



Catch trends of bottom trawl fauna with an emphasis on prawns and stomatopods, off Goa, India

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Catch trends of bottom trawl fauna off Goa, India were investigated at fortnightly intervals from February 2006 – May 2008 with the exception of June – October months (monsoon). Inter-comparison of faunal abundance data obtained during February to April months of 2006, 2007 and 2008 indicated that abundance during 2006 and 2008 were significantly higher as compared to 2007. Available fish landing data for the region also corroborated this trend. The dominance of sub-adults among stomatopods during post-monsoon season (November – January), juveniles and sub-adults among prawns during pre-monsoon (February – May), indicated recruitment to the fishery. Comparison with 40-year-old published data indicated significant reduction in the overall yield ($P = 0.043$; $\alpha = 0.05$). Additionally, yields of 12 out of 15 fish groups across the demersal trophic spectrum decreased significantly ($P = 0.031$; $\alpha = 0.05$). However, catches of miscellaneous species increased 17 times, and were dominated by pufferfishes. The profusion of pufferfish is attributed to the perennial breeding habit of these fishes combined with increased removal of potential predators such as sharks and catfishes. Marine Trophic Index (MTI) and Fishing-in-Balance Index (FiB) decreased at rates of 0.017 and 0.016 per decade, respectively, implying that sustained fishing pressure over the next few decades could lead to potential trophic cascade and dominance of resilient opportunistic species such as puffers.

[**Keywords:** Catch composition, Demersal, Fishing pressure, Marine, Temporal variation]

Introduction

The faunal composition in the trawl catches especially from the tropical waters represents a diverse community structure comprised of vertebrates and invertebrate population¹. These communities are exposed to an array of dynamic coastal processes that regulate their biological realms and such events have potential applications in fisheries management². Enormous demand for demersal fish and shellfish is apparent from the recent figures that suggest their growing contribution to the global mechanized fishery³. However, indiscriminate exploitation, pollution and habitat loss have led to reduction of population stocks of several species⁴. Moreover, uneven weather patterns owing to recent climatic phenomena also affect the productivity of the oceans, thus influencing their occurrence and distribution⁴. Therefore, it is imperative to assess the temporal variations of demersal faunal catches in order to elucidate the combined effects of climatic changes and exploitation on their populations. Further, an

evaluation of the catch trends on decadal scale would enable to comprehend the magnitude of loss caused by indiscriminate fishing.

Moreover, a review of published literature on the demersal fish communities from the Indo-Pacific regions⁵⁻⁹ revealed distinct variations in species composition with season and depth, suggesting that the species composition is determined by variations in the coastal bathymetry, weather conditions, tidal action, and periodicity of spawning and recruitment. The coastal fishery off Goa on the west coast of India is supported by a wide array of demersal fishes and invertebrates¹⁰. The fish community therein is characterized by marked temporal variations in species composition, quantity and diversity⁸. However, no attempts have been made to describe the temporal variations of epi-benthic macro-invertebrates, thereby leaving large lacunae in the understanding of demersal trawl community.

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

1. Are there any significant temporal variations in the quantity (abundance) of the major trawled organisms, namely penaeid prawns and stomatopods, off Goa?
2. Which are the factors responsible for such variations?
3. Are there any variations in the trawl catch composition off Goa over the last forty years, and what are the probable implications of such variations on the coastal ecosystem?

Materials and Methods

Goa with a 105 kilometres coastline is characterized by diverse habitats^{11,12}. This region receives maximum precipitation during the southwest monsoon *i.e.* June-September⁸. The largest estuarine network in the region namely the Mandovi-Zuari estuarine complex supports a large number of economically important species⁸. Intensive fishing is carried out by mechanized and traditional crafts in the coastal fishing grounds off Goa^{8,10,13}. Release of untreated sewage¹⁴, mining spills, and aquaculture sludge into the coastal waters pose major threats to the marine biota. Moreover, ballast water exchange and dredging activities in the vicinity of the Mormugao Port are potential threats to the marine food web and benthic habitat structure¹⁵.

The present study area comprised of 20 m transect off Calangute beach (Fig. 1) as this fishing ground is

known to yield one of the highest fish catch rates off Goa along with high proportions of prawns and stomatopods¹⁰. The present observations were carried out along this region to enable comparison with earlier published literature¹⁰.

