Seasonal variations in habitat selection and catch trends of Sciaenids (Family: Sciaenidae) from the tropical waters off Goa, west coast of India

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Seasonal variations in species composition, habitat selection and catch trends of sciaenids off Goa, west coast of India were investigated for twelve seasons from 2006-2011, with the exceptions of June-September (monsoon). Present observations based on 248 hours fishing effort (186 trawl operations) revealed 14 species of the family Sciaenidae. Sciaenid abundance ($\alpha = 0.05$, $P = 0.03071$) and weight ($\alpha = 0.05$, $P = 0.1426$) was significantly higher during pre-monsoon than the post- monsoon season with an exception of post-monsoon 2009. Analysis of spatial variation revealed that sciaenid abundance varied significantly ($\alpha = 0.05$, $P = 0.0593$) between sandy and rocky habitats with dominance of juveniles and adults respectively. Dominance of juvenile population along sandy regions irrespective of the season indicates perennial recruitment and emphasizes the importance of the near shore sandy regions as potential nursery grounds. An assessment of sciaenid landings of Goa (1969-2004) revealed significant increase (R=0.709) during the initial phase of post-mechanization (1969-1986) due to increase in fishing effort and expansion of the demersal fishery to deeper waters. In contrast, marginal decrease during 1986-2004, despite the elevated fishing effort, suggested reduced resilience of the sciaenid populations in the region towards seasonal hypoxia and sustained fishing pressure, with a slow recovery rate.

[**Keywords:** Coastal waters, temporal variations, fisheries, tropical environment]

Introduction

The family Sciaenidae represents a strongly provincialized worldwide group of near shore fishes containing some 270 extant species[1]. Family is confined to shallow coastal and estuarine environment with few freshwater taxa and open ocean regions and cold extreme temperate zone were effective barriers to distribution of this group[2]. Some species of family Sciaenidae are localized while others have wide range of distribution[3].

Along the Indian coast extensive work has been carried out regarding population dynamics, taxanomy, size class and other aspects of sciaenids[4,5,6,7]. 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[8] and size range distribution is very scanty[9].

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[8, 10], among which the sciaenids constitute a major group that contribute around 10% to the total demersal fish catches of the region[11].

Against this background, the present investigation attempted to address the following questions viz. Are there any significant spatio-temporal variations in the abundance and diversity of sciaenids off Goa? Does habitat play a role in determining the distribution of these fishes? 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?

Materials and Methods

The coastline of Goa is aligned NNW-SSE, faces the Arabian Sea with diverse bathymetry and habitats[12]. Coastal waters receive perennial nutrient-rich freshwater influx from the adjoining estuaries, particularly the Mandovi-Zuari estuarine complex (15°25'N-15°31'N and 73°45'E-73°59'E)[13]. Present study area (Fig. 1) comprised (i)
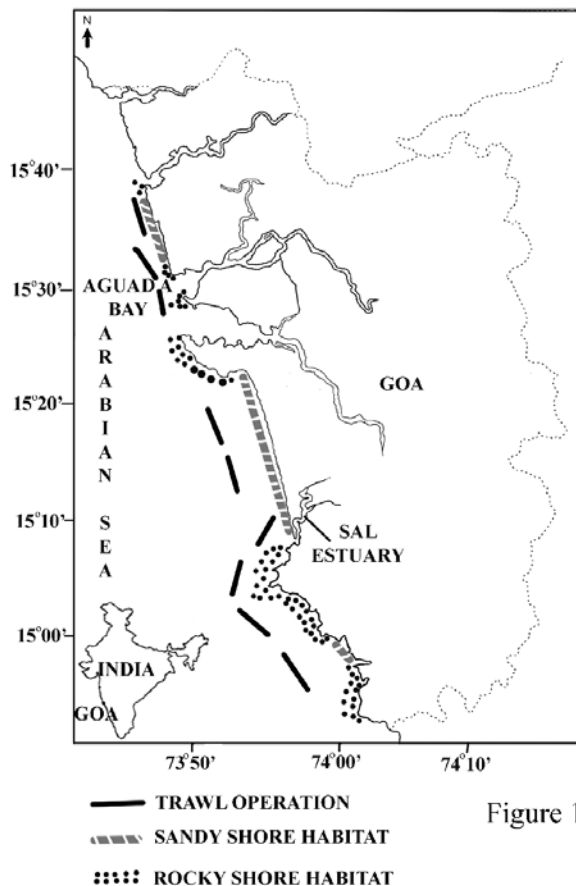
fishing grounds (sand-silt substratum) located off

