waters (30–80 m depths) that supported the bulk of the elasmobranch landings (personal observation), there was no increase in their catches corresponding to increase in HTL fishes (Figure 5.5) suggesting the role of the biological attributes of these species. The 38 elasmobranch species listed by the CMFRI as bulk contributors towards the elasmobranch fishery off the Southwest coast of India are known to be long-lived with slow growth rate, late maturity and low fecundity (Raje *et al.*, 2007). All the above attributes make these species highly vulnerable to the ever-increasing fishing effort. Most of the individuals caught in demersal fishing gear are young-of-the-year and juveniles, which are discarded back into the sea and whose recruitment to the coastal ecosystem depends on their survival rate. However, there is no documentation of survival of these under-sized individuals. Further, there is no assorted data on species and gear available for landings of large sharks.

5.6. Conclusion

It is apparent from the present investigation that the productive coastal waters provide a potential habitat for the juvenile population. However, indiscriminate fishing by bottom trawlers along the coastal fishing grounds result in incidental trapping of juveniles that are subsequently discarded, thereby putting tremendous pressure on their population processes. The dietary analysis of the elasmobranchs suggest a clear ontogenic shift, however more comprehensive data is needed to elucidate this aspect. It is inevitable that continuous monitoring of these communities that are subjected to such elevated levels of exploitation would generate more comprehensive database and enable a better understanding of their biological attributes. These, in turn, would assist in addressing specific issues pertaining to sustainable harvest and management of these resources.

Chapter 6.

Seasonal variation in habitat selection and catch trends of sciaenids.

6.1. Introduction

The family Sciaenidae represents a strongly provincialized worldwide group of near shore fishes containing some 270 extant species (Nelson, 1994). This family is confined to shallow coastal and estuarine environments with few freshwater taxa, whereas, open ocean regions and cold temperate zones are effective barriers to the distribution of this group (Schwarzhans, 1993). Some species of family Sciaenidae are localized while others have wide range of distribution (Lal Mohan, 1991).

Along the Indian coast, extensive work has been carried out regarding population dynamics, taxanomy, size class and other aspects of sciaenids (Talwar, 1973; Lal Mohan, 1982; Vivekanandan *et al.*, 2005). Most of these studies are based on single species and restricted to population and fishery. Comprehensive studies pertaining to their distribution patterns and catch trends have been rarely attempted. In addition to the above, the information related to the seasonal variations in abundance (Ansari *et al.*, 1995) and size range distribution (Joseph and Jayaprakash, 2002) are very scanty.

The coastal bays and estuaries of Goa, Central west coast of India are among the most productive habitats used by a variety of fishes and invertebrates. The demersal fishery resources of Goa include benthic fishes and invertebrates (Prabhu and Dhawan, 1974; Ansari *et al.*, 1995), among which the sciaenids constitute a major group that contribute around 10% to the total demersal fish catches of the region (CMFRI, 2012).

Against this background, the present investigation attempted to address the following questions:

1. Are there any significant spatio-temporal variations in the abundance and diversity of sciaenids off Goa?
2. Does habitat play a role in determining the distribution of these fishes?

3. Are there any variations in the sciaenid catches from the region over the last thirty five years, and what are the probable implications of such variations for the sciaenid population?

6.2. Methodology

Size classes were determined by comparing the Total length (TL) of the specimens with published values of L_m (mean length at first maturity) from Fishbase (Froese and Pauly, 2012). Sex ratio was defined as the number of males to females.

. In addition, data on sciaenid fish landings and fishing effort (number of mechanized vessels) for Goa from 1969–2004 (CMFRI, 2012) were analyzed.

6.3. Results

6.3.1. Species composition

Altogether fourteen species belonging to six genera of the family Sciaenidae were recorded from the trawl catches taken along the near shore waters off Goa (Table 6.1). Relative abundance values were highest for *Otolithes ruber* (47.23 %) followed by *Johnius borneensis* (18.60 %), *Otolithes cuvieri* (16.92 %) and *Johnius dussumieri* (6.18 %); the values for the remaining ten species were less than 5 % each (Table 6.1). In addition, *O. ruber* (74.00 %FO) was the most frequently occurring species followed by *J. borneensis* (41.00 %), *O. cuvieri* (31.01 %) and *J. dussumieri* (11.30 %); % FO of the remaining ten species was less than 10 % each (Table 6.1).

6.3.2. Seasonal variations – Total sciaenids

Analysis of temporal variations revealed that sciaenid abundance ($\alpha = 0.05$, $P= 0.03071$, Table 6.2) and weight ($\alpha = 0.05$, $P = 0.1426$, Table 6.3) were significantly

Table 6.1. Species composition of family Sciaenidae along the coast of Goa, west coast of India

Sl. No.	Species	(N)	Relative abundance	Frequency of occurrence (%)	Size range (cm)	Sex ratio (M:F)	L_m(cm)	J:A (%)
1	*Daysciaena albida* (Cuvier, 1830)	2	0.079	0.69	12	0:100	23.3	100:0
2	*Dendrophysa russelii* (Cuvier, 1829)	4	0.15	1.40	8-14	50:50	11.5	50:50
3	*Johnius amblycephalus* (Bleeker, 1855)	36	1.42	8.00	3-10	50:50	15.0	100:0
4	*Johnius belangerii* (Cuvier, 1930)	36	1.23	2.10	7-19	44:56	9.0	17:83
5	*Johnius borneensis* (Bleeker, 1851)	470	18.60	41.00	5-18	53:47	15.9	71:29
6	*Johnius carutta* Bloch, 1793	38	1.50	4.80	10-20	85:15	14.0	79:21
7	*Johnius coitor* (Hamilton, 1822)	42	1.66	4.80	8-22	86:14	10.6	45:55
8	*Johnius dussumieri* (Cuvier, 1830)	156	6.18	11.30	5-20	45:55	11.5	18:82
9	*Johnius elongatus* LalMohan, 1976	64	2.53	9.00	3-20	38:62	18.5	71:29
10	*Kathala axillaris* (Cuvier, 1830)	18	0.71	3.40	6-16	56:44	16.9	100:0
11	*Nibea maculate* (Bloch & Schneider, 1801)	2	0.079	0.69	5-15	0:100	18.0	100:0
12	*Otolithes cuvieri* Trewavas, 1974	436	16.92	31.01	5-30	53:47	23.3	96:4
13	*Otolithes ruber* (Bloch &Schneider, 1876)	1198	47.23	74.00	5-34	55:45	22.6	79:21
14	*Pennahia anea* (Bloch, 1793)	54	2.14	4.90	5-18	57:43	14.0	64:36
	Total sciaenids	**2256**	-	-	-	**54:46**	-	**78:22**

Table 6.2. Seasonal variation in sciaenid abundance using one way ANOVA (α = 0.05)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	424.99	1	424.99	4.7624	0.030709	3.9068
Within Groups	12850.25	144	89.24			
Total	13275.24	145				

Table 6.3. Seasonal variation in sciaenid weight using one way ANOVA (α = 0.05)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	0.02266	0.1426	2.9486
Within Groups	36396.33	144	1654.37			
Total	36433.83	145				

Table 6.4. Spatial (Habitat wise) variation in sciaenid abundance using one way ANOVA (α = 0.05)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	183.7802	1	183.7802	3.61351	0.0593	2.739735
Within Groups	7527.16	148	50.85919			
Total	7710.94	149				

higher in the pre-monsoon than the post-monsoon season (Figure 6.1a, b). An exception to this trend was observed during post-monsoon, 2009 (Figure 6.1a), due to the occurrence of large number of juveniles in December, 2009. The dominance of juveniles in December, 2009 is validated by the lesser weight of sciaenids despite higher abundance during this season.

6.3.3. Seasonal variations - Species wise

Analysis of seasonal variations in species abundance revealed that *O. ruber*, *O. cuvieri*, *J. borneensis*, *J. elongatus* and *J. dussumieri* occurred regularly in both pre-monsoon and post-monsoon seasons (Figure 6.2). All the above species displayed comparatively higher abundances during the pre-monsoon than the post-monsoon season (Figure 6.2). Exceptionally, the abundances of three species namely *O. ruber*, *J. borneensis* and *J. elongatus* were the highest during post-monsoon 2009. *Pennahia anea* occurred only during the post-monsoon season, except during pre-monsoon 2011. In addition, *J. amblycephalus*, *J. carutta* and *Kathala axillaris* occurred intermittently throughout the study period. The trends observed suggest that species richness was higher during the pre-monsoon than the post-monsoon season.

6.3.4 Spatial variations – Habitat wise

Total sciaenid abundances were observed to differ significantly between the sandy and rocky habitats (ANOVA, $\alpha = 0.05$, $P = 0.0593$, Table 6.4). Sciaenid catches were comparatively higher in rocky habitats during the pre-monsoon season. On the other hand, their abundances were comparatively higher in sandy habitats during the post-monsoon season, except post-monsoon, 2011 (Figure 6.3a). Analysis of sciaenid weight data suggested that weight was higher in the rocky than the sandy habitat

Figure 6.1. Seasonal variation in (a) abundance (N/h) and (b) weight (Kg/h) of sciaenids during the present study (Pre: Pre-monsoon; Post: Post-monsoon)

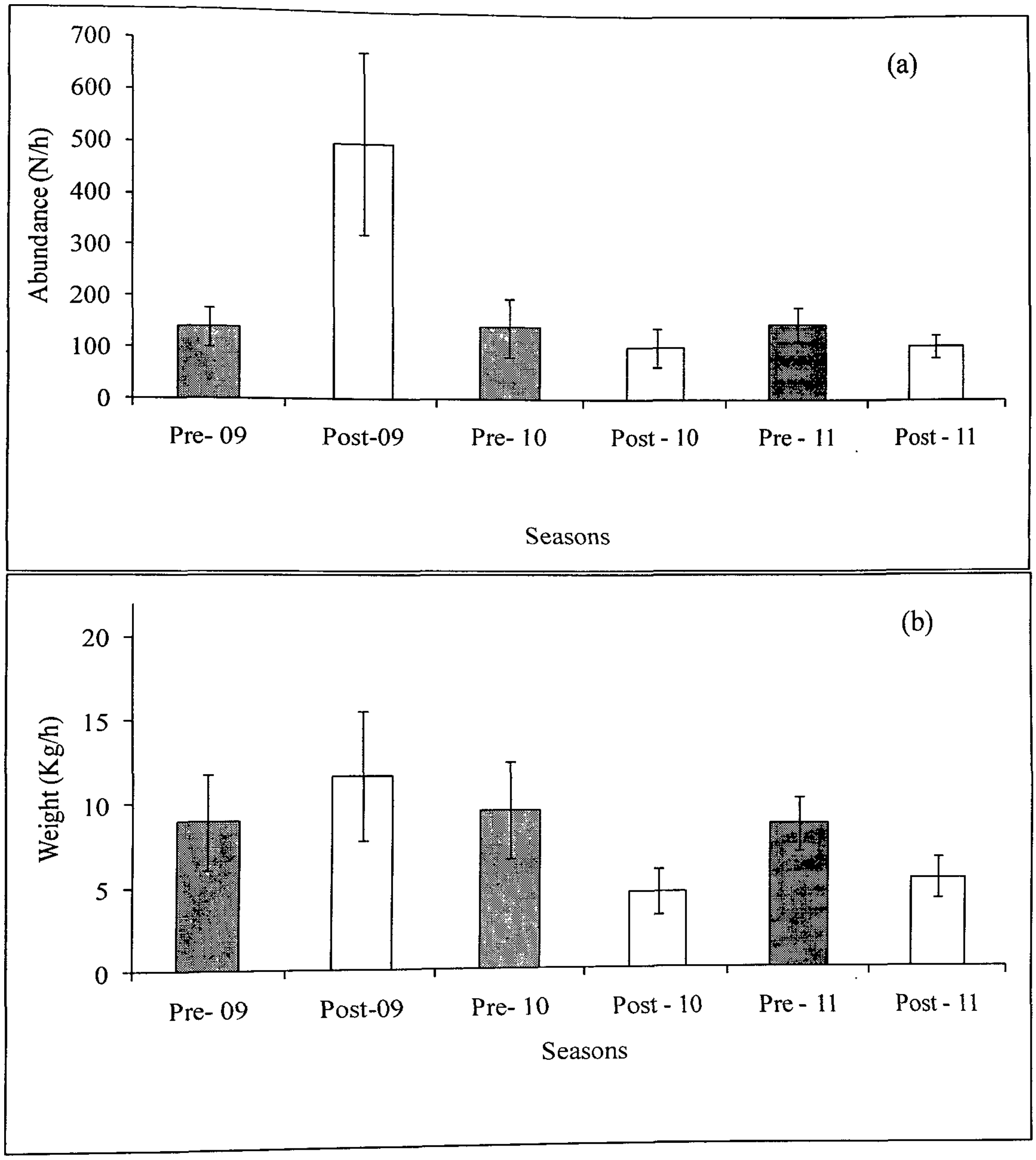


Figure 6.2. Seasonal variation in abundance of different species of sciaenids during the present study (2009 – 2011)

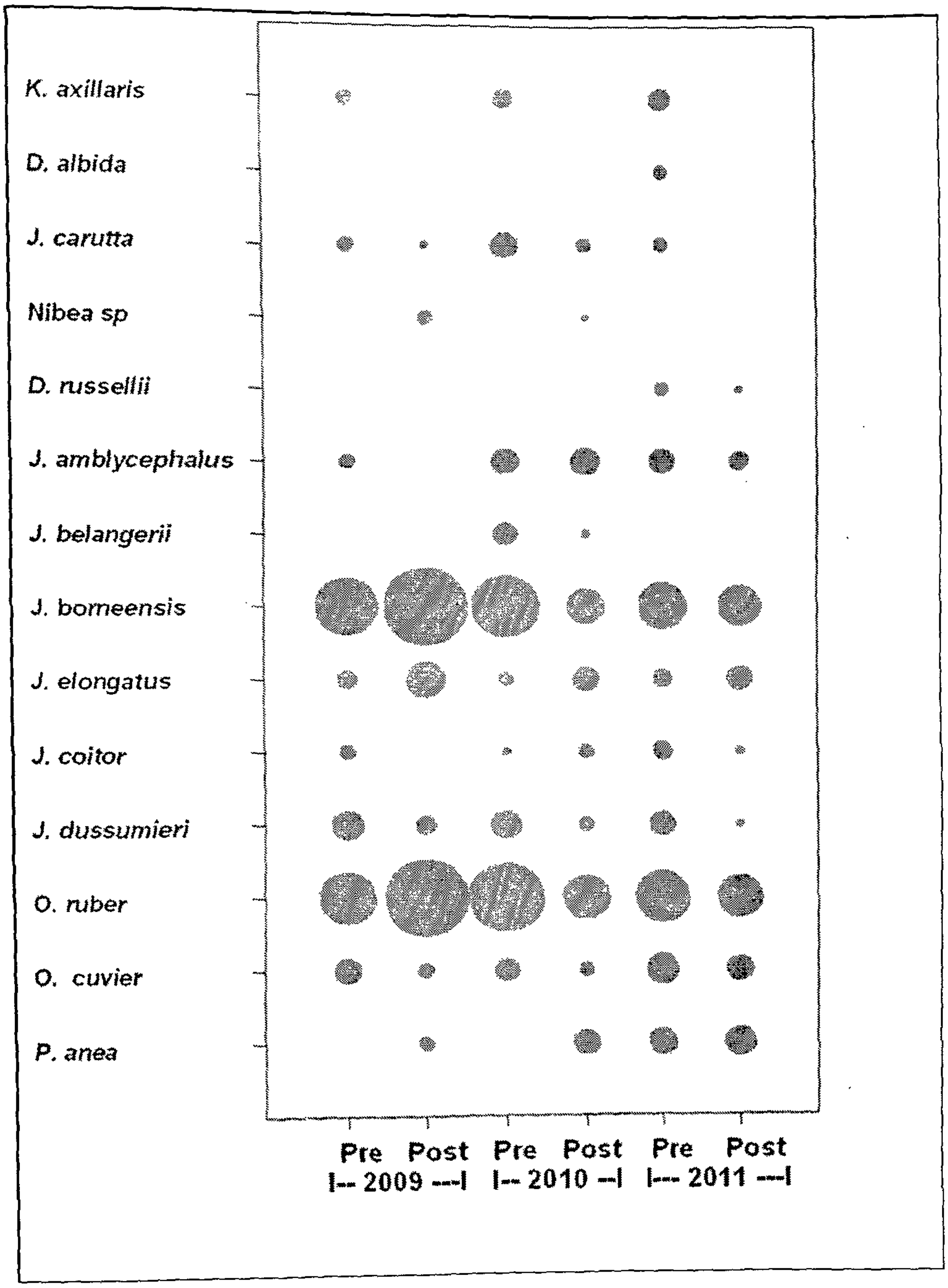
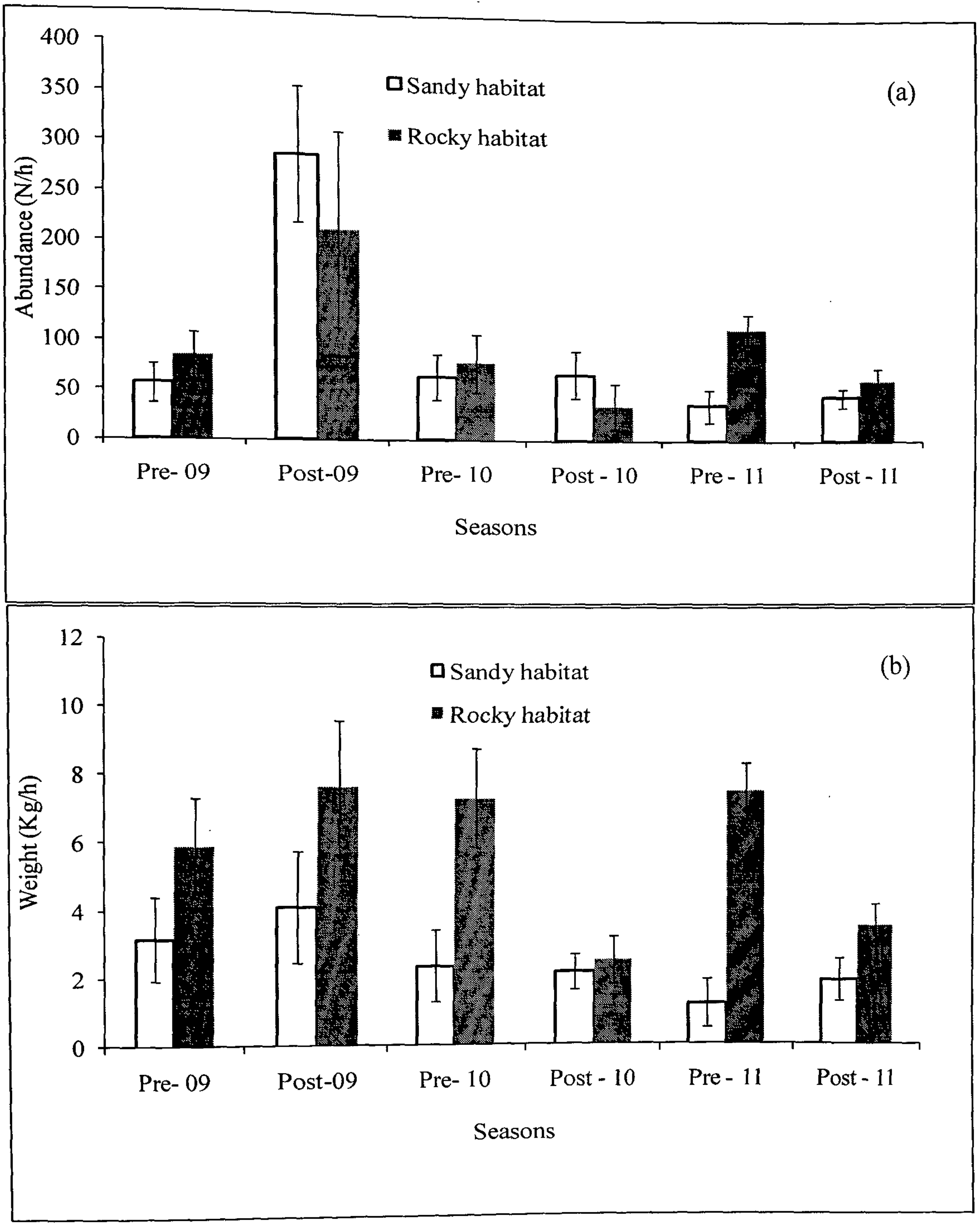