Seasons were defined as monsoon (June – September), post-monsoon (October – January) and pre-monsoon (February – May) following Ansari *et al.*⁸. Sampling consisted of five trawl hauls per month, each haul of 1 – 2 h duration on-board a 9 m long, single day commercial trawler. A total of 75 hauls were taken during February – April 2006, December 2006 – May 2007, November 2007 and January – May 2008 with a total effort of 137 hours. A four-seam nylon trawl net with mouth end and cod end mesh sizes of 15 and 9 mm, respectively, was towed at approximately 2 knots (4 km h⁻¹) speed. After hauling, the catch was segregated into pre-determined faunal groups following Prabhu & Dhawan¹⁰, and each group was weighed for further analysis.

Fauna was identified by morphological, meristic and morphometric methods aided by published literature¹⁶⁻²¹. For the purpose of quantitative analysis of trawl catch data, the fauna was classified to the species level, whenever possible.

Abundance trends of trawl catches were assessed by dividing the entire study period into five sampling seasons namely Pre-monsoon 2006 (February – April 2006), Post-monsoon 2006 (December 2006 –

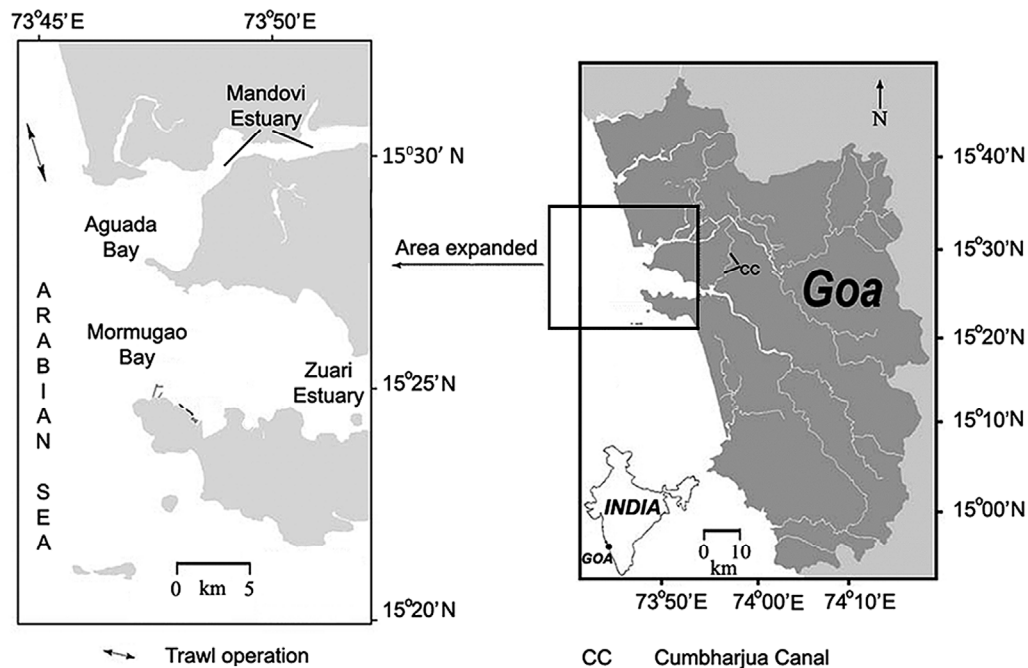


Fig. 1 — Map indicating sampling sites off Goa, central west coast of India

January 2007), Pre-monsoon 2007 (February – May 2007), Post-monsoon 2007 (November 2007 – January 2008) and Pre-monsoon 2008 (February – May 2008). Taxa/faunal abundances recorded in each near shore haul were standardized to per hour (*i.e.* numbers h^{-1}) due to variability in the trawl duration. Relative abundances of 37 pre-determined faunal groups were computed for each season. Information on their trophic levels was obtained from Bhathal & Pauly²² and Fishbase²³. Subsequently, seasonal averages of abundance values were derived.

Repeated measures ANOVA using the Wilk's lambda probability distribution was performed on abundance data to test the Null Hypothesis (H_0) that "There is no difference in faunal abundance between the years 2006, 2007 and 2008". Abundance data for prawns, stomatopods and total catch collected during the months of February – April of the years 2006, 2007 and 2008 was selected to perform this analysis due to regular sampling during these months.