Fig. 1— Map showing the sampling grounds along the Goa coast

Sinquerim-Calangute shores, lower regions of Mandovi-Zuari estuaries (clayey substratum), adjacent Aguada and Mormugao bays (mixed substratum interspersed with submerged rocky patches) situated between 15°32'N-15°28'N latitudes and 73°45'E-73°57'E longitudes, and (ii) fishing grounds off the mouth of the Sal estuary located between 15°00'N-15°16'N latitudes and 73°41'N-74°00'E longitudes, which comprise two different habitats i.e. silty substratum towards the north and submerged rock outcrops towards the south. 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 estuary[14].

Sampling was carried out during 2006-2011 and comprised 186 bottom trawl hauls with a total effort

of 248 hours. Trawl net with 20 m head and foot rope lengths along with mesh sizes of 25, 15 and 9 mm at mouth end, middle and cod end, respectively was towed at an estimated speed of 2-3 knots. Fish catch obtained from bottom trawls and seines was first examined for species composition. In the case of trawl hauls, five sub-samples, each weighing approximately 1 kg were randomly picked. Out of the 186 trawl hauls, 156 yielded catch in excess of 30 kg, hence only these were subjected to sub-sampling.

Data on species composition and size class was based only on trawl catches, as beach seines did not yield sciaenids. Fish identification involved meristic counts and morphometric measurements up to the nearest 0.01 cm using vernier callipers, whereas the life stage of specimens was determined through comparison of present morphometric data with published data[15]. Relative abundance of each species was expressed as a percentage of the total sciaenid abundance.

Frequency of occurrence of each species in the trawl catches was computed as follows.

$$\%FO_i = (O_i / T_n) \times 100$$

where FO_i - Frequency of occurrence of species 'i', O_i - No. of recurrences of species 'i' in the trawl catches, T_n - total no of trawls taken.

Species abundance and weight data from five sub-samples of each trawl haul were computed as follows.

$$X = [x_1 + x_2 + x_3 + x_4 + x_5] / 5$$

where 'X' mean of five sub-samples, 'x' denotes abundance or weight of a taxon in a sub-sample.

The above data was standardized to 60 minute trawl due to variability in trawling duration and grouped into 'pre-monsoon' and 'post-monsoon' seasons to determine the seasonal variations in abundance of the fishes. Species wise abundance data were normalized using the square root transformation function and plotted using the Surfer-5 software. Comparison between seasons and habitats was done with ANOVA[16] using the Microsoft Excel 2007 program.

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[15]. Sex ratio was defined as the number of males to females.

To study the 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 156 trawls, 88 trawls were operated in the sandy habitat and the remaining 68 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.

In addition, data on sciaenid fish landings and fishing effort (number of mechanized vessels) for Goa from 1969-2004[11] were analyzed.