Figure 6.3. Spatio-temporal variations in (a) abundance (N/h) and (b) weight (Kg/h) of sciaenids from the study area (Pre: Pre-monsoon; Post: Post-monsoon)



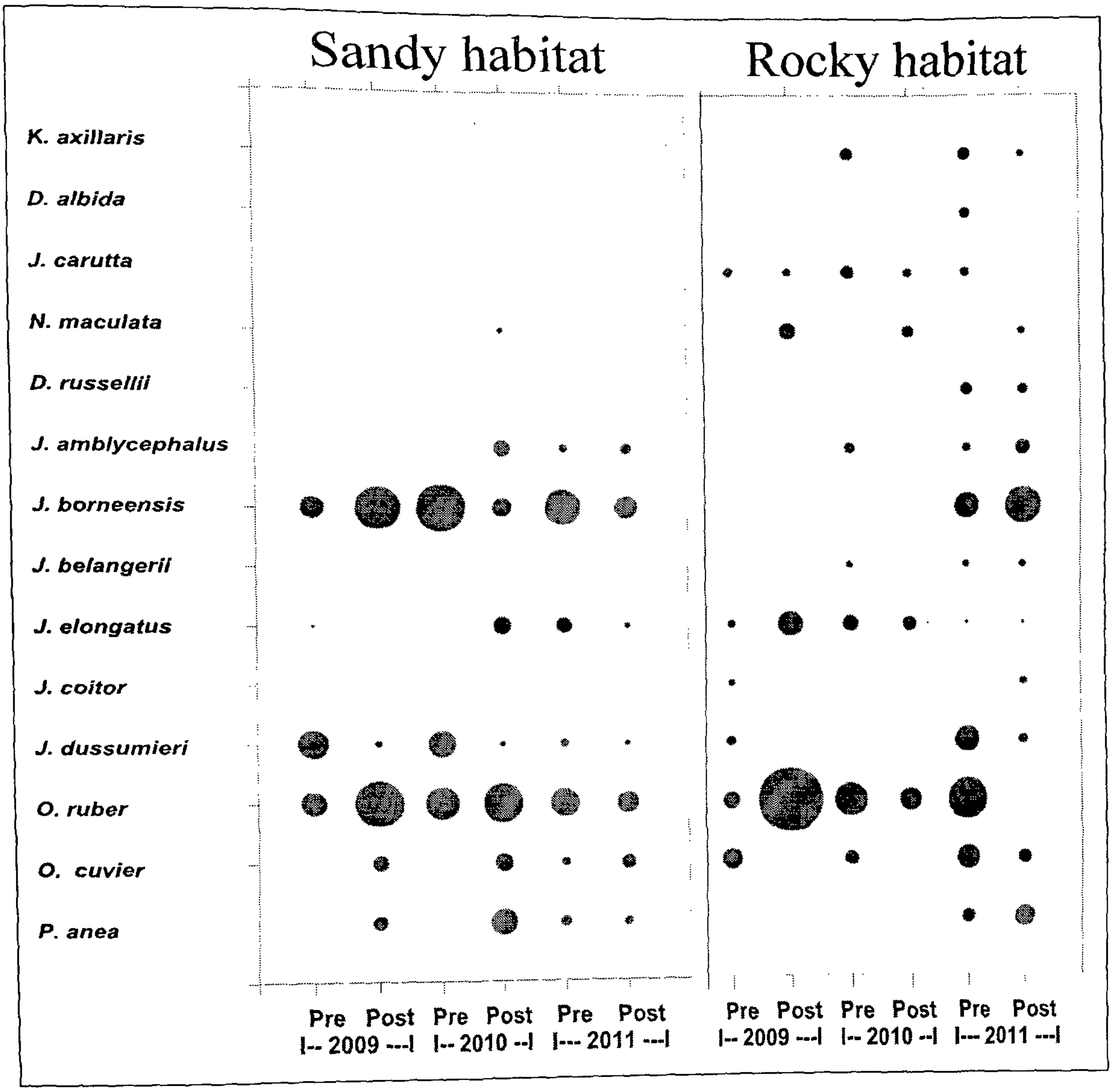
throughout study period (Figure 6.3b). Further, the observations made on the relative importance of occurrence of different size groups suggest that juveniles and adults occurred in high numbers along sandy and rocky shores respectively as evidenced by high abundance coinciding with low weight and vice versa (Figure 6.3a, b).

Analysis of spatial variations in the species composition of sciaenids revealed that all the fourteen species occurred in rocky habitats, whereas only eight occurred in the sandy habitats (Figure 6.4). Among these, five species namely *Nibea maculata*, *J. carutta*, *J. coitor*, *J. belangerii*, *Daysciaena albida* and *K. axillaris* occurred only in rocky habitats (Figure 6.4). Season wise segregation of the above data revealed that *O. ruber*, *O. cuvieri*, *J. borneensis* and *J. dussumieri* occurred in sandy habitat during all the seasons, whereas only *O. ruber* and *J. elongatus* occurred in the rocky habitat during all the seasons. *Pennahia anea* was observed in the sandy habitat mostly during the post-monsoon season (except pre-monsoon, 2011), whereas its occurrence in the rocky habitat was intermittent (Figure 6.4).

6.3.5. Size classes

Morphometric measurements of sciaenids revealed specimens ranging from 5–34 cm TL. Their comparison with published L_m values revealed that 78 % of the specimens were juveniles and the remaining 22 % were adults. Species wise data (Table 6.1) revealed that *J. belangerii*, *J. dussumieri* and *J. coitor* were dominated by adults (83, 82 and 55 % of total numbers, respectively), whereas *O. cuvieri*, *O. ruber*, *J. carutta*, *J. borneensis*, *J. elongatus* and *P. anea* (96, 79, 79, 71, 71 and 64 % of total numbers, respectively) were dominated by juveniles. In addition, *J. amblycephalus* and *K. axillaris* comprised exclusively of juveniles (Table 6.1).

Figure 6.4. Temporal variations in species abundance of sciaenids among sandy and rocky habitats



6.3.6. Sex ratio

Sex ratio for all the fish specimens was 54:46. Species wise sex ratios are provided in Table 6.1.

6.3.7. Catch trends (1969 – 2004)

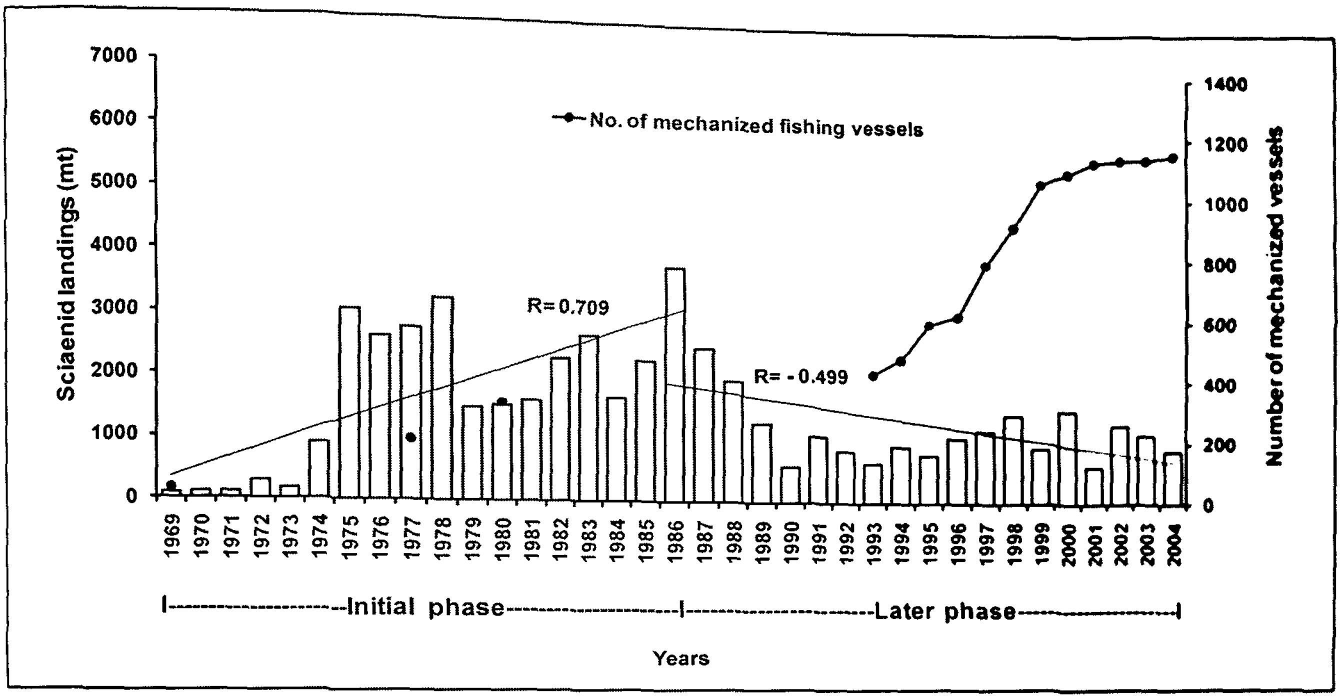
Annual fish landing data for Goa coast from 1969–2004 (CMFRI) revealed that sciaenid catches were highly variable (1432.20 ± 951.12 mt) during the above period (Figure 6.5), and their contribution to the total marine fish landings of the region ranged between 0.26 and 12.09 %. Analysis of their trends revealed significant increase in their landings (R = 0.709) during the initial phase of post-mechanization (1969–1986). This was followed by gradual decrease in the landings (R = 0.499) during 1986–2004, which was marked with fluctuating trends (Figure 6.5). Data on fishing effort in terms of number of fishing vessels operating off Goa was patchy and reveals 1200 % increase in the fishing effort during 1969–1986, followed by 300 % increase up to 2004 (Figure 6.5).

6.4. Discussion

Sciaenids are among the major groups of demersal fishes that contribute approximately 10–12 % to the total marine fish landings of Goa (Department of Fisheries, Goa, 2011). Despite the commercial importance of sciaenids, only few studies focus on their species composition and temporal variations (Prabhu and Dhawan, 1974; Ansari *et al.*, 1995), indicating lack of information on the spatio–temporal variations in the distribution and population dynamics of sciaenids.

An assessment of species composition suggested sciaenids to be a highly speciose group comprising 14 species. Three species namely *J. amblycephalus, J. coitor* and *J. carutta* are reported for the first time from Goa coast. Published literature from Goa

Figure 6.5. Catch trends of sciaenid landings (1969 – 2004) and the fishing effort off the Goa coast



reported only eleven species of sciaenids from the bay-estuarine waters in the region (Talwar, 1973; Prabhu and Dhawan, 1974; Ansari *et al.*, 1995). The greater number of species observed during the present study could be attributed to a high fishing effort of 165 hours involving intensive sampling (96 trawls) that encompassed diverse near shore and estuarine habitats. Fishbase (Froese and Pauly, 2012) suggested that these species are among the common inhabitants of estuarine and near shore shelf waters in the Indo-Western Pacific regions.

Estimation of relative abundance of different species revealed *O. ruber* to be the most abundant species followed by *J. borneensis* and *O. cuvieri. Otolithes ruber* is an inhabitant of shallow coastal waters (Froese and Pauly, 2012) and the high catches off Goa coast could be due to sampling in coastal and estuarine waters less than 25 m depth. However, published literature (Lal Mohan, 1991; Apparao *et al.*, 1992; Joseph and Jayaprakash, 2002) reported that *O. cuvieri* was the most abundant species along the west coast of India. The differences in reporting of the dominant sciaenid species off the west coast could be due to the inclusion of data from deeper waters, wherein *O. cuvieri* is more abundant. Low relative abundances (less than 5 %) of other species (Table 6.1) could be attributed to the transient nature of their populations in the shallow coastal waters (Ansari *et al.*, 1995).

Another parameter that determines species distribution is the frequency of occurrence (%FO). *Otolithes ruber* was the most regularly occurring species followed by *J. borneensis, O. cuvieri, J. dussumieri* and *J. elongatus*. This observation suggested that these species are permanent residents of the coastal waters (Ansari *et al.*, 1995). With regards to the other species, low % FO values (less than 10 %) suggested that these species are either quasi-residents of the coastal waters or altogether rare in the coastal ecosystems. Hence, further studies on migration patterns of their life stages will provide a better understanding of the sciaenid assemblages of the region.

Sciaenid abundance and weight varied significantly between the pre-monsoon and post-monsoon seasons, except post-monsoon, 2009. Higher abundances and biomass values during the pre-monsoon season could be attributed to the recruitment of juvenile fishes facilitated by the availability of adequate prey (Ansari *et al.*, 1995). However, the occurrence of large number of *O. ruber* and *J. borneensis* juveniles during December, 2009 may have resulted in higher sciaenid abundance during post-monsoon, 2009. The dominance of juveniles during that period is reflected in the lack of significant increase in weight of sciaenids. In addition, observations also revealed that the occurrence of juveniles was of higher magnitude along the sandy shores as compared to the rocky habitats, suggesting that the juvenile population of sciaenids forage on smaller benthic invertebrates along the sandy habitats and later the adults move to the rocky habitats feeding on larger food items as evident from gut content (Manojkumar, 2008; Abdurahiman *et al.*, 2010).

Assessment of temporal variations of abundance of the sciaenid species suggested that only five out of the fourteen species (*O. ruber*, *O. cuvieri*, *J. borneensis*, *J. elongatus* and *J. dussumieri*) occurred regularly in both seasons. These observations are consistent with the %FO values discussed above, thereby validating that these are the permanent residents of shallow coastal waters. Further, the dominance of juvenile fishes irrespective of the season suggested the occurrence of a perennial recruitment pattern following multiple spawning periods (Joseph and Jayaprakash, 2002; Froese and Pauly, 2012). These fishes undertake amphidromous migration due to their dependence on the estuarine waters as nursery grounds (Blaber *et al.*, 1989). Exceptionally, the dominance of adult fishes among *J. dussumieri* suggested that this species spends its entire life in the coastal waters. On the other hand, the seasonal abundance peaks of *P. anea* (post-monsoon) and *J. amblycephalus* (pre-monsoon) are consistent with slightly low % FO values and suggested that they are quasi-residents in the near shore ecosystems (Ansari *et al.*, 1995; Blaber *et al.*, 1995). Higher species richness during the pre-monsoon season may be attributed to the occurrence of both resident and quasi-resident species (Yemane *et al.*, 2010). Similar variations in the population of demersal fishes have been reported from the coastal waters along the west coast of India (Ansari *et al.*, 1995).

Segregation of species abundance data for the different habitats revealed that rocky habitats supported more species (N=14) as compared to the sandy habitats (N=8). This suggested that the rocky substrata provide large number of niches for wide array of coastal fishes. The marginal differences in species abundances recorded among different habitats with respect to seasons suggested that most sciaenids do not exhibit seasonality in habitat selection due to habitat patchiness and perennial prey availability (Yemane *et al.*, 2010).