Weight (kg) of individual trawl hauls taken in a sampling day were summed up to derive the fishery yield 'X' for that particular day expressed as $\text{kg boat}^{-1} \text{day}^{-1}$. Subsequently, the overall fishery yield was derived as the mean of fishery yield 'X'.

The effects of the demersal fishing on the coastal ecosystems of Goa were evaluated using two ecosystem indicator ratios namely the Marine Trophic Index (MTI)²⁴ and Fishing-in-Balance (FiB) Index²⁵. To aid computation of the MTI, the trophic level values for various fish and invertebrate species/groups were obtained from Bhathal & Pauly²² and Fishbase²³.

Marine fish landing data for Goa for the years 1969 – 2011 was obtained from the Central Marine Fisheries Research Institute website²⁶. Fishing effort data (in terms of number of mechanized fishing vessels) and Maximum Sustainable Yield (MSY) were obtained from Monteiro¹³.

Sea Surface Temperature (SST) and chlorophyll data for the study area were obtained from NASA Earth Observations website²⁷. Subsequently, regression analysis was employed to assess the influence of SST and Chlorophyll concentration on temporal variations of total fauna, prawns and stomatopod abundance.

Results

The number of samples examined for each sampling season are as follows. Pre-monsoon 2006: N = 15; Post-monsoon 2006: N = 10; Pre-monsoon

2007: N = 20; Post-monsoon 2006: N = 10; and Pre-monsoon 2008: N = 20.

Total faunal abundance observed for Pre-monsoon 2006 was $36.675 \times 10^3 \text{ h}^{-1}$. Subsequently, the abundance decreased to $11.481 \times 10^3 \text{ h}^{-1}$ during Post-monsoon 2006 and thereafter increased to $37.820 \times 10^3 \text{ h}^{-1}$ during Pre-monsoon 2008 (Fig. 2).

Repeated measures ANOVA indicated that total faunal abundance during February – April differed significantly between the three sampling years (Wilks' lambda = 0.076, $F(2, 20) = 54.935$, $P < 0.001$, $\eta^2 = 0.924$). Further, pair wise comparisons revealed that total faunal abundance was significantly higher during the years 2006 and 2008 as compared to 2007 ($P = 0.001$ and $P = 0.052$, respectively).

Marine fish landings data for the Goa coast²⁶ revealed that the total landings for the years 2006, 2007 and 2008 were 105539, 97162 and 110508 metric tonnes (mt), respectively. Demersal fish (only finned fish) landings during the above years were 14299, 11505 and 14375 mt, respectively; whereas, crustacean landings for the above years were 2904, 1405 and 5687 mt, respectively.

Abundance of prawns was the highest during Pre-monsoon 2006 ($16.448 \times 10^3 \text{ h}^{-1}$), and subsequently decreased by more than 50 % during the next three sampling seasons, and then increased to $16.097 \times 10^3 \text{ h}^{-1}$ during Pre-monsoon 2008 (Fig. 3; Table 1). Prawns dominated the catches during Pre-monsoon 2006, Post-monsoon 2006, Pre-monsoon 2007 and Pre-monsoon 2008. This is attributed to the highly

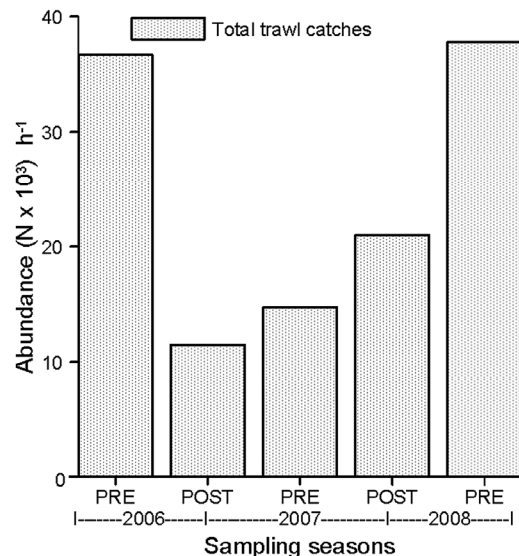


Fig. 2 — Season wise abundance trend of total trawl catches from the near shore trawl catches off Goa