Results

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 1). Relative abundance values were the highest for *Otolithes ruber* (47.23 %) followed by *Johnius borneensis* (18.60 %), *Otolithes cuvieri*
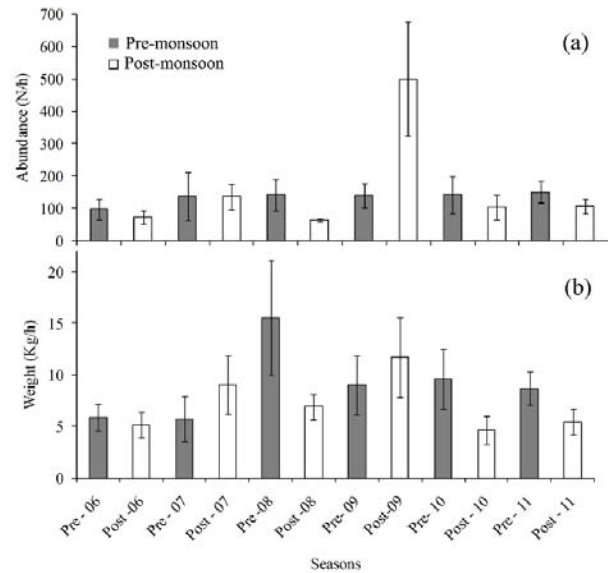

Fig. 2— Seasonal variation of abundance.hr^{-1} and weight (kg hr^{-1}) of sciaenids during present study (Pre: Pre-monsoon; Post: Post-monsoon).

Table 1— Species composition of family Sciaenidae along the coast of Goa, west coast of India.

Sl. No.	Species	N	Relative abundance	FO (%)	Size range (cm)	Sex ratio (M:F)	L$_m$ (cm)	Juvenile: Adult ratio
1	*Daysciaena albida*	2	0.079	0.69	12	0:100	23.3	100:0
2	*Dendrophysa russelii*	4	0.15	1.40	8-14	50:50	11.5	50:50
3	*Johnius amblycephalus*	36	1.42	8.00	3-10	50:50	15.0	100:0
4	*Johnius belangerii*	36	1.23	2.10	7-9	44:56	9.0	17:83
5	*Johnius borneensis*	470	18.60	41.00	5-18	53:47	15.9	71:29
6	*Johnius carutta*	38	1.50	4.80	10-20	85:15	14.0	79:21
7	*Johnius coitor*	42	1.66	4.80	8-22	86:14	10.6	45:55
8	*Johnius dussumieri*	156	6.18	11.30	5-20	45:55	11.5	18:82
9	*Johnius elongatus*	64	2.53	9.00	3-20	38:62	18.5	71:29
10	*Kathala axillaris*	18	0.71	3.40	6-16	56:44	16.9	100:0
11	*Nibea maculata*	2	0.079	0.69	5-15	0:100	18.0	100:0
12	*Otolithes cuvieri*	436	16.92	31.01	5-30	53:47	23.3	96:4
13	*Otolithes ruber*	1198	47.23	74.00	5-34	55:45	22.6	7:21
14	*Pennahia anea*	54	2.14	4.90	5-18	57:43	14.0	64:36
	Total sciaenids	**2256**	-	-	-	**54:46**	-	**78:22**

(16.92 %) and *Johnius dussumieri* (6.18 %); the values for the remaining ten species were less than 5 % each (Table 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 1).

Analysis of temporal variations revealed that sciaenid abundance ($\alpha = 0.05$, $P = 0.03071$) and weight ($\alpha = 0.05$, $P = 0.1426$) were significantly higher in the pre-monsoon than the post monsoon season (Fig. 2 a, b). An exception to this trend was observed during post-monsoon 2009 (Fig. 2a), due to the occurrence of large number of juveniles in December 2009. The dominance of juveniles in December 2009 is validated by the less weight of

sciaenids despite higher abundance during this season. The other exception to the trend was observed during pre-monsoon 2008 (Fig. 2b), when the sciaenid weight was markedly high despite of less abundance owing to the occurrence of large number of adults.
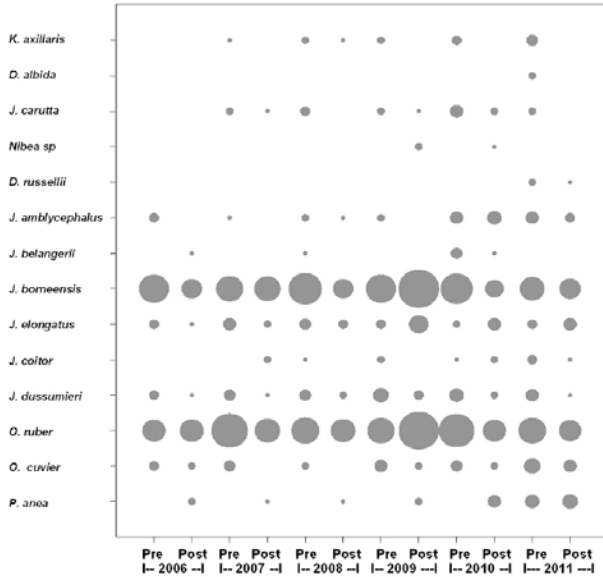