Analysis of sex ratio suggested a lack of significant variations, except in the case of *J. coitor* and *J. carutta* where males significantly outnumbered the females.

Analysis of sciaenid catch trends along Goa from 1969 to 2004 suggested that the initial post-mechanization process enabled the expansion of the coastal demersal fishery beyond the conventional 50 m depth region. This facilitated the exploitation of deeper water sciaenid resources up to 80 m depth as evident from the significant increase in landings up to 1986. However, the subsequent decrease in the fish landings despite the elevated fishing effort could be attributed to two factors, sub-surface hypoxia and elevated exploitation. Sub-surface hypoxic conditions (wherein the dissolved oxygen concentration drops below 0.2 $ml.l^{-1}$) in the coastal waters off Goa (Naqvi *et al.*, 2009) coincide with the spawning period of sciaenids (Joseph and Jayaprakash, 2002).

Primarily, sub-surface hypoxic conditions impel the fish to migrate away from the hypoxic regions. Secondly, if the hypoxic conditions develop after the spawning activity, it may result in large scale mortality of eggs (North and Houde, 2004). Recent intensification of the hypoxia phenomenon appears to have probably affected the sciaenid landings, particularly in 2001, and is apparent from the decreased catches during the later phase of the landing trends. The second factor affecting the sciaenid fishery off Goa could be due to the increased fishing effort itself during the later phase. It is construed from the present observations that rapid removal of juvenile fishes could have rendered the coastal sciaenid populations highly vulnerable to sustained fishing pressure. Hutchings (2000) opined that efforts to maximize sustainable yield could result in prolonged declines in fish catches, and that recovery of highly fished stocks could take longer time owing to reduced resilience towards increased fishing pressure.

6.5. Conclusion

The present observations from the near shore fishing grounds off Goa, west coast of India indicated that out of fourteen sciaenid species, five were residents of near shore waters. Sciaenid populations were significantly high in pre-monsoon as compared to the post-monsoon due to the increased recruitment of juveniles facilitated by the availability of adequate prey. Higher species richness in rocky habitats is attributed to the habitat complexity with micro-niches for wide array of demersal fishes. On the other hand, higher abundances in sandy habitats are attributed to high biomass of benthic invertebrates acting as foraging grounds. The analysis of sciaenid catch trends for Goa indicate an initial increase in the landings corresponding to the elevated fishing effort and expansion of demersal fishery to deeper waters (80 m depth). The subsequent reduction in the landings is attributed to the combined effects of coastal hypoxic conditions and elevated fishing pressure on the sciaenid populations. Therefore, it is suggested that further studies involving long-term monitoring of the trawl catches are necessary to improve our present understanding of the issues pertaining to ecological responses of sciaenid populations to coastal phenomena and increased exploitation.

Chapter 7.

Trophic dynamics and diet overlapping of sciaenids

7.1. Introduction

Diet composition studies are vital to interpret community ecology as resource utilization by organisms influences population interactions within a community, and are essential in studies pertaining to the food web, trophic dynamics and resource partitioning (Odum, 1971; Linton *et al.*, 1981). Data on different prey items consumed by fish may eventually result in the identification of stable food preferences, and enable the creation of trophic models as a tool to understand complex ecosystems (Colloca *et al.*, 2010; Gabler and Amundsen, 2010). Published literature on the feeding habits (Sardina and Cazorla, 2005; Hajisamae and Ibrahim, 2008; Hajisamae, 2009; Abdurahiman *et al.*, 2010) and diet overlap (Barrera Oro, 2003; Colloca *et al.*, 2010) of marine fish communities indicates that extensive studies have been carried out in most of the major estuarine and coastal ecosystems. Further, much of the studies on the diet of demersal fishes were restricted to the temperate species (Tyler, 1972; Targett, 1981; Barrera Oro, 2003; Albertsson, 2004; Carmona *et al.,* 2012), whereas those pertaining to the tropical Indian waters, especially on sciaenids are scanty, and generally related to total demersal fish fauna (Abdurahiman *et al.*, 2010). However, no attempt has been made to address trophic interactions among different sciaenid species. The present paper elucidates feeding behaviour, diet spectrum of sciaenids, with emphasis on their diet overlap, feeding guilds and ontogenic shift considering the species available in this region.

7.2. Methodology

7.2.1. Stomach content analysis

Altogether 1284 stomachs belonging to 10 species were examined for diet analysis. Morphological parameters (Standard Length, Total Length) and weights of individual specimens were recorded.

Fish specimens were segregated into three size classes (Small, < 10 cm; Medium, 10-15 cm and Large, > 15 cm). Values of Length at first maturity (L_m) for each species were obtained from Fishbase (Froese and Pauly, 2012) to segregate data into juveniles and adults. Four species namely *Johnius elongatus*, *Johnius belangerii, Kathala axillaris* and *Pennahia anea* were not considered for this analysis due to the unavailability of adequate number of specimens of different sizes.

To study the ontogenic shift and resemblance between different size class, the diet data was examined by means of multi-dimensional scaling (MDS) ordination tool with Bray-Curtis Similarity using PRIMER statistical package version 6.0 (Clarke and Gorley, 2001). Percentage similarity (SIMPER) was used to determine the prey categories which formed the grouping.

Relationship between prey items and size class of sciaenids was investigated by means of Principle Component Analysis (PCA) using CANCO version 4.5 (ter Braak and Smilauer, 1998)

7.3. Results

7.3.1. Feeding intensity

Out of the 1284 stomachs examined for diet analysis (Table 7.1), 32 % of the stomachs were observed to be fully filled, 55 % were partially filled and only 13 % were empty. Further, the vacuity index (VI) varied considerably between species, ranging from 5.56 (*Otolithes ruber*) to 30.0 (*Pennahia anea*; Table 7.1).

7.3.2. Prey selection

Fifty one prey items belonging to different faunal groups such as teleosts, crustaceans, molluscs, annelids and other invertebrates (Table 7.2) were observed.

Table 7.1. Details of diet analysis, %FO for each prey category of different species of sciaenids

Species	*J. dussumieri*	*O. cuvier*	*O. ruber*	*J. borneensis*	*J. carutta*	*J. coitor*	*P. anea*	*J. belangerii*	*J. elongatus*	*K. axillaris*	Total Sciaenids
N	344	60	292	196	92	88	40	48	84	40	1284
VI	18.60	6.67	5.56	10.20	13.04	18.18	30.00	16.67	9.52	12.50	13.00
B_i	0.36	0.52	0.89	0.51	0.32	0.46	0.37	0.50	0.77	0.50	0.52
TL_i	3.9	4.0	4.0	3.0	3.8	3.6	3.9	3.4	3.1	3.2	3.6
N_j	21	10	23	33	08	10	08	08	14	07	51
L_m (cm)	11.50	23.50	22.50	15.90	14.00	10.60	14.00	09.00	18.50	16.90	NA
J:A	38:62	78:22	79:21	69:31	60:40	45:55	64:36	17:83	71:29	90:10	68:32
Prey categories (%FO Values)											
Teleosts	35.34	82.33	40.11	21.27	43.80	22.72	28.57	16.67	38.09	33.33	32.56

Prawns	**50.23**	**20.00**	**58.11**	**38.30**	**00.00**	**54.54**	**88.33**	**59.90**	**61.90**	**86.78**	**56.93**
Stomatopods	01.17	00.00	04.17	02.13	00.00	00.00	00.00	00.00	00.00	00.00	00.75
Crabs	11.62	13.33	29.71	22. 66	00.00	13.63	14.28	16.67	04.76	44.44	18.47
Molluscs	00.00	00.00	00.00	08.51	00.00	00.00	00.00	00.00	04.76	00.00	01.33
Annelids	13.96	00.00	16.67	14.90	47.61	13.63	00.00	00.00	00.00	00.00	10.68
Foraminifera	01.17	00.00	00.00	06.38	00.00	00.00	00.00	00.00	00.00	00.00	00.75
Zooplankton	26.74	26.67	55.83	78.36	28.57	27.27	42.86	16.67	23.80	55.55	39.25
OI	01.17	00.00	00.00	08.51	04.76	04.55	00.00	08.33	00.00	00.00	02.73
Algae	4.65	06.67	04.17	06.38	04.76	04.55	14.30	08.33	09.52	00.00	06.33

N - total numbers of specimens analyzed; VI - Vacuity Index; B_i - Diet breadth; TL_i- Trophic level; N_j - Number of prey items; L_m (cm) - length at first maturity; J:A - ratio of juveniles and adults; OI - Other invertebrates

Table 7.2. Major prey categories and their respective %FO values

Prey items	%FO	Prey items	%FO	Prey items	%FO
Teleosts		**Crabs**		**Zooplankton**	
Leiognathus spp.	0.21	*Portunus pelagicus*	1.04	Calanoid copepod	15.32
Cynoglossus spp.	0.88	*Portunus sanguinolentus*	0.21	*Mysis* sp.	12.90
Thryssa spp.	0.21	Unidentified crab	19.22	Megalopa larva	0.21
Sardinella longiceps	1.78	**Molluscs**		*Lucifer* sp.	1.61
Opisthopterus tardoore	0.83	Unidentified Gastropod	0.47	Unidentified zooplankton larvae	1.32
Johnius spp.	0.41	*Cerithedia* spp.	0.21	Ctenophores	0.21
Stolephorus commersonnii	2.40	Unidentified Bivalve	0.42	*Sagitta* sp.	0.32
Otolithes ruber	0.47	*Dentalium* larvae	0.21	Veliger larva	0.21
Unidentified Clupeid fish	0.35	**Annelids**		*Siphonophore* sp.	2.50

Dussumieria acuta	0.42	Unidentified Polychaete	7.73	Cycloid copepod	2.16
Unidentified telesots	35.11	Annelid larva	1.04	Fish larva	2.06
Parachaeturichthys polynema	0.48	*Lecithoepitheliata* sp.	0.84	Prawn larva	3.00
Prawns		Turbellaria	1.05	*Evidna* sp.	0.42
Acetes indicus	7.70	**Other benthic invertebrates**		**Algae**	
Parapenaeopsis stylifera	1.94	Unidentified Isopod	0.83	Filamentous algae	4.50
Metapenaeus dobsoni	5.40	*Lensia* sp.	0.47	*Coscinodiscus* sp.	1.16
Exhippolysmata ensirostris	0.77	Unidentified Sea urchin	0.63	*Skeletonema* sp.	0.66
Unidentified prawn	41.12	*Obelia* sp.	0.78		
Stomatopods		**Foraminifers**			
Miyakea nepa	0.75	*Globigerina* sp.	0.21		
		Unidentified Foraminifera	0.54		

Among these, large crustaceans (prawns %FO 55.93, crabs %FO 20.47) were found to be the major food items followed by teleosts (%FO 43. 56). Among the crustaceans, *Acetes indicus* (%FO 7.70) and *Metapenaeus dobsoni* (%FO 5.40) were the major prey taxa. Among the teleosts, clupeids such as *Sardinella longiceps*, *Stolephorus commersonnii*, *Opisthopterus tardoore* and *Thryssa* sp. were the major taxa followed by leiognathids and soles (Table 7.2). It was observed that a significant number of the guts examined contained partly digested teleosts and prawns. This rendered the identification of these groups down to the species level difficult. Hence, they were grouped as unidentified teleosts and prawns, respectively. In addition to these, polychaetes, copepods, stomatopods (*Miyakella nepa*) and sea urchins were also found in small quantities in the guts.

Segregation of individual species data revealed that *Otolithes cuvier*, *Johnius carutta* and *O. ruber* preyed mainly upon teleosts with the corresponding %FO values of 82.33, 43.88 and 40.11, respectively (Table 7.1). On the other hand, *P. anea* (88.33), *K. axillaris* (86.78), *J. elongatus* (61.90), *J. belangerii* (59.90), *Johnius coitor* (54.54), and *Johnius dussumieri* (50.23) were found to prefer crustaceans; *Johnius borneensis* preferred zooplankton (78.36; Table 7.1).

7.3.3. Diet breadth

In order to understand the nature of feeding (generalist / specialized), the overall diet breadth computed for sciaenids was 0.52. The maximum diet breadth of 0.89 was observed in *O. ruber* (23 prey items), whereas the minimum (0.32) was observed in *J. carutta* (8 prey items). Although, *J. borneensis* fed on 33 prey items, its diet breadth was less (0.51) owing to the dominance of a few zooplankton species (mysis, copepods) in the diet (Table 7.1). Further, computation of diet breadth (B) with respect to size groups revealed that small and medium sized juveniles, revealed a higher diet breadth than the adults, except in *Johnius coitor* and *Kathala axillaris* (Figure 7.1).

7.3.4. Ontogenic shift

Multidimensional scaling ordination using proportions of ten prey groups observed in three size categories of six sciaenid species showed that they could be segregated into four groups (Figure 7.2) with an overall 40 % similarity. The first group (G1) comprising of small, medium and large individuals of *J. carutta,* showed 60 % similarity among its constituents. The second group (G2) comprising small individuals of *J. borneensis, J. coitor, O. ruber, O. cuvier,* and medium sized *O. cuvier,* and *J. borneensis,* showed 60 % similarity. The third group (G3) comprising medium sized *O. ruber*, *J. coitor*, *J. dussumieri,* and large sized *J. coitor* and *J. borneensis,* showed 60 % similarity. The fourth group (G4) comprising large sized *O. ruber*, *O. cuvier* and *J. dussumieri,* showed 80% similarity. SIMPER analysis revealed that G1 stomachs had greater proportions of annelids and teleosts, and were marked by the absence of prawns, stomatopods and crabs; zooplankton dominated the diets in G2; G3 was characterized by high proportions of prawns; teleosts dominated the diets in G4.

In the PCA biplots, 3 axes explaining 93.04 % of the relationship between sciaenids and their prey categories were extracted (Table 7.3). Prawns, zooplankton and teleosts were the major prey groups determining ontogenic shift among the different size groups of sciaenids. The PCA revealed that small sized individuals were closely related to zooplankton. Exceptionally, large individuals of *J. borneensis* also showed proximity with zooplankton. Medium sized individuals of *J. coitor*, *J. dussumieri* and *O. ruber* showed a close relationship with prawns. Medium sized *J. carutta* showed a close relationship with both zooplankton and annelids. Large sized individuals of *O. ruber*, *O.*

Figure 7.1. Ontogenic shift in the diet breadth of sciaenids

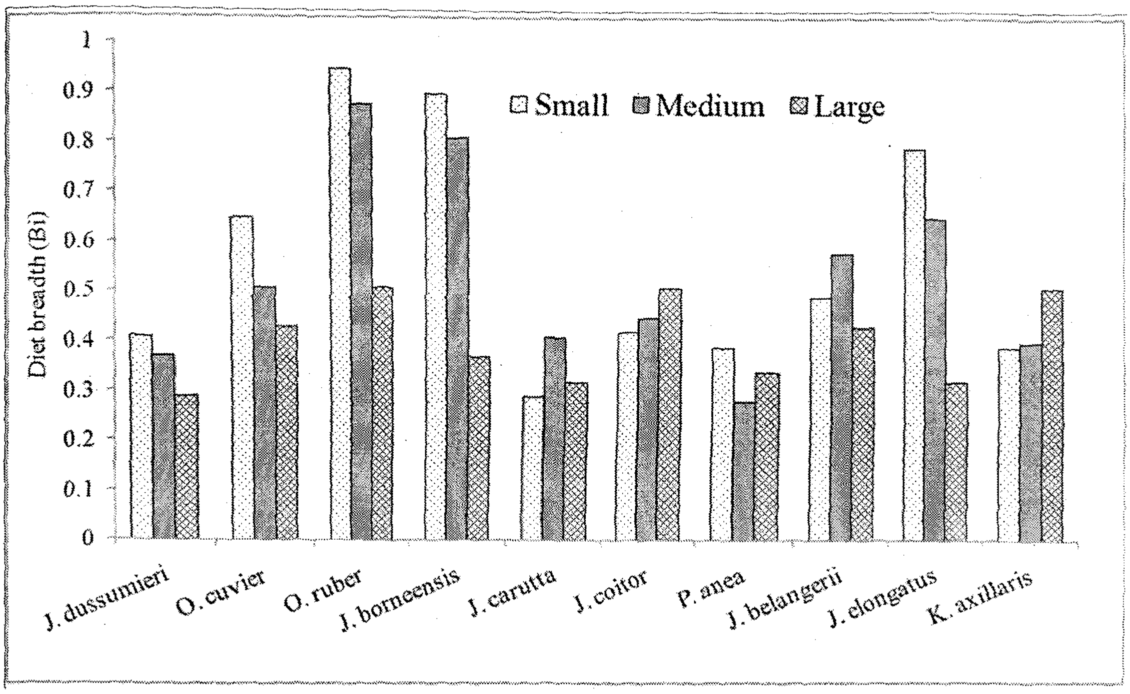
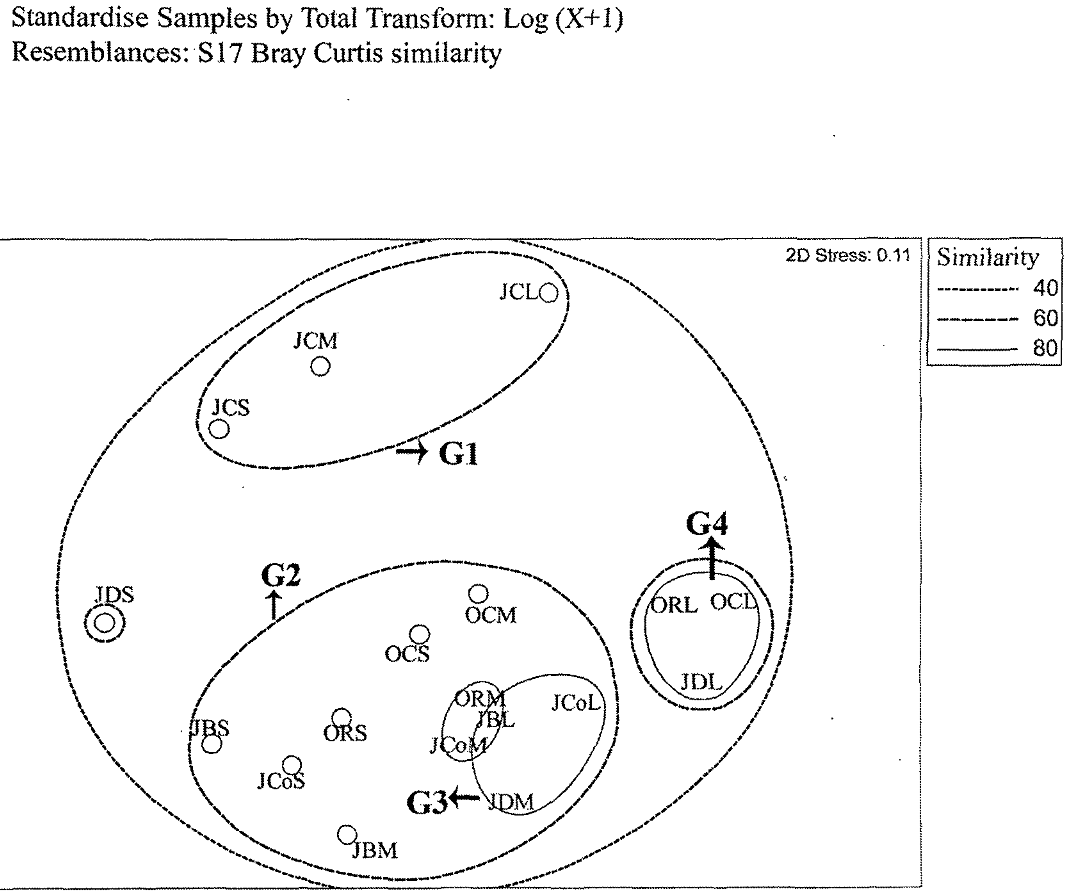