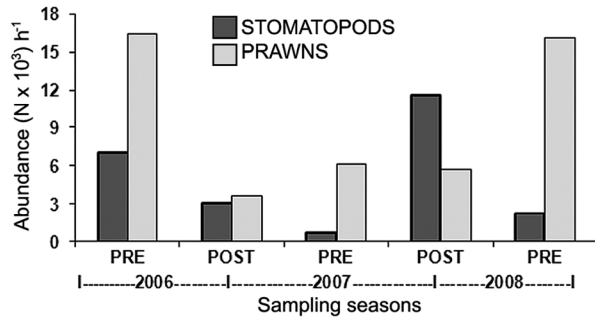


Fig. 3 — Season wise abundance trend of penaeid prawns and stomatopods from the near shore trawl catches off Goa

Table 1 — Season-wise faunal abundance in demersal trawl catches and contribution of prawns and stomatopods

Sampling season	Total faunal abundance (x 10 ³)	Contribution (%)	
		Prawns	Stomatopods
Pre-monsoon 2006	36.675	44.85	19.32
Post-monsoon 2006	11.481	31.30	27.12
Pre-monsoon 2007	14.735	41.41	4.97
Post-monsoon 2007	20.995	27.49	55.04
Pre-monsoon 2008	37.820	42.56	5.92

abundant estuarine prawn *Metapenaeus dobsoni* (Miers, 1878) during all of the above seasons (Fig. 4). *Parapenaeopsis stylifera* (H. Milne Edwards, 1837), an exclusively marine species was the second most abundant species, and occurred mainly during Pre-monsoon 2006, Post-monsoon 2007 and Pre-monsoon 2008 (Fig. 4). *Metapenaeus affinis* (H. Milne Edwards, 1837) was third most abundant, and occurred only during Pre-monsoon 2006 and Pre-monsoon 2008 (Fig. 4).

Prawn abundance during February-April differed significantly between the three years (Wilks' lambda = 0.236, $F(2, 20) = 14.597$, $P = 0.001$, $\eta^2 = 0.764$). However, pair wise comparisons revealed significant inter-annual differences between 2006 and 2007 ($P = 0.001$).

The stomatopods were represented by only one species *i.e.* *Miyakella nepa* (Latreille, 1828). Their abundance decreased from $7.084 \times 10^3 \text{ h}^{-1}$ in Pre-monsoon 2006 to $0.732 \times 10^3 \text{ h}^{-1}$ in Pre-monsoon 2007, followed by a peak in Post-monsoon 2007 ($11.555 \times 10^3 \text{ h}^{-1}$) when they dominated the trawl catches. Thereafter, their abundance subsequently decreased to $2.240 \times 10^3 \text{ h}^{-1}$ in Pre-monsoon 2008 (Fig. 3; Table 1).

Stomatopod abundances recorded during February – April did not vary significantly among the three years (Wilks' lambda = 0.656, $F(2, 20) = 2.365$, $P = 0.15$, $\eta^2 = 0.344$).

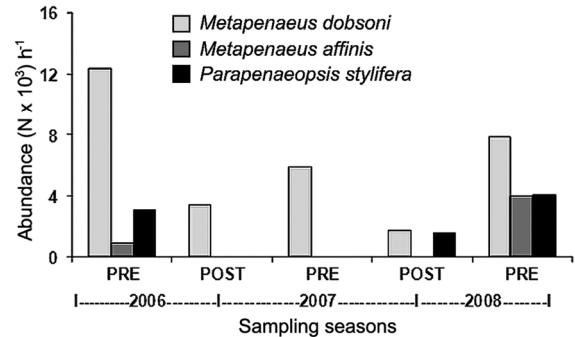


Fig. 4 — Season wise abundance trend of major penaeid prawns (*Metapenaeus dobsoni*, *M. affinis* and *Parapenaeopsis stylifera*) from the near shore trawl catches off Goa

Assessment of trawl catch composition during the five sampling seasons (Table 2) revealed that prawns registered higher relative abundance values during pre-monsoon seasons, whereas stomatopods peaked during the post-monsoon. Assessment of seasonality among other by-catch organisms revealed clear abundance peaks of anchovies, silver bellies and echinoderms (sea stars) during the pre-monsoon season.