Fig. 3— Seasonal variation in abundance of sciaenids (Pre: Pre-monsoon; Post: Post-monsoon).
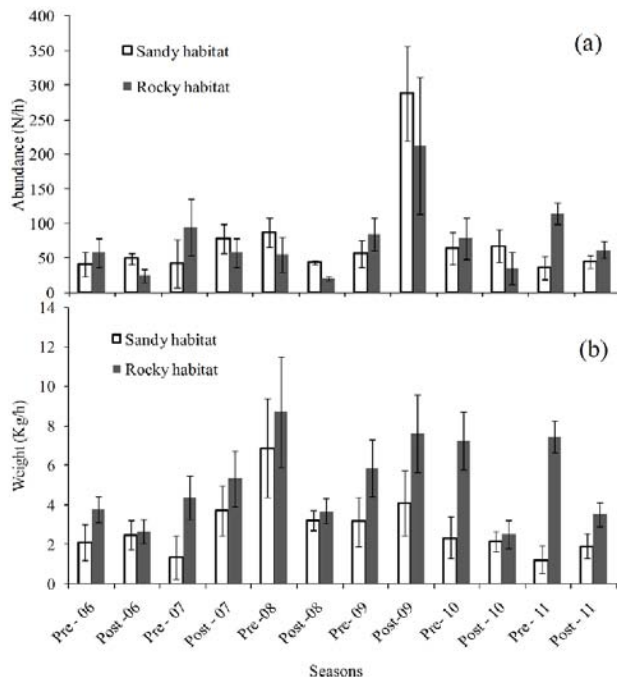

Fig. 4— Spatio-temporal variations in (a) abundance (number hr^{-1}) and (b) weight (kg hr^{-1}) of sciaenids (Pre: Pre-monsoon; Post: Post-monsoon).

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 (Fig. 3). All the above species displayed comparatively higher abundances during the pre-monsoon than the post-monsoon season (Fig. 3). 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 *K. 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.

Total sciaenid abundances were observed to differ significantly between the sandy and rocky habitats (ANOVA, α = 0.05, P= 0.0593). Sciaenid catches were comparatively higher in rocky habitats during the pre-monsoon season, except pre-monsoon 2008. On the other hand, their abundances were comparatively higher in sandy habitats during the post-monsoon season, except post-monsoon 2011 (Fig. 4a). 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 (Fig. 4b).

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 (Fig. 5). Among these, five species namely *Nibea maculata*, *J. carutta*, *J. coitor*, *J. belangerii*, *Daysciaena albida* and *K. axillaris* occurred only in rocky habitats (Fig. 5). 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 (Fig. 5).

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 % adults. Species wise data (Table 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,*

Fig. 5— Temporal variations in species abundance of sciaenid among sandy and rocky habitats.

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 1). Sex ratio for all the fish specimens was 54:46. Species wise sex ratios are provided in Table 1.