Figure 7.2. Bray-Curtis similarity index: Multidimensional coordination analysis showing the grouping of sciaenids at different similarity levels. JDS, JDM and JDL: *J. dussumieri* small, medium, large: OCS, OCM and OCL: *O. cuvier* small, medium and large: ORS, ORM and ORL: *O. ruber* small, medium and large: JBS, JBM and JBL: *J. borneensis* small, medium and large: JCS, JCM and JCL: *J. carutta* small, medium and large: JCoS, JCoM and JCoL: *J. coitor* small, medium and large, respectively



Standardise Samples by Total Transform: Log (X+1)
Resemblances: S17 Bray Curtis similarity

Table 7.3. Eigen values of Principal Component Analysis for ontogenic shift in diet of sciaenid species

Eigen values	**Axis 1**	**Axis 2**	**Axis 3**
Eigen values	22.53	3.49	2.47
Percentage	73.58	11.415	8.05
Cumulative Percentage	73.57	84.99	93.04

cuvier, *J. dussumieri* and *J. borneensis* were closely related to teleosts. The other prey categories (Figure 7.3) did not wield significant influence on any of the size categories of sciaenids.

7.3.5. Feeding guilds

Cluster analysis using the gut content data enabled to segregate this group into three major guilds namely prawn feeder (A), fish feeder (B) and zoo-planktivore (C) (Figure 7.4). The major guild 'A' comprised of *J. dussumieri*, *P. anea*, *J. elongatus J. belangerii*, *J. coitor* and *K. axillaris*. Guild 'B' comprised *O. ruber*, *O. cuvier* and *J. carutta*. The third major guild 'C' comprised only of a single species *J. borneensis*. *Johnius coitor* and *K. axillaris,* both omnivores, were grouped under the prawn feeder guild. In addition, *J. carutta* was found to feed upon comparable proportions of teleosts and zoo-benthos (polychaetes), hence isolated as zoo-benthivore under the Guild B.

7.3.6. Diet overlap

Altogether, 45 combinations were considered for computation of percentage of diet overlap between the 10 species to assess intra-specific competition, if any. The results revealed that only five combinations namely *J. belangerii* and *O. cuvier* (61.25 %), *K. axillaris* and *J. elongatus* (60.00 %), *P. anea* and *O. cuvier*, (56.78 %), *J. carutta* and *O. cuvier* (54.64 %), and *J. carutta* and *J. borneensis* (55.06 %) displayed significant (> 50 %) diet overlapping (Table 7.4).

7.4. Discussion

Among 14 species of sciaenids only 10 species were considered for diet analysis due to their regular availability. The degree of stomach fullness assessed by Vacuity

Figure 7.3. Principle Component Analysis elucidating the major factors influencing ontogenic shift in diet of sciaenid species

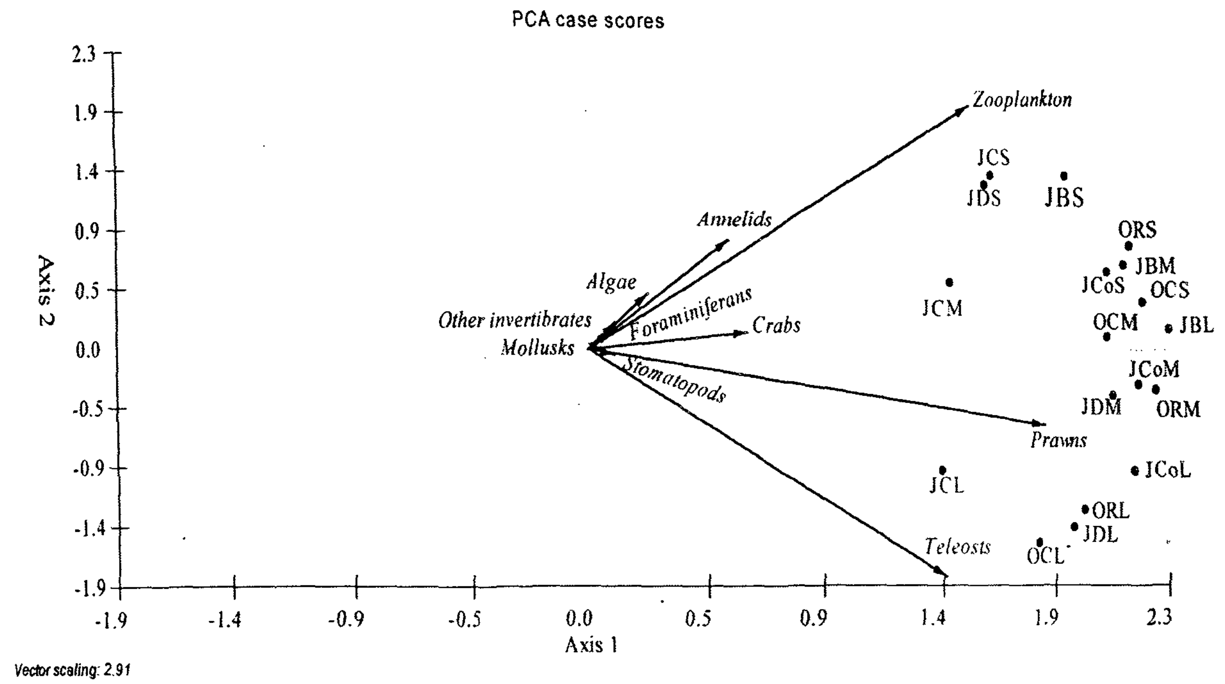


Figure 7.4. Guilds based on feeding behaviour of sciaenids: Prawn feeder (A), Fish feeder (B) and Zoo-planktivore (C)

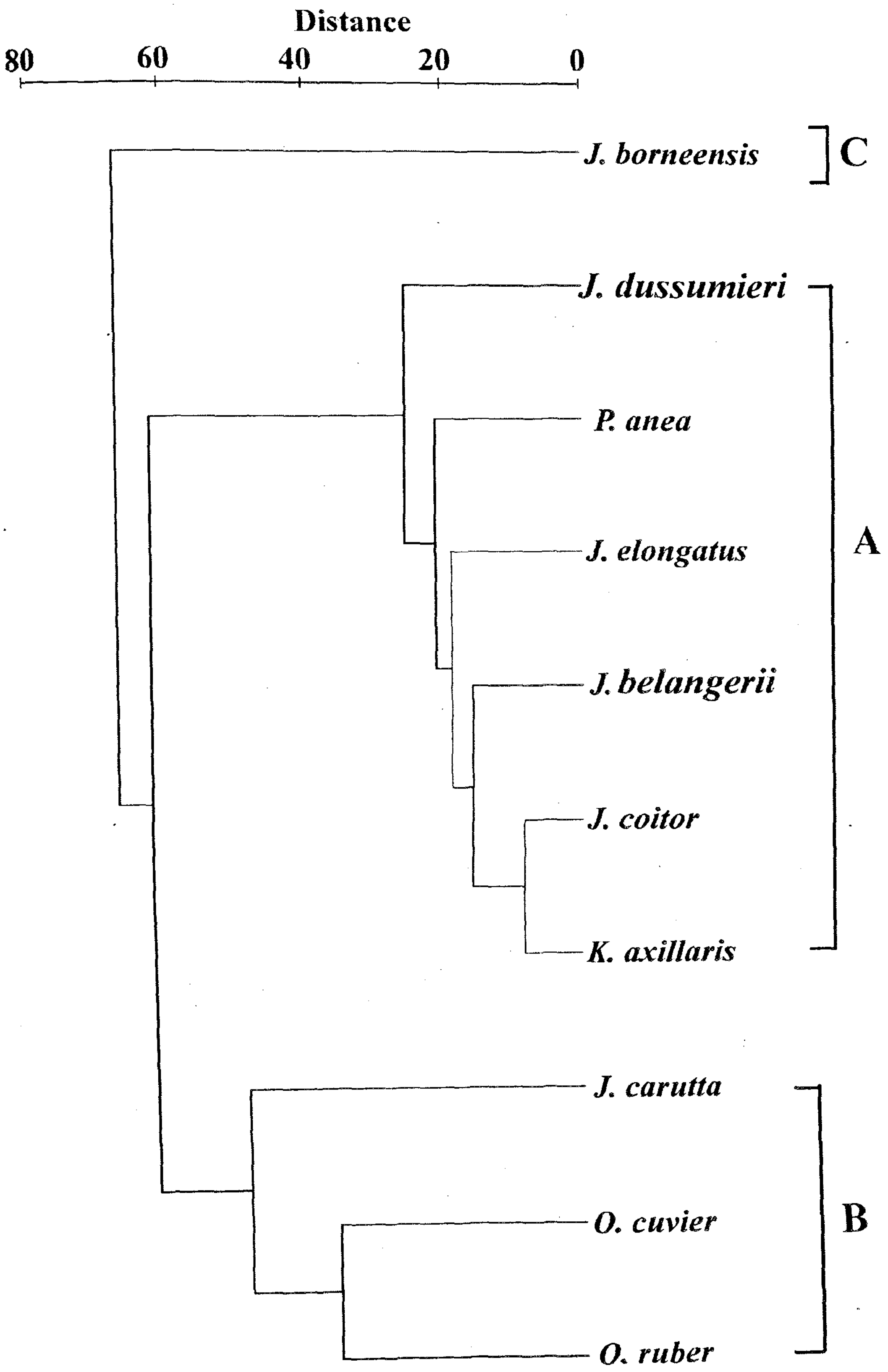


Table 7.4. Matrix indicating percentage of diet overlapping among the sciaenid species

Species	*J. dussumieri*	*O. cuvier*	*O. ruber*	*J. borneensis*	*J. carutta*	*J. coitor*	*P. anea*	*J. belangerii*	*J. elongatus*
K. axillaris	20.32	24.45	23.53	45.00	13.51	30.12	18.07	14.45	60.00
J. elongatus	26.40	38.81	33.64	48.00	14.60	32.60	27.57	40.33	
J. belangerii	22.42	61.25	15.04	35.04	30.00	35.00	18.07		
P. anea	26.45	56.78	23.17	42.80	42.38	42.43			
J. coitor	26.56	37.50	22.15	9.82	38.03				
J. carutta	22.00	54.64	15.04	55.06					
J. borneensis	21.20	45.02	23.53						
O. ruber	29.68	28.09							
O. cuvier	31.43								

Index (VI) revealed that feeding intensity was high among sciaenids (Table 7.1), except *Pennahia anea* (VI = 30), suggesting greater food intake. This was evident by the occurrence of diverse prey items (N = 51; Table 7.2). However, a close look at the data suggested that they prefer to feed on variety of prawns (%FO 56.93), and zooplankton (%FO 39.25) followed by teleosts (%FO 32.56). Published literature (Nasir, 2000; Manojkumar, 2003; Abdurahiman *et al.*, 2010) indicated that sciaenids are predominantly carnivorous that feed on teleosts, shrimps and other crustaceans. Additionally, a small fraction of the diet also comprised of annelids, algae, foraminifera and sea urchins (Table 7.2). These observations suggest that sciaenids inhabiting shallow coastal areas forage upon sediment communities inhabiting the sediment-water interface. Further, the occurrence of algae and other invertebrates could be attributed to non-perceptive feeding in the turbid coastal waters (Fennessy, 2000). Detailed analysis of the observed prey items (%FO) suggested that large crustaceans (*Metapenaeus dobsoni, Acetes indicus*, crabs and unidentified shrimps), teleosts (*Sardinella longiceps, Stolephorus commersonnii*) and zooplankton (copepods, mysis) were the major prey items. Further, it was observed that most of the sciaenid species fed on prawns, with the exception of *Otolithes cuvier* and *Johnius carutta,* which preferred teleosts, and *J. borneensis,* a zooplanktivore (mysis and prawn larvae).

Analysis of diet breadth suggested that sciaenids as a group, were slightly generalized feeders (B = 0.52), and also include a few specialized feeders as evident from the gut content indicating wide array of prey items. Species wise, the diet breadth ranged between 0.32 (*J. carutta*) and 0.89 (*O. ruber*). In addition, diet breadth values suggested that *O. ruber, O. cuvier*, *J. borneensis*, *J. belangerii*, *J. elongatus* and *Kathala axillaris* were generalized feeders (B > 0.50), whereas *J. dussumieri, J. carutta, J. coitor* and *P. anea* were specialized feeders (B < 0.50). These differences within the family could be due to inter-specific differences in dentition patterns (Froese and Pauly, 2012) and diet preferences. Earlier studies on the diet composition of two species namely *J. dussumieri* and *O. cuvier* (Manojkumar, 2003; Abdurahiman *et al.*, 2010) suggested that they were generalized feeders.

Assessment of the occurrence of ontogenic shift in sciaenid diet was carried out using multivariate ordination techniques. Multidimensional scaling ordination analysis demonstrated that sciaenids could be categorized into four feeding groups based on their size and prey selection. SIMPER analysis revealed the prey preferences of the respective feeding groups. Results of the SIMPER analysis suggested that segregation of these groups was determined by the presence or absence of major prey items such as prawns, zooplankton and teleosts. These results were corroborated by PCA, which indicated that prawns and zooplankton were the major prey items of the various size categories of the sciaenids. PCA clearly elucidated an apparent ontogenic shift wherein, the small sciaenids largely feed on zooplankton, annelids and algae whereas, medium and large sized sciaenids prefer teleosts and prawns. The above analyses further suggested that large sized sciaenids exhibit a narrow diet spectrum comprising only prawns and teleosts whereas, the occurrence of zooplankton, benthos (annelids, other invertebrates), algae, molluscs and foraminifers in small sized fishes is suggestive of a comparatively broader diet spectrum. It is apparent from the above analysis that prawns and zooplankton are the major food resources for the fishes inhabiting demersal marine environments (Abdurahiman *et al.*, 2010).

Available literature pertaining to the age-related patterns in the diets of sciaenid species (Lal Mohan, 1985; Nasir, 2000; Manojkumar, 2003; Abdurahiman *et al*, 2010) suggested that *O. ruber*, *O. cuvier* and *J. dussumieri* fed mainly on teleosts and crustaceans during their entire life cycle. However, juveniles of these species may feed on zooplankton (copepods) and zoo-benthos (polychaetes) abundantly available in the shallow coastal waters (Lal Mohan, 1985; Nasir, 2000; Manojkumar, 2003). The present observations on the occurrence of algal strands and sea urchin spines in the guts of juveniles of all the six species are noteworthy, and may be attributed to the collection of fish samples from submerged patchy algal beds (< 25 m depth) as evidenced by occurrence of sea urchins (Hegde and Rivonker, 2013) and algae (*Sargassum* sp. and *Ulva* sp.) in the trawl catches. The observations made in the present study envisage that both habitat and size contribute to the ontogenic shift in diet. Further, it is clear that shifts in the diets with respect to size occur in sciaenids, and has important implications for both trophic dynamics and sciaenid community.

It is known that juveniles have smaller mouth structure and different denticulation pattern (Froese and Pauly, 2012), which could also be the reason for ontogenic shift observed in the present study. Yasuda (1960) claimed that a fish's gape determines its ability to capture prey items while its jaw determines the size of prey items. Further, Sardina and Cazorla (2005) studied the morphometric relation of prey selectivity of two sciaenids (*Cynocian guatucupa* and *Micropogonias furneiri*) and reported differences in feeding behaviour between the juveniles and adults due to variations in the mouth gape and length of the maxilla.