MTI values were relatively higher (> 3.0) during Post-monsoon 2006, Pre-monsoon 2007 and 2008, when prawns and stomatopods together constituted 37.62, 37.88 and 37.72 % of the relative faunal abundance, respectively. On the other hand, MTI values were relatively lower (< 3.0) during Pre-monsoon 2006 and Post-monsoon 2007, when prawns and stomatopods together constituted 51.06 and 62.37 % of relative faunal abundance, respectively.

Satellite-derived SST values for the study area ranged between 26.08 and 30.12 °C, those of chlorophyll concentration ranged between 0.23 and 5.73 mg l⁻¹. Correlation between monthly abundances of total fauna, prawns and stomatopods with SST was low ($R^2 = 0.08$, 0.10 and 0.098, respectively). Similarly, correlation between monthly abundances of total fauna, prawns and stomatopods with chlorophyll concentration was also found low ($R^2 = 0.167$, 0.121 and 0.106, respectively).

Total fishery yield (kg boat⁻¹ day⁻¹) as well as yields of 15 fish groups were compared with earlier published data¹⁰ which revealed a decrease from 914.00 kg boat⁻¹ day⁻¹ in 1971 – 72 to 305.40 kg boat⁻¹ day⁻¹ in 2006 – 08. Concomitant to this, a significant decrease ($P = 0.043$; $\alpha = 0.05$) was observed in the total demersal trawl catches in the study area. Further, there was a significant decrease ($P = 0.031$; $\alpha = 0.05$)

Table 2 — Season-wise relative abundance of faunal groups observed in demersal trawl catches and corresponding Marine Trophic Index

Faunal groups	Trophic level	Relative abundance (%)				
		Pre-monsoon 2006	Post-monsoon 2006	Pre-monsoon 2007	Post-monsoon 2007	Pre-monsoon 2008
Prawns	2.51	37.10	23.60	34.17	25.08	27.89
Stomatopods	3.00	13.96	14.02	3.71	37.29	9.83
Brachyura	2.70	8.48	13.08	3.81	4.75	4.65
Anomura	2.70	0.71	0.70	0.90	0.34	0.93
Cephalopods	3.30 - 3.70	2.30	2.10	2.71	1.36	3.59
Gastropods	2.00	0.00	0.00	0.00	0.00	0.66
Bivalves	2.00	0.18	0.00	0.00	0.34	0.00
Echinoderms	3.30	1.24	0.93	5.91	0.00	0.66
Rays	3.58	0.00	0.00	0.00	0.00	0.27
Sharks	4.00	0.53	0.23	0.00	0.34	0.66
Clupeids	2.50 - 3.27	4.24	4.44	6.51	7.12	4.38
Anchovies	3.20 - 3.40	5.12	2.10	5.51	3.05	5.05
Catfishes	3.44	1.94	1.64	4.21	1.36	0.53
Eels	3.84	0.88	2.10	0.80	0.34	1.06
Mulletts	2.42	0.00	0.23	0.00	0.00	0.00
Carangids	3.00 - 4.40	0.88	0.23	0.10	1.02	1.06
Pomfrets	3.20	0.18	0.00	0.10	0.00	0.13
Rabbitfishes	2.80	0.18	0.23	0.10	0.00	0.13
Silver bellies	3.17	9.19	4.21	12.63	2.71	19.26
Whitefish	3.20	1.41	2.80	1.70	1.36	1.99
Threadfin breams	3.53	0.00	2.10	0.40	0.00	0.40
Silver whittings	3.40	0.18	0.00	0.10	0.00	0.13
Barracudas	4.40	0.00	0.23	0.10	0.00	0.53
Threadfins	3.55	0.00	0.00	0.10	0.00	0.40
Croakers	3.50	1.94	3.74	3.71	5.08	4.52
Groupers	3.90	0.18	0.47	0.20	0.34	0.00
Other perches	3.20	1.24	4.44	4.01	0.68	3.45
Scombrid fishes	3.40 - 4.40	0.00	0.70	0.20	0.00	0.40
Ribbon fishes	4.20	2.12	2.80	3.01	2.37	2.26
Sweepers	3.50	0.00	0.23	0.00	0.00	0.00
Dragonets	3.40	0.00	0.23	0.10	0.00	0.00
Flatfishes	3.39	2.30	3.74	1.90	2.71	2.26
Lizardfishes	4.30	0.00	0.70	0.20	0.34	0.13
Codlets	3.30	0.00	0.00	0.00	0.00	0.13
Puffers	3.90	2.83	7.01	2.71	1.36	2.12
Toadfishes	3.60	0.00	0.00	0.10	0.00	0.00
Miscellaneous	3.33	0.71	0.93	0.30	0.68	0.53
MTI		2.944	3.067	3.042	2.997	3.056