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 (Fig. 6), 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 (Fig. 6). 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 (Fig. 6).
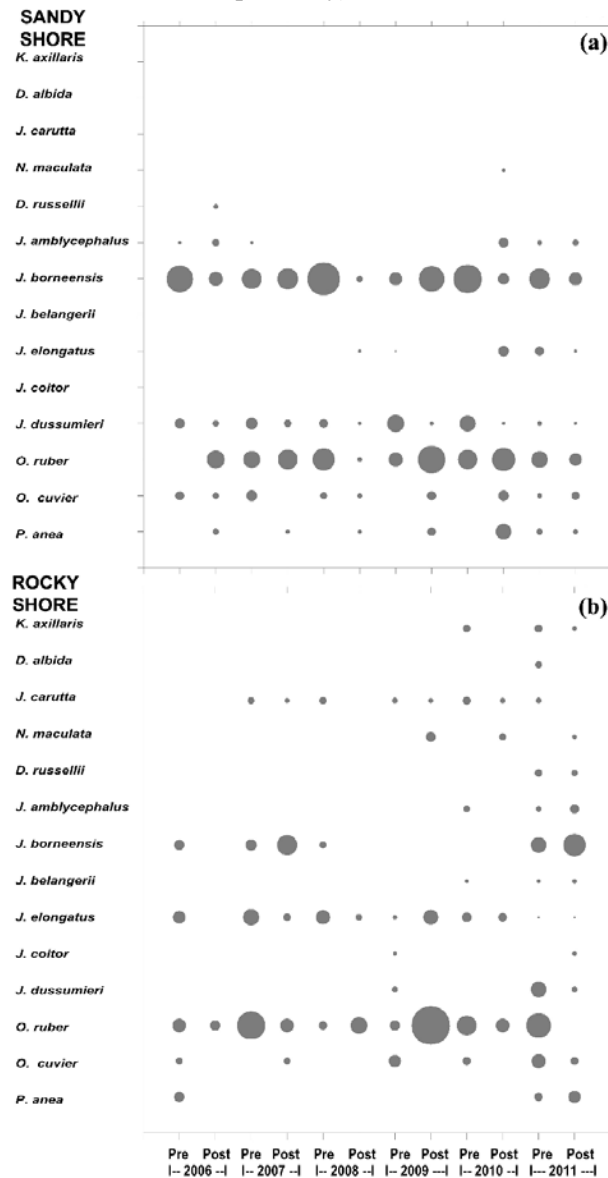
Discussion

Sciaenids are among the major groups of demersal fishes that contribute approximately 10-12 % to the total marine fish landings of Goa[17]. Despite the commercial importance of sciaenids, only few studies focus on their species composition and temporal variations[8, 10]. Therefore, there exist lacunae in the understanding of the spatial-temporal variations in the distribution and population dynamics of sciaenids, with implications for fishery management practices.

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 reported only eleven species of sciaenids from the bay-estuarine waters in the region[5, 8, 10]. The greater number of species observed during the present study could be attributed to a larger fishing effort of 248 hours involving intensive sampling (186 trawls) that encompassed diverse near shore and estuarine habitats. Fishbase[15] suggested that these species are among the common inhabitants of estuarine and near shore shelf waters in the Indo-Western Pacific regions. The shelf waters off Goa are highly productive[18] and known to support wide array of prey including demersal teleosts and epi-benthic invertebrates[8, 14]. Secondly, the habitat heterogeneity

within the coastal ecosystems[12, 19] provides suitable niches for various sciaenid species.