Analysis of diet breadth of small, medium and large-sized individuals (Figure 7.1) revealed that species such as *O. ruber*, *O. cuvier*, *J. borneensis* and *J. elongatus* showed a tendency towards varying their feeding habits and preferences with their life stage. Small individuals of these species showed high diet breadth indicating a generalized feeding behaviour, whereas large individuals showed less diet breath suggesting a more specialized feeding nature. Earlier studies (Nasir, 2000; Abdurahiman *et al.*, 2010) suggested that diet breadth increases with the increase in the trophic level and the body size of fishes. Contrary to this, the present observations revealed that among sciaenids, diet breadth decreases with increase in size. It is apparent from the present study that the juveniles fed on a wide range of prey items such as zooplankton, annelids, foraminifera, algae and small crustaceans, whereas adults fed only on teleosts and prawns. Further analysis revealed that teleosts, crabs and stomatopods occurred only in large sized matured fishes with fully gorged stomachs. Hence, based on the above feeding behaviour, the sciaenid population from this region was classified into three feeding guilds (Figure 7.4).

Prawn feeder (A): The diet of species assigned to this guild (*J. dussumieri*, *K. axillaris*, *J. belangerii*, *J. elongatus*. *J. coitor* and *P. anea*) was dominated by prawns (*M. dobsoni*, *A. indicus*, *Parapenaeopsis stylifera*) as evident from %IRI values (%FO > 50). Among the above mentioned species, *J. coitor*, *P. anea* and *K. axillaris*, fed in addition to prawns, on various other organisms such as teleosts (%FO 22.72, 28.57 and 33.33 respectively), crabs (%FO 13.63, 14.28 and 44.44, respectively), zooplankton (%FO 27.27, 42.86 and 55.55 respectively) in small quantities (Table 7.1). This suggests that few sciaenids possess omnivorous nature of feeding due to the availability of diverse demersal prey organisms. However, the comparison of L_m with size ranges of *J. coitor* and *K. axillaris* suggested that the dominance of juveniles among the sciaenid population along the Goa coast could be one of the reasons for the mixed feeding behaviour attributed to these species.

Fish feeder (B): Fish feeders (*O. cuvier, O. ruber* and *J. carutta*) were predominantly piscivores, feeding mainly on teleosts and small quantity of prawns. Among these species, *J. carutta* was observed to feed on zoo-benthos, particularly polychaetes and other annelids.

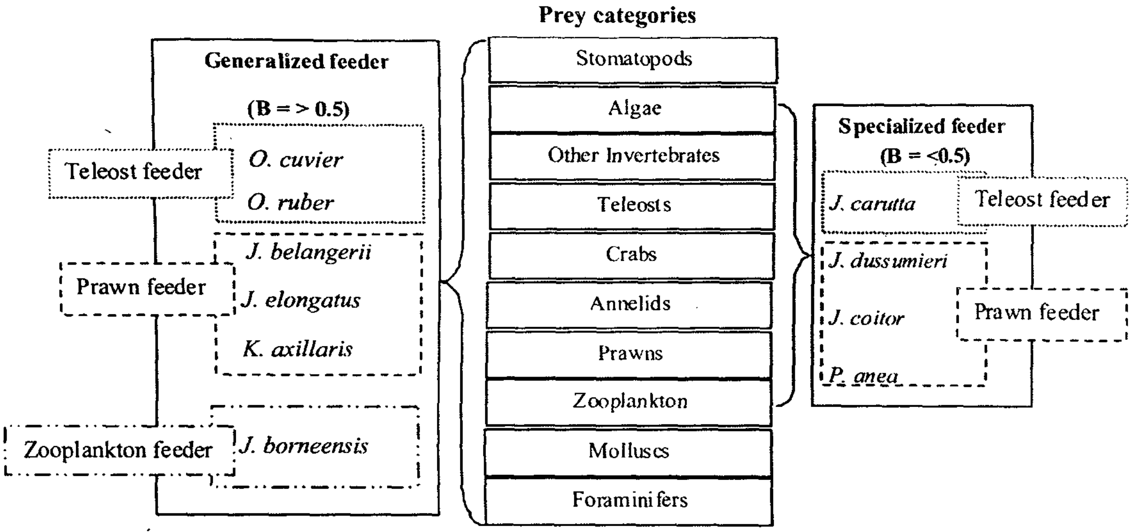
Zoo-planktivore (C): *J. borneensis* was observed to feed preferably on zooplankton as evidenced by the %FO (Table 7.1).

Based on the above observation a flow diagram explaining the prey selectivity of sciaenids was constructed to understand the trophic relations (Figure 7.5). Generalized feeders were found to feed on all the ten prey categories as major or minor diet whereas, the specialized feeders fed only on seven prey categories (Figure 7.5). Molluscs, foraminiferans and stomatopods were not observed in the stomachs of specialized feeders.

The concept of diet overlap is usually related to the magnitude of competition for diet. The present observations suggest that there was not much diet overlap between these species. However, diet analysis of *J. belangerii* and *O. cuvier* showed high diet overlap (61.25 %, Table 7.4) as similar food items were observed in both these species (Table 7.1). Further, *O. cuvier* showed more than 50 % diet overlap with *J. belangerii*, *P. anea* and *J. carutta* probably due to narrow diet breadth values (0.50, 0.37 and 0.32, respectively) which indicates specialized nature of prey selectivity (Table 7.1). Species with highly specialized trophic behaviour may show more diet overlap with associated species (Colloca *et al.*, 2010). However, *K. axillaris* and *J. elongatus* also showed significant diet overlap (60 %; Table 7.4), although the former is a specialized and the latter is a generalized feeder.

In addition to the above, the extent of diet overlap in other combinations was low (< 50 %), thereby indicating lack of inter-specific competition (Table 7.4). Although, *O. ruber* and *O. cuvier* were placed in the same guild (Figure 7.4), the observed diet overlap

Figure 7.5. Schematic representation of feeding guilds of sciaenids



was less (28.09) as evident from the variability in %FO of various prey items observed in their gut contents. Moreover, *O. ruber* was found to have comparable preference for teleosts (%FO 40.11) and prawns (%FO 58.11), whereas *O. cuvier* fed mainly on teleosts (%FO 82.33) and zooplankton (%FO 26.67; Table 7.1). Other species, except *J. dussumieri*, *J. carutta*, and *P. anea,* were found to be generalized feeders with less diet breadth values (Table 7.1). Earlier studies (Garrison and Link, 2000; Hajisamae, 2009) suggested that low diet overlap could be prevalent in the presence of diverse range of prey items and generalized feeders. The range of prey types consumed by each fish is large, thus there is little mutual reliance on a single or few prey items among any pair of sciaenid species and the potential for a strong diet overlap is reduced.

Low diet overlap could also occur if the individual size classes among the various species are segregated and individual prey items are listed specifically instead of broad categories (Barrera Oro, 2003). The present assessment of diet overlap involved all the 51 prey items, which could be a reason for the less diet overlap. The above observations suggest that the degree of diet overlap and competition for food resources are not the only factors structuring the sciaenid community. Predators in the ecosystem generally switch among a suite of available prey largely depending upon prey abundance. However, it is pertinent that further detailed studies, analysis of the variations in mouth parts and the use of stable isotopes would provide better insight on the nature of ontogenic shift in the diets among this group.

7.5. Conclusion

Sciaenids off the Goa coast showed high feeding intensity with preference for crustaceans, teleosts and zooplankton. Although the ontogenic shift in diet was apparent, large fishes of some species showed diet preferences similar to those of juveniles. Hence, the sciaenid populations of the near shore coastal waters could be considered as facultative omnivores. Analysis of Bray-Curtis similarity index and Principle Component Analysis showed that there are four different feeding groups based on size, and prawns, zooplankton and teleosts are the major prey items which influence this segregation. The segregation of feeding guilds suggested resource partitioning within this group. Low diet overlap observed in the study reflected that individual species within this family did not have similar diet preferences. The generalized feeding nature and low diet overlap among the sciaenid species could be attributed to high productivity and prey diversity of the tropical ecosystems. Further, the present observations suggest that competition is not a key factor which regulates population of sciaenids along Goa coast.

Chapter 8.

Summary

The present study envisages providing comprehensive information on the demersal fish community along the estuarine and shelf regions (up to 25 m depth) of Goa, central west coast of India.

1. The demersal marine community comprised 184 taxa categorized in seven major faunal groups. These include 16 new records, among which one species is a new record for the entire Indian coast, five first records for the west coast of India, and ten first records for Goa coast. Total abundance was consistent during the pre-monsoon as compared to post-monsoon due to the prevalence of calm conditions, constant salinity and temperature that offered a relatively favourable environment to the demersal fauna. Crustaceans dominated the trawl catch during the study period and spatial variations suggested that stomatopods and prawns compete, indicating disproportionate partitioning of resources between these groups. Echinoderm catches were mostly restricted to the pre-monsoon and abundance peaks from March to May suggested their spawning aggregations in the coastal waters, whereas, lower abundance during other periods suggested migration to deeper waters to avoid strong onshore wave surges.
2. A new record of the sea urchin *Temnopleurus decipiens* is described from the Indian waters outside its known geographical range. Detailed re-description and comparative analysis with other congeneric species prompted to provide revised key to the genus *Temnopleurus.* A detailed comparison with another congener, namely *Temnopleurus toreumaticus* revealed that apart from the position of the anus and the presence of a suranal plate, there were notable differences in the diameter of the apical system, plan of sutural pits, pore pairs structure, ratio of spine length to maximum test diameter, and colour banding of the spines.

3. Nine elasmobranch species were observed along the shallow coastal waters off Goa among which, *Chiloscyllium griseum*, *Himantura walga* and *Scoliodon laticaudus* were the most common. Elasmobranchs showed significant spatial variations and their population was dominated by juveniles. The observations revealed that there were no discernible differences in abundance and weight of elasmobranchs between the seasons suggesting lack of seasonal variation. Dietary analysis of the three commonly observed species revealed the dominance of teleosts, followed by crustaceans in their diet. Further, analysis of the catch trends (1969-2004) of elasmobranchs revealed decrease in recent times suggesting reduction in trophic level of the regional fishery perhaps caused by fishing out of carnivores coupled with increased catches of low trophic level fishes.
4. Fourteen species of sciaenids were recorded during the present study. Among these, one species (*Johnius coitor*) is new record for the west coast of India and two others (*J. amblycephalus* and *J. carutta*) are first records for Goa coast. Sciaenid abundance was higher during pre-monsoon as compared to post-monsoon. Analysis of species distribution pattern revealed significant evidence for habitat selection between sandy and rocky habitats.
5. Sciaenids were found to be generalized feeders, however, they preferred to feed on prawns and teleosts. Apparent ontogenic shift was observed with respect to diet preferences and diet breadth as well. Sciaenids did not show significant evidence for competition due to availability of diverse prey items and their generalized feeding behaviour. These observations revealed that competition is not the factor which controls the population dynamics of the sciaenid fishes in the tropical ecosystems.

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Appendix

Publication list

1. Hegde M R and Rivonker C U (2013) A new record of *Temnopleurus decipiens* (De Meijere, 1904) (Temnopleuroida: Temnopleuridae) for the Indian waters - A comparative diagnosis. *Zoosystema* (35), 97 – 111.

2. Hegde M R, Padate V P, Velip D T and Rivonker C U (2013) An updated inventory of new records of coastal macrofauna along Goa, west coast of India, *Indian Journal of Geo-Marine Sciences.*

3. Hegde M R, Padate V P and Rivonker C U, (in press) Biological aspects and catch trends of elasmobranchs in the inshore waters of Goa, west coast of India, is accepted in *International Journal of Marine Science.*

A new record of *Temnopleurus decipiens* (de Meijere, 1904) (Echinoidea, Temnopleuroida, Temnopleuridae) from Indian waters

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ABSTRACT

The first report of the sea urchin (Echinodermata, Echinoidea) species, *Temnopleurus decipiens* (de Meijere, 1904) is given from Indian waters (Goa, west coast of India). A complete redescription of the species has been made based on test morphology using 27 phenotypic parameters. This species differs from the original description in that "the ocular plates do not reach the periproct margin." A detailed comparison with another congener, namely *Temnopleurus toreumaticus* (Leske, 1778) revealed that apart from the position of the anus and the presence of a suranal plate, notable differences were also observed in the diameter of the apical system, plan of sutural pits, pore-pairs structure, ratio of spine length to maximum test diameter, and colour banding of the spines. Further, the paper provides a modified taxonomic key to all the seven extant species of the genus *Temnopleurus* L. Agassiz, 1841 with two additional characters.

KEY WORDS
Sea urchin,
Temnopleurus,
morphology,
first record,
India.

RÉSUMÉ

Une nouvelle signalisation de Temnopleurus decipiens *(de Meijere, 1904) (Echinoidea, Temnopleuroida, Temnopleuridae) dans les eaux indiennes.*

L'oursin de mer, *Temnopleurus decipiens* (de Meijere, 1904), est signalé pour la première fois dans les eaux indiennes (Goa, côte ouest de l'Inde). Nous redécrivons entièrement l'espèce sur la morphologie du test en utilisant 27 paramètres phénotypiques. Cette espèce diffère de la description originale par le fait que « les plaques oculaires n'atteignent pas la limite du/des périprocte(s) ». Une comparaison détaillée avec un autre congénère, *Temnopleurus toreumaticus* (Leske, 1778), a révélé qu'en plus de la position de l'anus et de la présence d'une plaque suranale, des différences importantes étaient aussi observées au niveau du diamètre du système apical, du plan des fossés suturaux, de la structure des paires de pores, du rapport entre la longueur des épines et le diamètre maximal du test, et des bandes colorées des épines. Notre article propose également une clé taxonomique modifiée, avec deux caractères additionnels, pour les sept espèces existantes du genre *Temnopleurus* L. Agassiz, 1841.

MOTS CLÉS
Echinide,
Temnopleurus,
morphologie,
premier enregistrement,
Inde.

INTRODUCTION

Sea urchins (Echinodermata, Echinoidea) inhabit sea grass beds, coral reefs (Nybakken & Bertness 2005), intertidal regions (Lawrence 2006), and feed on benthic invertebrates and algae (Norderhaug & Christie 2009). Among the various families of echinoids that inhabit the Indo-west Pacific, the Temnopleuridae A. Agassiz, 1872 comprise 14 genera and 25 species (Kroh & Mooi 2011; Kroh 2012) that are known for their comparatively wide distribution (Clark & Rowe 1971). Among the temnopleurid genera, *Temnopleurus* L. Agassiz, 1841, which comprises seven extant and one fossil species, is the most abundant (Mortensen 1943; Smith 2005; Schultz 2006; Kroh *et al.* 2011) and its distribution ranges from the east coast of Africa and Madagascar to Japan, Hawaii and Australia (Clark 1912; Mortensen 1943; Clark & Rowe 1971; Schultz 2006). Published literature on temnopleurid sea urchins (Mortensen 1943; Clark & Rowe 1971) suggests that the structure of apical system and peristome, arrangement of pore-pairs and sutural pits are the most important criteria for species identification. Information available for Indian waters (Bell 1888, 1889, 1902; Koehler & Vaney 1914; Sane & Chhapgar 1962; Clark & Rowe 1971; Schultz 2006; Sastry 2007) reveal the occurrence of only three temnopleurid species, namely *Temnopleurus toreumaticus* (Leske, 1778), *T. reevesii* (Gray, 1855) and *T. apodus* (A. Agassiz & Clark, 1906).

The present paper describes a new record of *Temnopleurus decipiens* (de Meijere, 1904) for the Indian region (Goa, west coast of India). This description is complimented by a comparative analysis of morphological characters present in *T. decipiens* and *T. toreumaticus* with their extant congeners using test characters (N = 22; *sensu* Coppard & Campbell 2006). Further, two additional morphological characters namely "spine length with respect to the test diameter" and "colour banding on spine" are used to differentiate the seven extant species of *Temnopleurus*.

MATERIAL AND METHODS

STUDY AREA

The coastal region of Goa, located on the central west coast of India, is dotted with rugged sea-cliffs that continue into the sea as submerged rocky patches (Wagle 1993) and contains patchy coral reefs (Padate *et al.* 2010a). These habitats support a wide array of marine fauna and sustain stocks of several economically important (Ansari *et al.* 1995), as well as rare species (Padate *et al.* 2010 a, b). The near-shore seabed consists of silty-clay down to 50 m depth and sandy-silt from 50 to 100 m depth (Wagle 1993), with an average slope of 1.5 m/km until the 30 fathom contour (54.8 m).. The submarine contours are approximately parallel to the coastline.

The present study area (Fig. 1) is located in the vicinity of the Sal estuary (between 15°00'N and 15°20'N latitudes and between 73°41'E and 74°00'E longitudes) that demarcates two different habitats, namely sandy shores in the north as well as exposed rocky shores, promontories and submerged rock in the south.

SAMPLE COLLECTION

52 trawling stations were selected off Goa, west coast of India (Fig. 1), with a total effort of 86 hours of bottom trawls from January 2009 to April 2010 in order to assess the diversity and the community structure of demersal fauna. Trawl nets with a mesh size of 15 and 9 mm at mouth and cod end, respectively, were towed at a speed of *c.*3-4 km/h. The sampling duration was 1-3 h. The sea urchin specimens were obtained in bulk quantities during March-April 2009 and March-April 2010. However, only good quality intact specimens were taken to the laboratory for morphological examination (Table 1). These specimens were examined under a stereomicroscope (Olympus SZX9, Olympus, Japan) and morphological characters were recorded. Altogether, 37 sea urchins were identified down to family level using morphological features such as test texture, arrangement of ambulacral pore-pairs and structure of the Aristotle's lantern (Mortensen 1943; Clarke & Rowe 1971; Coppard *et al.* 2005; Smith 2005). Subsequently, species identification was carried out using external characters such as test colour, shape, arrangement of ambulacral pore-pairs, sutural pits near the peristome, form of apical system and periproct, position of anal opening and presence of a suranal plate. Morphological

parameters (see Abbreviations) were measured using electronic calipers (Absolute Digimatic) with an accuracy of 0.01 mm. The apical system as well as ambulacral and interambulacral plates were examined for identification and differentiation of the species (Mortensen 1943; Clarke & Rowe 1971; Schultz 2006). Further, seven morphological ratios were derived from these morphometric parameters following Coppard & Campbell (2006). All the photographs were taken using Nikon D60 Digital SLR camera.

ABBREVIATIONS

AD	apical disc diameter;
GD	gonopore diameter (*sensu* Coppard & Campbell 2006);
GPH	genital plate height;
GPW	genital plate width;
HTD	horizontal test diameter;
PPD	periproct diameter;
PSD	peristome diameter;
SL	spine length;
VTD	vertical test diameter.

SYSTEMATICS

Class ECHINOIDEA Leske, 1778
Subclass EUECHINOIDEA Bronn, 1860
Superorder CAMARODONTA Jackson, 1912
Order TEMNOPLEUROIDA Mortensen, 1942
Infraorder TEMNOPLEURIDEA Kroh & Smith, 2010

Family TEMNOPLEURIDAE A. Agassiz, 1872

DIAGNOSIS. — Test well sculptured, usually with distinct pits, troughs or pores at the angles of the sutures at least in juveniles and usually throughout life. Primary tubercles imperforate, with or without crenulation; those in ambulacral and interambulacral zones similar in size. Pore-pairs forming a simple adradial band which does not expand adorally. Apical disc dicyclic, peristome much larger than apical disc; buccal notches obsolete; Aristotle's lantern of the camarodont type. Periproct subcircular with smooth edges (periproctal plates not indenting apical ring); ambulacra trigeminate, with echinid-style compounding (Smith 2005).

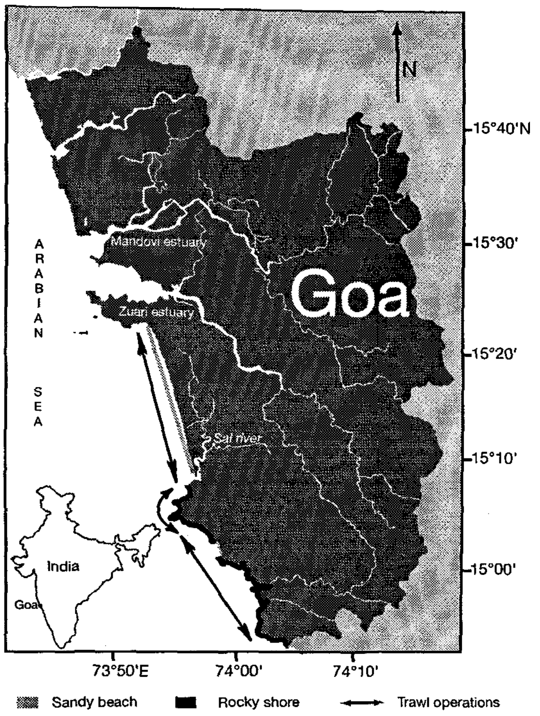

FIG. 1. — Map of studied area in India indicating trawl operations.

Genus *Temnopleurus* L. Agassiz, 1841

DIAGNOSIS. — Test profile hemispherical to subconical, rather thick-shelled with conspicuous crenulations, size often exceeding 40 mm HTD. Ambulacral plating trigeminate, pore-pairs arranged in near-vertical arcs forming a single adradial band; each compound plate comprising a single primary tubercle located closer to the pore zone and smaller perradial tubercles scattered randomly across the plate. Interambulacral plates with a central primary tubercle, smaller secondary and military tubercles scattered randomly over the remainder of the plate. Conspicuous pits and troughs present at the angle of sutures, usually with horizontal extensions; primary tubercles imperforate and distinctly crenulated. Peristome with 10 buccal plates and 10 buccal tube-feet, buccal notches very feeble. Periproct subcircular, usually with eccentric opening and some larger periproctal plates. Genital plates with tubercles forming a ring around the periproct (Mortensen 1943; Clarke & Rowe 1971; Smith 2005).

REMARKS

Observation of sea urchins collected during the present study revealed two forms of the genus

TABLE 1. — Details of sampling locations, depth and specimens examined.

Species	Date	Geographical location	Depth (m)	Number of specimens
Temnopleurus decipiens (de Meijere, 1904)	21.III.2009	15°04'N, 73°55'E	18	4
	04.IV.2009	15°05'N, 73°55'E	17	5
	18.III.2010	15°04'N, 73°56'E	20	3
	30.III.2010	15°03'N, 73°58'E	20	5
Temnopleurus toreumaticus (Leske, 1778)	21.III.2009	15°06'N, 73°56'E	10	6
	28.IV.2009	15°07'N, 73°54'E	15	8
	18.III.2010	15°09'N, 73°52'E	8	3
	30.III.2010	15°08'N, 73°53'E	10	3

Temnopleurus that prompted us to look into the systematics of both these forms. A review of published literature (Leske 1778; de Meijere 1904; Mortensen 1943; Clark & Rowe 1971; Smith 2005; Schultz 2006) resulted in the identification of two species *Temnopleurus decipiens* and *T. toreumaticus* in Indian waters.

Temnopleurus decipiens (de Meijere, 1904)

Genocidaris decipiens de Meijere, 1904: 76, pl. 16, figs 264-266.

MATERIAL EXAMINED. — Off Betul fishing jetty, Goa, west coast of India, 15°04'N, 73°55'E, 17-20 m depth, 17 specimens, test diameter ranging from 5.4 to 21.30 mm.
Representative specimens are preserved in 70% ethanol and have been deposited as voucher samples (N = 16) at the Marine Biology Laboratory, Department of Marine Sciences, Goa University.

TYPE LOCALITY. — Labuan Badjo, Flores and Saleh Bay, Indonesia.

HABITAT AND DISTRIBUTION. — *Temnopleurus decipiens* has been reported from the Philippines, the eastern Indian Ocean (Clark & Rowe 1971; Marsh & Morrison 2004), the South China Sea (Lane et al. 2000) and Western Australia (Marsh & Morrison 2004; Fig. 6). Lane *et al.* (2000) reported this species from depths of 18-40 m around the coastal shelf waters of southern China. The present specimens of *T. decipiens* (as well as *T. toreumaticus*) were found to inhabit a sandy and muddy bottom at 15-20 m depth along the near-shore coastal waters of Goa, but were absent in all estuarine trawls.

DESCRIPTION
Test small, dome-shaped (hemispherical), well sculptured with convex aboral surface; flattened oral surface with sunken peristome (Fig. 2A). HTD ranges from 5.42 to 21.30 mm ($\mu = 14.60 \pm 4.78$ mm) and VTD from 2.74 to 12.92 mm ($\mu = 8.22 \pm 3.15$ mm); test width about twice its height (μ VTD/HTD ratio = 0.56:1). Test comprises of five pairs of alternately placed ambulacral and interambulacral plates, interambulacral plates placed at about the level of ambulacral plates (Fig. 2C). Colouration of the naked test light green to grey (Fig. 2C).

Ambulacral plates compound trigeminate, their pore-pairs bearing numerous tube feet (in living specimens) arranged in a straight line forming a single adradial band. Single primary tubercle of each ambulacral plate closed to the pore zone, surrounded by randomly scattered smaller secondary tubercles; tubercles imperforate and distinctly crenulated.

Interambulacral plates covering a slightly larger area of the test than the corresponding ambulacra. Each interambulacral plate having a central primary tubercle surrounded by smaller secondary and miliary tubercles that cover the remainder of the plate (Fig. 3A). Primary tubercles imperforate and distinctly crenulated. Wedge-shaped pits located at the angle of the suture, and arranged in a zig-zag manner along the middle of the interambulacrum; lateral extensions of the pits separating the interambulacral plates and reaching the pore-pair zone (Fig. 3B); sutural pits near the peristome also conspicuous (Fig. 3C).

Peristome large (PSD 35.18 ± 3.33% of HTD), roughly circular in outline with very feeble buccal

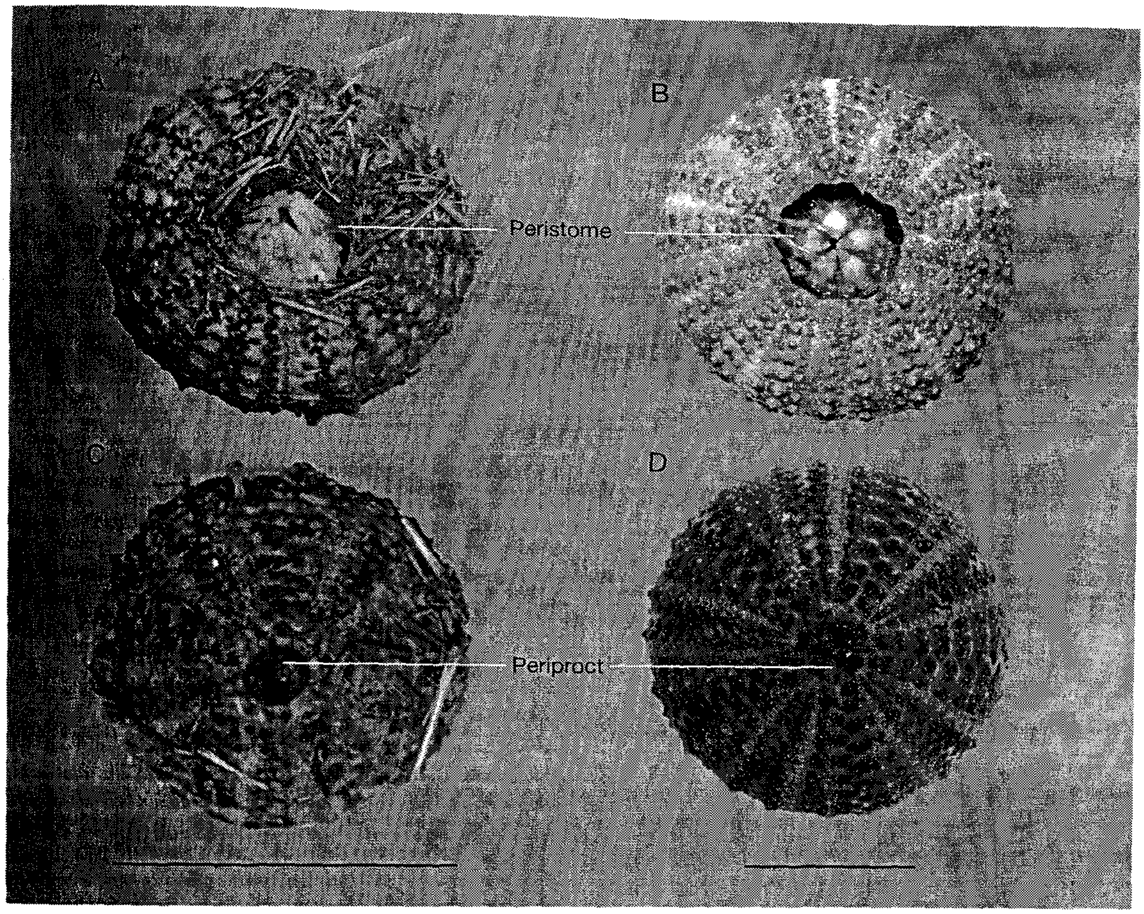

FIG. 2. — **A**, **B**, oral views of *Temnopleurus decipiens* (de Meijere, 1904) (**A**) and *Temnopleurus toreumaticus* (Leske, 1778) (**B**); **C**, **D**, aboral views of *T. decipiens* (**C**) and *T. toreumaticus* (**D**). Scale bars: 10 mm.

notches; covered with soft skin, comprising of five pairs of buccal plates with buccal tube feet emanating from them. Aristotle's lantern of the camarodont type (i.e., with a paired rod-like epiphysis bridging across the upper end of pyramid [Fig. 3D]).

Apical system dicyclic, relatively large, but smaller than the peristome (AD 25.14 ± 3.96% of HTD). Apical system with four equal-sized genital plates and one larger genital plate with madreporite. Inner part of each genital plate with small tubercles, outer part naked. The number of tubercles varying with the size of the specimens: 1-2 tubercles in specimens < 5 mm, whereas 3-4 tubercles in larger specimens. Genital plate wider than long (mean GPH:GPW = 0.87:1). Gonopore roughly circular, approximately ⅓ of genital plate size (GD 32.57 ± 7.40% of GPH) and located at the centre of each genital plate. Ocular plates oval-shaped, placed at the junction of two adjacent genital plates, not reaching the periproct margin; covered with 3-4 small tubercles. Conspicuous triangular pit present at the junction of the ocular plate with its two adjacent genital plates. Periproct roughly circular in outline, approximately ⅐ of maximum test diameter (PPD 13.89 ± 2.17% of HTD), composed of brown plates; anal opening eccentric, located opposite genital plate "I". Suranal plate conspicuous, located opposite the anus, covering approximately half the periproct (Fig. 3E).

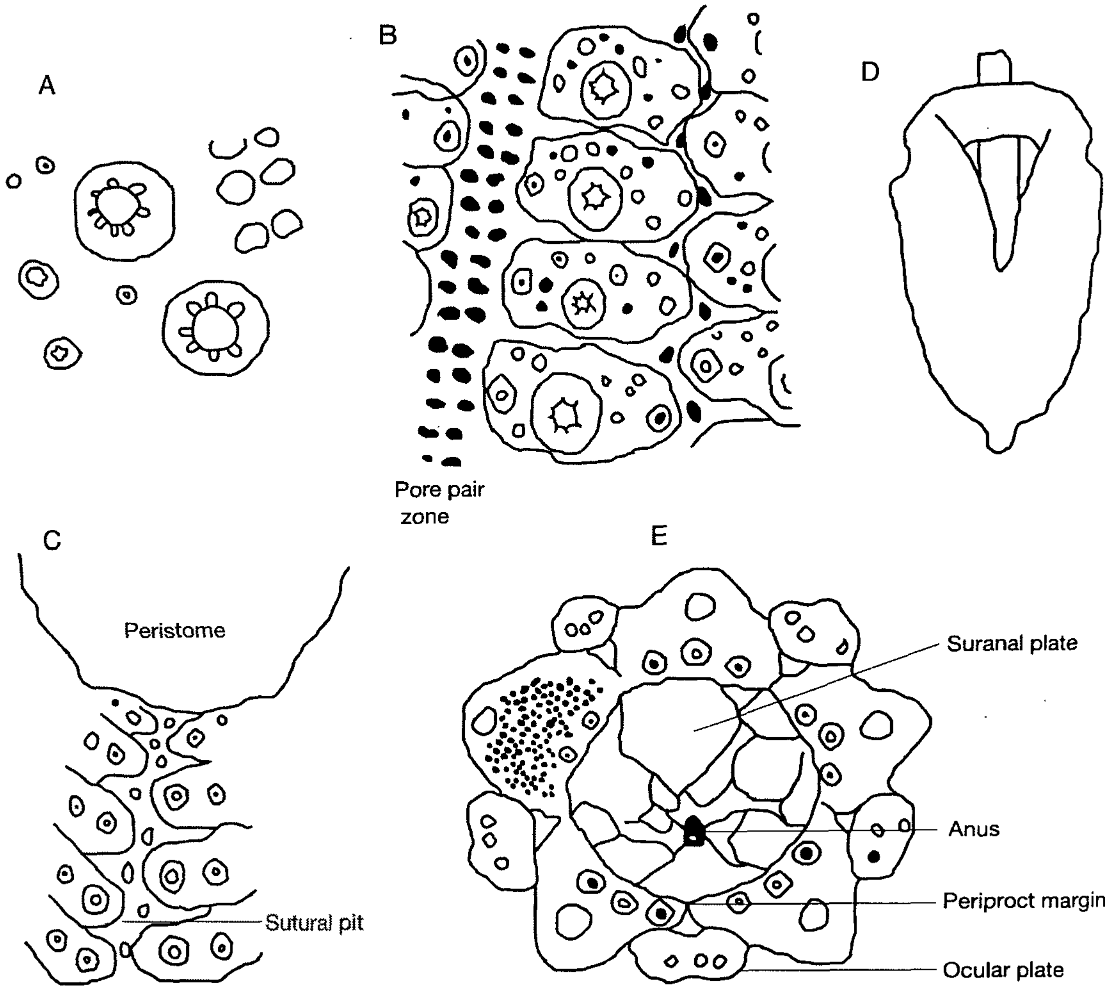

FIG. 3. — *Temnopleurus decipiens* (de Meijere, 1904): **A**, primary tubercle; **B**, interambulacrum; **C**, sutural pit near peristome; **D**, pyramid of Aristotle's lantern; **E**, apical system. Scale bar: 10 mm.

Spines thin, total length not exceeding maximum test diameter (SL 61.80 ± 11.74% of HTD), their surface covered with fine longitudinal ridges. Spine colouration white with alternating reddish or purple bands (Fig. 4A).

Temnopleurus toreumaticus (Leske, 1778)

Cidaris toreumatica Leske, 1778: 155, 156, tab. X.

TYPE LOCALITY. — Unknown.

MATERIAL EXAMINED. — Off Betul fishing jetty, Goa, west coast of India, 15°04'N, 73°55'E, 8-20 m depth, 20 specimens, test diameter ranges from 12.47 to 40.24 mm. Representative specimens are preserved in 70% ethanol and have been deposited as voucher samples (N = 19) at the Marine Biology Laboratory, Department of Marine Sciences, Goa University.