Estimation of relative abundance 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[15] and the high catches off Goa coast could be due to sampling in coastal and estuarine waters less than 25 m depth.
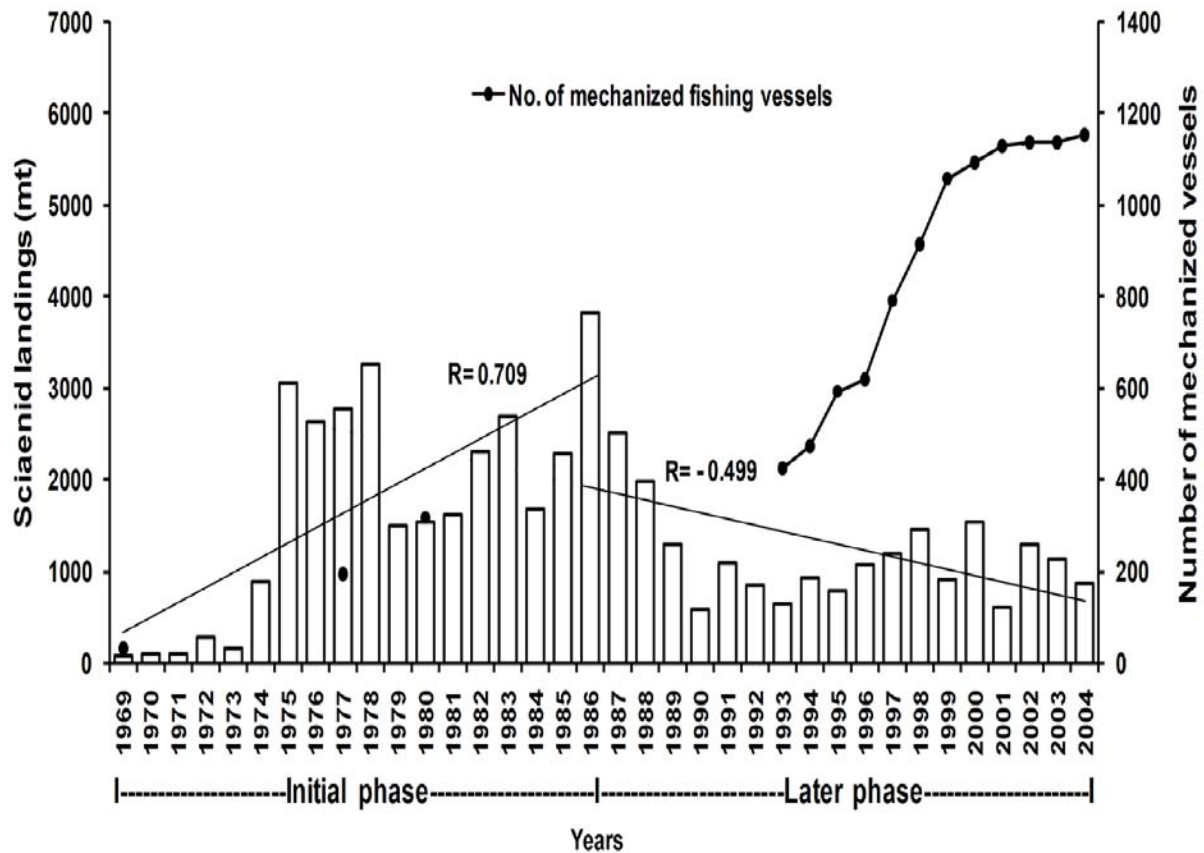

Fig. 6— Catch trends in sciaenid landings (1969 to 2004) and the fishing effort in the study area.

However, published literature[3, 9, 20] reported that *O. cuvieri* was the most abundant 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 (< 5%) of other species (Table 1) could be attributed to the transient nature of their populations in the shallow coastal waters[8]. 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[8]. With regards to the other species, low % FO values (< 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. 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 [21, 22]. 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[9, 15]. These fishes undertake amphidromous migration due to their dependence on the estuarine waters as nursery grounds[23]. 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[8, 24]. Higher species richness during the pre-monsoon season may be attributed to the occurrence of both resident and quasi-resident species[25]. Similar variations in the population of demersal fishes have been reported from the coastal waters along the west coast of India[8]. 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. On the other hand, the structural complexity of the rocky substratum might obstruct the formation of large shoals. The marginal differences in species abundances recorded for different habitats with respect to the different seasons indicated that most sciaenids do not exhibit seasonality in habitat selection due to habitat patchiness and perennial prey availability[25]. 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 for 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[26] coincide with the spawning period of sciaenids[9]. 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[27]. 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. It is opined[28] that efforts to maximize sustainable yield could result in prolonged declines in fish catches, and that recovery of highly fished stocks could take longer owing to reduced resilience towards increased fishing pressure.

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. 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.

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