HABITAT AND DISTRIBUTION. — *Temnopleurus toreumaticus* is a fairly wide-spread species known to occur

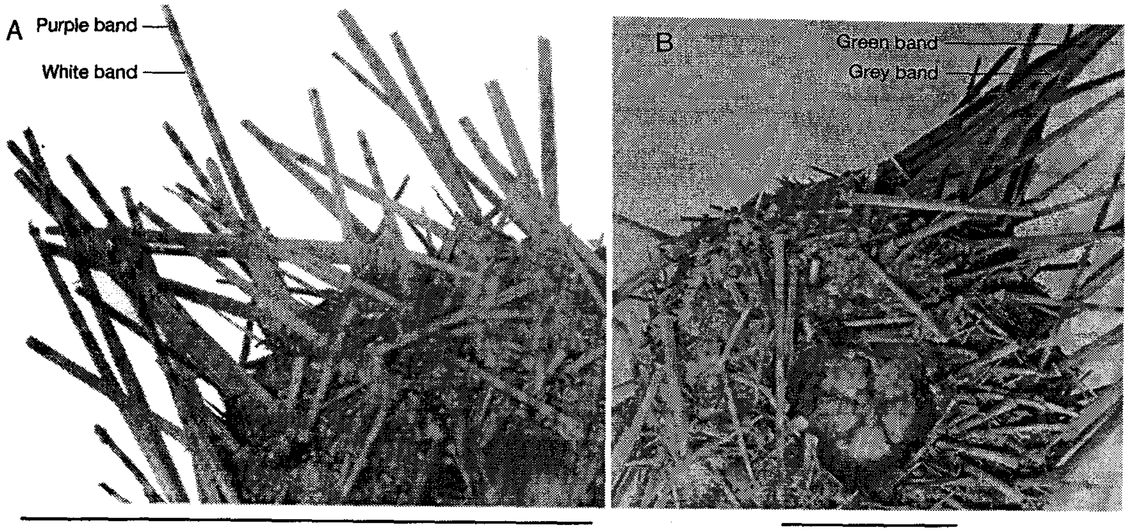

FIG. 4. — Banding on spines of: **A**, *Temnopleurus decipiens* (de Meijere, 1904); **B**, *Temnopleurus toreumaticus* (Leske, 1778). Scale bars: 10 mm.

in East Africa, Madagascar, the Persian Gulf, the Red Sea and on the east coast of Australia (Clark & Rowe 1971; Fig. 6). In Japan, this species is found from northern Honshu to southern Kyushu (Mortensen 1943; Schultz 2006). Kitazawa *et al.* (2007) studied the habitats of this sea urchin species in Shirikiwa Bay, Japan and showed that *T. toreumaticus* inhabits the intertidal and subtidal zones of muddy beaches and can also be found near rocky patches with rich assemblages of algae. Published reports for Indian waters (Ramsay 1885; Clark & Rowe 1971) suggest that this species is widely distributed and inhabits sandy and muddy substrata between 5-40 m depth.

DESCRIPTION

Test dome-shaped, rigid, well sculptured with a convex aboral surface; flattened oral surface with sunken peristome (Fig. 2B). HTD ranging from 12.47 to 40.24 mm (μ = 33.92 ± 7.34 mm) and VTD from 6.68 to 25.82 mm (μ = 20.59 ± 5.23 mm); test width about twice its height (μ VTD/HTD ratio = 0.61:1). Test comprised of five pairs of alternately placed ambulacral and interambulacral plates, interambulacral plates placed at about the level of the ambulacral plates (Fig. 2D). Naked test displaying an olive green to dark grey colour (Fig. 2D).

Ambulacral plates compound trigeminate, their pore-pairs bearing numerous tube feet (in living specimens) and arranged in slightly vertical arcs forming a single adradial band. The single primary tubercle of each ambulacral plate close to the pore zone and surrounded by randomly scattered smaller secondary tubercles; tubercles imperforate and distinctly crenulated.

Interambulacral plates covering a slightly larger area of the test than the corresponding ambulacra. Each interambulacral plate having a central primary tubercle surrounded by smaller secondary and miliary tubercles that cover the remainder of the plate (Fig. 5A). Primary tubercles imperforate and distinctly crenulated. Wedge-shaped pits located at the angle of the suture, and arranged in a zig-zag manner along the middle of the interambulacrum; lateral extensions of the pits separating the interambulacral plates and reaching the pore-pair zone (Fig. 5B). In specimens larger than 25 mm HTD, these pits extending horizontally over the entire surface of the plate. However, sutural pits near the peristome inconspicuous (Fig. 5C).

The peristome is large (PSD 34.26 ± 1.87% of HTD) and roughly circular in outline with very feeble buccal notches. It is covered with soft skin and comprises of five pairs of buccal plates with buc-

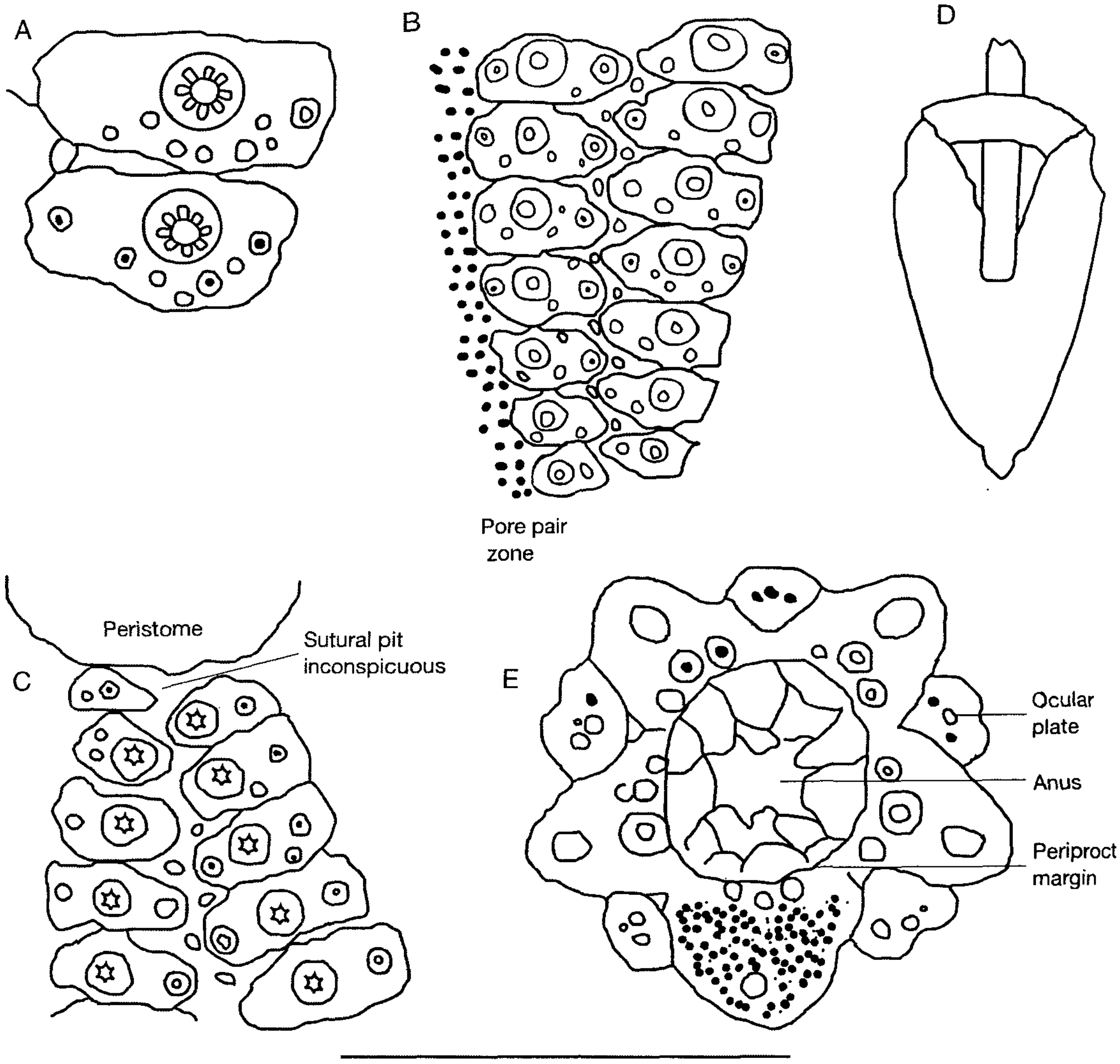

FIG. 5. — *Temnopleurus toreumaticus* (Leske, 1778): **A**, primary tubercle; **B**, interambulacrum; **C**, sutural pit near peristome; **D**, pyramid of Aristotle's lantern; **E**, apical system. Scale bar: 10 mm.

cal tube feet emanating from them. The Aristotle's lantern is of the camarodont type (i.e., with a paired rod-like epiphysis bridging across the upper end of the pyramid (Fig. 5D)).

Apical system dicyclic and smaller than the peristome (AD 19.86 ± 2.02 % of HTD), with four equal-sized genital plates and one larger genital plate with madreporite. Inner part of each genital plate with small tubercles, outer part naked. The number of tubercles varying with the size of the specimen: 1-2 tubercles in specimens < 12 mm, whereas 3-5 tubercles in larger specimens.

Genital plate wider than long (mean GPH:GPW = 0.82:1). Gonopores roughly circular and approximately ⅓ of the genital plate's size (GD 35.21 ± 5.98 % of GPH); located at the centre of each genital plate. Ocular plates oval-shaped and placed at the junction of two adjacent genital plates, but

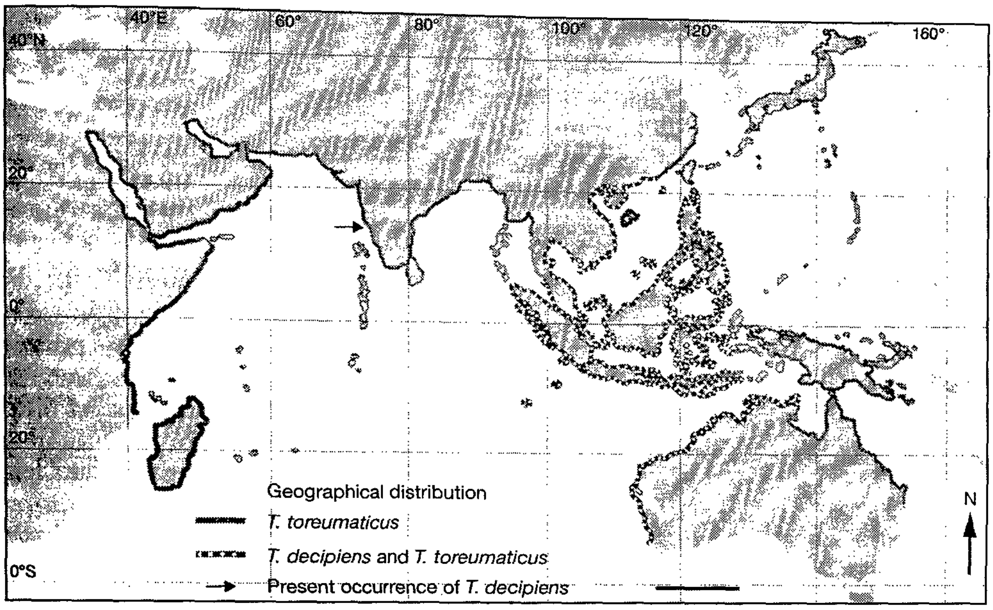

FIG. 6. — Geographical distribution of *Temnopleurus decipiens* (de Meijere, 1904) and *Temnopleurus toreumaticus* (Leske, 1778). Scale bar: 1 000 km.

not reaching the periproct margin. Ocular plates covered with 3-4 small tubercles. A small depression present at the junction of the ocular plate with its two adjacent genital plates. Periproct roughly circular in outline, $\frac{1}{10}$ of maximum test diameter (PPD 11.40 ± 1.58 % of HTD) and composed of dark brown plates. Anal opening located near the centre of the periproct; suranal plate absent (Fig. 5E).

Spines thick, with a total length not exceeding maximum test diameter (SL 61.80 ± 11.74 % of HTD). Their surface covered with fine longitudinal ridges. Spine colouration grey with alternating greenish or brownish bands (Fig. 4B).

BRIEF DESCRIPTION OF OTHER SPECIES OF THE GENUS *TEMNOPLEURUS*

Temnopleurus michaelseni (Döderlein, 1914)

HABITAT AND DISTRIBUTION. — Littoral zone down to 16 m depth along the western and southern coasts of Australia (Schultz 2006).

DESCRIPTION

Maximum test diameter 25 mm. Suranal plate distinct and rounded; anal opening eccentric in the periproct. Ambulacral pore-pairs arranged in a straight series. Deep sutural furrow continuous along the entire length of the sutures. Grooves in ambulacra and interambulacra are deeply depressed and separated. Primary spines short, less than half the test diameter, coloured reddish brown at the base changing to greenish at the tip (Mortensen 1943; Schultz 2006).

Temnopleurus alexandri (Bell, 1884)

HABITAT AND DISTRIBUTION. — Littoral zone down to 50 m depth (Schultz 2006) from the eastern Indian Ocean to the coasts of Australia (Clark & Rowe 1971).

DESCRIPTION

Maximum test diameter 80 mm. Genital plate with some larger tubercles at the inner edge, absence of distinct suranal plate and anal opening near the centre of the periproct. Pore-pairs arranged in oblique arcs. Each interambulacral plate containing up to seven primary tubercles arranged in horizontal series. Sutural pits deep at the oral side. Spines short, pointed, less than half the test diameter, coloured greenish at the base, distally more purplish (Mortensen 1943; Schultz 2006).

Temnopleurus hardwickii (Gray, 1855)

HABITAT AND DISTRIBUTION. — Coastal waters from 5 to 35 m depth off Japan, Korean peninsula and northern China (Schultz 2006).

DESCRIPTION

Test rather strong with a maximum diameter of 46 mm. Apical system inflated; genital plate with numerous tubercles. Periproct large without distinct suranal plate; anus opening near the centre of the periproct. Pore-pairs arranged in a straight vertical series. Sutural pits and furrows deep, continuous over the oral side. Spines short, less than ¼ of the test diameter, with dark brown colour at base and light brown at the distal end (Mortensen 1943; Schultz 2006).

Temnopleurus reevesii (Gray, 1855)

HABITAT AND DISTRIBUTION. — Coastal waters from 36 to 200 m depth (Clark 1912) in East Africa, Madagascar, the eastern Indian Ocean, the Philippines, Malaysia, China and Japan (Clark & Rowe 1971; Schultz 2006).

DESCRIPTION

Test fragile, hemispherical, test diameter 30-45 mm. Apical system with ocular plate "I" inserted. Anal opening strongly eccentric in the periproct with distinct suranal plate. Pore-pairs arranged in a straight vertical series. Sutural pits small, furrows shallow, continuous at the oral side as well. Spines short, about half the diameter of the test, with brownish to light greyish tinge (Clark 1912; Mortensen 1943; Schultz 2006).

Temnopleurus apodus
(A. Agassiz & Clark, 1906)

HABITAT AND DISTRIBUTION. — Coastal waters from 100 to 325 m depth off Hawaii (Clark 1912), in the South China Sea (Lane *et al.* 2000) and on the east coast of India (Sastry 2007).

DESCRIPTION

Small-sized species with a maximum test diameter of 7 mm. Pore-pairs arranged in slightly vertical arcs. Apical system distinctly larger than peristome. Only five buccal plates present on peristome, madreporic pores few (12-14) in number. Suranal plate covering more than half the periproct, anal opening very eccentric. Primary spines slender and long, nearly equal to test diameter (Clark 1912; Mortensen 1943).

COMPARATIVE DIAGNOSIS

Our analysis of 27 morphological characters revealed significant differences between *T. decipiens* (N = 17) and *T. toreumaticus* (N = 20) with respect to the position of the anus, the presence of a suranal plate, the presence of sutural pits near the peristome and the arrangement of ambulacral pore-pairs. In addition, we observed subtle morphological differences with respect to the diameter of the apical system, the ratio of spine length to maximum test diameter and the colour banding on spines (Table 2). An attempt was made to compare our observations with the original description by de Meijere (1904) to provide a better picture of the taxonomy of these two species.

COMPARISON WITH THE ORIGINAL DESCRIPTION

De Meijere (1904) first described *T. decipiens* (originally as a *Genocidaris decipiens*) from sandy, coral and muddy bottom habitats down to 40 m depth from the Labuan Badjo, Flores and Saleh Bay, Indonesia. The specimens collected in the waters off Goa were found to resemble de Meijere's description with regard to the morphological characters "presence of a distinct suranal plate", "eccentric anal opening" and "zig-zag arrangement of sutural pits". However, they differed from the original description by the pattern of the ocular plate arrangement, such that "none

TABLE 2. — Comparison of morphological characters of *Temnopleurus decipiens* (de Meijere, 1904) and *Temnopleurus toreumaticus* (Leske, 1778).

Morphological characters	*T. decipiens* (N = 17)	*T. toreumaticus* (N = 20)
Test structure		
Test colour	Olive green to light green	Olive green to grey
Test shape	Hemispherical	Hemispherical
Arrangement of ambulacral pore-pairs	Straight series	Slightly vertical arcs
Sutural pits near peristome	Conspicuous	Inconspicuous
Form of apical system	Dicyclic	Dicyclic
Form of periproct	Large circular, brown plates	Circular, black plates
Position of anal opening	Eccentric	Subcentral
Suranal plate	Present	Absent
Colour of spine	Purple white bands	Brown green bands
Meristic counts		
Number of median series tubercles on interambulacra	1	1
Number of tubercles present on the genital plate	1-3	3-5
Morphometric measurements		
Mean horizontal test diameter (HTD) (mm)	14.60 ± 4.78	33.92 ± 7.34
Mean vertical test diameter (VTD) (mm)	8.22 ± 3.15	20.59 ± 5.23
Mean peristome diameter (PD) (mm)	5.06 ± 1.59	11.57 ± 2.45
Mean apical disc diameter (AD) (mm)	3.53 ± 0.92	6.64 ± 1.31
Mean periproct diameter (PPD) (mm)	1.99 ± 0.67	3.77 ± 0.63
Mean genital plate width (GPW) (mm)	1.25 ± 0.38	2.37 ± 0.51
Mean genital plate height (GPH) (mm)	1.06 ± 0.30	1.92 ± 0.33
Mean gonopore diameter (GD) (mm)	0.35 ± 0.13	0.68 ± 0.19
Mean spine length (SL) (mm)	10.63 ± 4.90	21.75 ± 4.70
Morphometric ratios		
VTD (% of HTD)	55.15 ± 4.76	60.38 ± 6.17
% of spine length to the HTD	73.00 ± 11.61	62.00 ±11.74
Peristome (% of HTD)	35.15 ± 3.33	34.26 ± 1.87
Apical system (% of HTD)	25.14 ± 3.96	19.86 ± 2.02
Periproct (% of HTD)	13.90 ± 2.17	11.40 ± 1.58
Diameter of gonopore (% GPH)	32.56 ± 7.40	35.20 ± 5.98
Height to width ratio of the genital plate	0.86:1 ± 0.11	0.78:1 ± 0.09

of the ocular plates placed near the periproctorial margin reach the periproct" (Fig. 4E). Another marked difference was the large test size (21.3 mm HTD) as compared to the original description (7.0 mm HTD).

COMPARATIVE ANALYSIS OF THE GENUS *TEMNOPLEURUS*

The distinctiveness of *T. decipiens* was asserted based on a comparison with our observations on *T. toreumaticus* and published descriptions of the other five congeners (Clark 1912; Mortensen 1943; Clark & Rowe 1971; Schultz 2006). Among the 27 morphological characters used in the taxonomic identification of species of the genus *Temnopleurus*, seven parameters (i.e., anal position, presence of suranal plate, sutural pits near peristome, pore-pair arrangement, number of buccal plate in the peristome, colouration of the primary spine and length of the spine with respect to test diameter) were used for our comparative analysis (Table 3).

This analysis revealed that *T. decipiens* shares the character "eccentric anus" and "presence of suranal plate" with *T. apodus*, *T. reevesii* and *T. michaelseni* as opposed to "subcentric anus" and "absence of distinct suranal plate" in *T. toreumaticus*, *T. hardwickii* and *T. alexandri*. In addition, *T. decipiens* possessed "conspicuous sutural pits near peristome", a character shared only with *T. reevesii*. Pore-pair arrangement was found to be in "straight vertical series" among *T. decipiens, T. reevesii, T. hardwickii* and *T. michaelseni,* whereas the same was observed to be "arced" in *T. toreumaticus, T. alexandri* and *T. apodus.* In *T. apodus,* it was observed that it possessed "peristome smaller than apical system" and "five buccal plates", whereas, the other species possessed "peristome larger than apical system" and "ten buccal plates". A comparison of another major character namely spine colouration revealed "purple to red" bands in *T. decipiens* and "brown to red" bands in *T. toreumaticus.* However, the other five species showed lack of colour bands on the spines. In addition, spine length in these species (*T. decipiens, T. toreumaticus* and *T. apodus*) was found to be "greater than half the test diameter" in contrast with "less than half the test diameter" in the other four species.

Revised key to the extant species of the genus *Temnopleurus* L. Agassiz, 1841

1. Anus located near the centre of the periproct (subcentral), suranal plate absent 2
— Anus located away from the centre (eccentric), distinct suranal plate present 4

2. 3-4 primary tubercles present on each interambulacral plate 3
— 7-8 primary tubercles present on each interambulacral plate ... *T. alexandri* (Bell, 1884)

3. Primary spines long, equal to half of horizontal test diameter, banded with reddish or brown colour bands, pore-pairs arranged in arcs .... *T. toreumaticus* (Leske, 1778)
— Primary spines short, length less than ¼ of the horizontal test diameter, spines never banded, pore-pairs arranged in a straight vertical series .... *T. hardwickii* (Gray, 1855)

4. Peristome larger than apical system, containing 10 buccal plates with 10 buccal tube feet ... 5
— Peristome smaller than apical system, containing five buccal plates with five buccal tube feet .... *T. apodus* (Agassiz & Clark, 1907)

5. Primary spines short, less than half of the test diameter, not banded 6
— Primary spines long equal to ⅔ of the test diameter, banded with dark purple or red-coloured bands .... *T. decipiens* (de Meijere, 1904)

6. Sutural pits deep, horizontal furrows deep and elongate, sutural pits at the oral side inconspicuous .... *T. michaelseni* (Döderlein, 1914)
— Sutural pits shallow, horizontal furrows shallow and not elongated, sutural pits at the oral side conspicuous .... *T. reevesii* (Gray, 1855)

Discussion

Temnopleurus is a well-studied echinoid genus distributed across the Indo-west Pacific region (Clark 1912; Mortensen 1943; Clark & Rowe 1971; Schultz 2006). This genus is comprised of seven extant and one fossil species. Four of the extant species (*T. decipiens, T. reevesii, T. apodus* and *T. michaelseni*) possessing an eccentric anus and a large suranal plate were initially included under subgenus *Toreumatica* Gray, 1855 (*sensu* Coppard *et al.* 2005). Recently, the subgenus *Toreumatica* has been accepted as the genus *Temnopleurus* (Kroh 2012). Among these, *T. decipiens* is one of the least studied species in respect of its biogeographical distribution (Clark & Rowe 1971) due to limited occurrence. The present study records the occurrence of *T. decipiens* for the first time from the Indian coast. The present finding assumes significance as it not only updates information about a rare echinoid species but also extends its known geographical range to the central Indian Ocean. Our observation reveals the occurrence of two species of the genus *Temnopleurus* (*T. decipiens* and *T. toreumaticus*) in the near-shore waters of Goa. Review of published literature (Mortensen 1943; Clark and Rowe

TABLE 3. — Comparison of morphological characteristics of all seven extant species of the genus *Temnopleurus* L. Agassiz, 1841. Abbreviations: **1**, Mortensen 1943; **2**, Schultz 2006; **3**, de Meijere 1904; **4**, Clark 1912; **HTD**, horizontal test diameter.

Morphological characters	Position of the anus	Suranal plate	Sutural pits near peristome	Pore-pair arrangement	No of buccal plates	Banding on spines	Relative length of spine to HTD	Ref.
T. toreumaticus	Subcentral	Absent	Inconspicuous	Arced	10	Red or brown	> ½ HTD	1, 2
T. hardwickii	Subcentral	Absent	Inconspicuous	Straight series	10	Absent	< ½ HTD	1, 2
T. alexandri	Subcentral	Absent	Inconspicuous	Arced	10	Absent	< ½ HTD	1, 2
T. decipiens	Eccentric	Present	Conspicuous	Straight series	10	Purple or red	> ½ HTD	1, 3
T. apodus	Eccentric	Present	Inconspicuous	Arced	5	Absent	> ½ HTD	1, 4
T. reevesii	Eccentric	Present	Conspicuous	Straight series	10	Absent	< ½ HTD	1, 2
T. michaelseni	Eccentric	Present	Inconspicuous	Straight series	10	Absent	< ½ HTD	1, 2

1971; Coppard *et al.* 2005; Smith 2005; Schultz 2006) suggests morphological differences between these species in respect of position of the anus within the periproct and the presence of a suranal plate. However, we were able to discern marked differences in respect of sutural pits near the peristome and two morphometric ratios, % of AD to HTD and ratio of spine length to HTD (Table 2). Further, comparison of *T. decipiens* with its original description by de Meijere (1904) revealed that the present specimens differed from the type specimen with respect to size, and the position of ocular plate with respect to periproct margin. Therefore, our observations suggest that the size of *T. decipiens* ranges from 5 to 21 mm, and the position of the ocular plate with respect to periproct margin vary within the species.

A comparative analysis of the extant species of the genus *Temnopleurus* (Clark 1912; Mortensen 1943; Clark & Rowe 1971; Coppard *et al.* 2005; Smith 2005; Schultz 2006) was carried out using seven morphological parameters (Table 3). This analysis suggested that apart from the structure of periproct, arrangement of sutural pits and ambulacral pore-pairs, the number of tubercles on the plate also varies between the species of genus *Temnopleurus*. In this context, a revised taxonomic key to all the extant species of the genus *Temnopleurus* is provided with two additional characters: the primary tubercle count and relative spine length, to differentiate between the congeners. However, the fossil species *Temnopleurus latidunensis* Clegg, 1933 was not taken into consideration for taxonomic comparison as the description lacked details of the structure of the periproct and the spines (Kroh *et al.* 2011).

CONCLUSION

In summary, the present study reveals the first record of *T. decipiens* from the Indian waters, and an attempt has been made to compare its morphology with its congeners. Further, molecular studies pertaining to the nucleic acid homology would decipher phylogenetic and intra-species variability among this group.

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An updated inventory of new records of coastal macrofauna along Goa, west coast of India

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An assessment of demersal macrofauna for 7 years (2005-2011) through continuous survey (250 trawls, 4 beach seines) with total effort of 424 hours along the bay estuarine and nearshore waters of Goa, yielded 84 new records for the region. Among these, *Charybdis* (*Charybdis*) *goaensis* was new to science. In addition, two species (*Thysanophrys armata* and *Callionymus sublaevis*) were found to be first records for the Indian waters, seven were new to the West coast of India and 74 others were new reports for this region.

[**Keywords:** New records, Macrofauna, Diverse habitat, Goa, West coast]

Introduction

Studies pertaining to the diversity of coastal macrofauna from the estuarine and shelf waters of Goa[1,2,3,4,5,6] were focussed on reporting commercial species, thereby creating lacunae on occurrence and distribution of rare and non-commercial species from this region. Hence, the establishment of a comprehensive database on the demersal marine fauna was pertinent in order to provide a platform towards improved understanding of the coastal biodiversity of Goa. Present study primarily attempts to provide baseline information on the species composition of coastal macrofauna through intensive sampling and subsequent creation of an inventory of all the components of the demersal community.

Materials and Methods

Present study area (Fig. 1) comprised two coastal regions namely (1) Nearshore fishing grounds (sand-silt substratum) up to 25 m depth. Regions of Mandovi-Zuari estuaries (15°32'N - 15°28'N latitudes and 73°45'E - 73°57'E longitudes with clayey substratum) and adjacent Aguada - Mormugao bays with mixed substratum interspersed with submerged rocky patches. (2) Nearshore fishing grounds down upto 25 m depth located off the mouth of the Sal estuary (15°00'N - 15°16'N latitudes and 73°41'N - 74°00'E longitudes). Coastal bathymetry along the northern side of the estuary is primarily silt, whereas towards the south it is marked with submerged rock outcrops.

The nearshore trawl operations were carried out on a fortnightly basis during February 2006 – November 2008 and November 2010 – February 2012 off North Goa, and January 2009 – January 2012 off South Goa with exception of the South-west monsoon season.

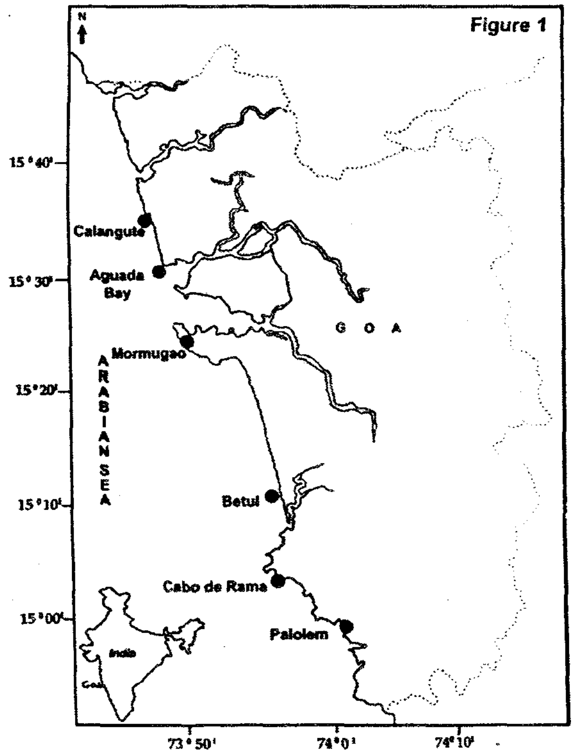

Fig. 1—Map showing sampling locations

Table 1—New records along with their habitats from Goa, West coast of India

Sr.No.	Species	Habitat
51	*Pempheris molucca* Cuvier, 1829[5,‡]	Coral reef/Rocky
52	*Dendrophysa russelii* (Cuvier, 1829)[5,‡]	Rocky
53	*Johnius amblycephalus* (Bleeker, 1855)[5,‡]	Muddy soft bottom
54	*Johnius carutta* Bloch, 1793[5,‡]	Muddy/Estuary
55	*Johnius coitor* (Hamilton, 1822)[5,‡]	Muddy/Estuary
56	*Epinephelus coioides* (Hamilton, 1822)[5,‡]	Coral/Sandy/Mangrove
57	*Epinephelus erythrurus* (Valenciennes, 1828)[5,‡]	Rocky/Coral reef
58	*Sparidentex hasta* (Valenciennes, 1830)[5,‡]	Rocky/Coral reef
59	*Pomadasys furcatus* (Bloch & Schneider, 1801)[5,‡]	Soft bottom/Coral reef
60	*Plectorhinchus gibbosus* (Lacepede, 1802)[5,‡]	Rocky/Coral reef
61	*Plectorhinchus schotaf* (Forsskal, 1775)[5,‡]	Rocky/Coral reef
62	*Yongeichthys criniger* (Valenciennes, 1837)[5,‡]	Muddy/Coral reef
63	*Parachaeturichthys polynema* (Bleeker, 1853)[5,‡]	Muddy/Coral reef
64	*Oxyurichthys paulae* Pezold, 1998[5,‡]	Muddy coral reef
65	*Callionymus japonicus* Houttuyn, 1782[5,‡]	Sandy/coral reef
66	*Callionymus sagitta* Pallas, 1770[5,‡]	Muddy/Mangrove/Estuary
67	*Eurycephalus carbunculus* (Valenciennes, 1833)[5,‡]	Muddy bottom
68	*Cynoglossus dispar* Day, 1877[5,‡]	Muddy bottom
69	*Synaptura albomaculata* Kaup, 1858[5,‡]	Muddy bottom
70	*Brachirus orientalis* (Bloch & Schneider, 1801[5,‡]	Coral reef/Sandy bottom
71	*Acreichthys hajam* (Bleeker, 1851)[5,‡]	Coral reef
72	*Odonus niger* (Rüppell, 1836)[5,‡]	Coral reef
73	*Diodon hystrix* Linnaeus, 1758[5,‡]	Coral reef
74	*Lactoria cornuta* Linnaeus, 1758[5,‡]	Rocky/Coral/ Sea grass
75	*Triacanthus nieuhofii* Bleeker, 1852[5,‡]	Sandy bottom
76	*Takifugu oblongus* (Bloch, 1786)[5,‡]	Estuary/Coral reef
77	*Arothron immaculatus* (Bloch and Schneider, 1801)[5,‡]	Sea grass
78	*Tetraodon fluviatilis* fluviatilis (Hamilton, 1822)[5,‡]	Estuary/Muddy bottom
79	*Arius subrostratus* Valenciennes, 1840[5,‡]	Muddy bottom
80	*Nemapteryx caelata* (Valenciennes, 1840)[5,‡]	Muddy bottom
81	*Netuma bilineata* Valenciennes, 1840[5,‡]	Muddy bottom
82	*Muraenesox bagio* (Hamilton, 1822)[5,‡]	Estuary/Mangrove
83	*Gymnothorax pseudothyrsoideus* (Bleeker 1853)[5,‡]	Coral reef/Muddy bottom
84	*Trachinocephalus myops* (Forster, 1801)[5,‡]	Sandy bottom/coral reef

[1]Padate *et al.* 2010a, [2] Padate *et al.* 2010b, [3]Padate *et al.* 2012, [4]Kumbhar and Rivonker, 2012 [5]Present study, *New to science, [δ]New to Indian waters, †New to west coast of India, ‡New to Goa coast

intensive sampling effort (424 hrs) and a focused approach to look at the rare species that enabled to uncover large number of species. Present study conducted sampling along diverse habitats such as bay-estuarine (mangrove dominated) and nearshore waters marked with various substrata (silt, sand, clay, submerged rocks). Further, published reports[26] suggest the existence of coral reef in vicinity of fishing grounds of Goa. Observations made in the present study also revealed coral reef inhabitant species (n = 20) in the nearshore trawl catches. In addition, the occurrence of red bellied yellow tail reef fusilier *Caesio cuning* in the nearshore trawl catches suggested the existence of coral reef patches in the vicinity of fishing grounds. Further, presence of artificial structures such as the grounded vessel *MV River* Princess enabled habitation by a wide array of demersal reef fish through provision of niches in the form of platform and crevices[23] probably might have played marked role in augmentation of diversity of coastal waters.

It is imperative from the data collected during the above period that sizable information coupled with reporting of new records has enabled to create a stronger database from this region. Hence, it appears mandatory that continuous monitoring of these coastal habitats needs to be carried out to generate a much better inventory in recent times.

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