in the catches of 12 fish groups namely elasmobranchs, carangids, pomfrets, catfishes, sciaenids, cephalopods, ribbonfishes, flatfishes, clupeoids, false trevally, stomatopods and prawns (Fig. 5). On the other hand, the proportion of miscellaneous species increased 17 times (Fig. 5). Miscellaneous species were characterized by unusually high catches of the half-smooth golden

pufferfish, *Lagocephalus spadiceus* (9.28±15.41 % of total trawl catches). Their proportions reached a peak (47 – 73 %) during January and February of 2007.

The Mean Trophic Index derived for the present data and that of Prabhu & Dhawan¹⁰ were 3.058 and 3.118, respectively. The Fishing-in-balance Index derived for the present data was -0.55 (against a base value of 0 assigned to the earlier data following Pauly

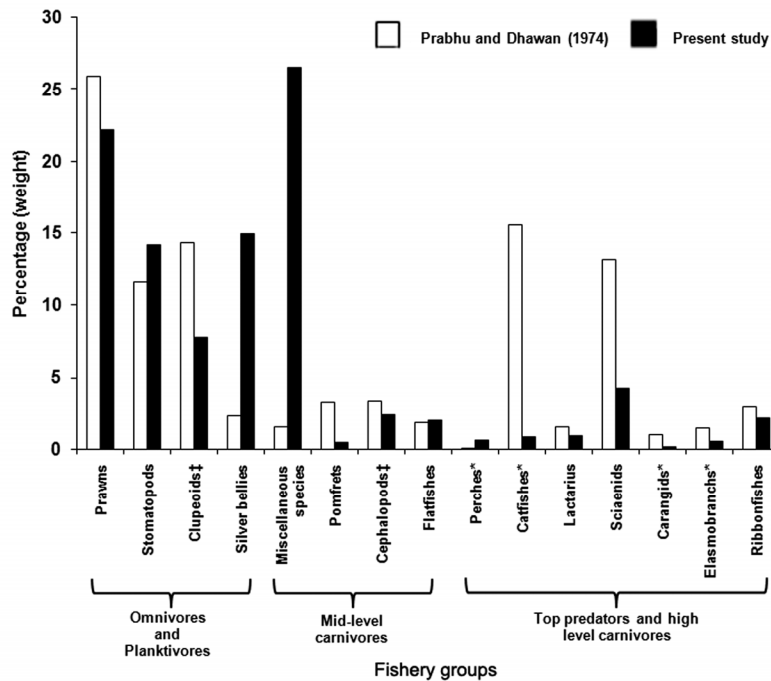


Fig. 5 — Species composition of demersal trawl catches off Goa coast – a comparison with Prabhu and Dhawan (1974)

*et al.*²⁵). Inter-comparison of these data revealed a decrease in both MTI and FiB ratios at the rate of 0.017 and 0.016 per decade, respectively.

Discussion

The present study area is subjected to intense fishing activity through exploitation by commercial trawlers in the near shore trawling grounds off Goa⁸ those overlap with diverse marine habitats^{11,12}. Intensive trawling activity is a potential cause of alteration of the marine habitats of this region, thus exerting enormous anthropogenic pressure on the demersal faunal diversity. However, there is dearth of information on the trends of the commercially exploited crustaceans from the trawl catches in this region^{8,10}. The present study analyzes catches of prawns and stomatopods, together with the overall trawl catch composition and this is further compared to a previous study attempted forty years ago¹⁰.

Penaeid prawns were the most abundant trawl catch organisms and comprised mainly of three species namely *Metapenaeus dobsoni*, *M. affinis* and *Parapenaeopsis stylifera*, which support bulk of the prawn fishery off Goa. The present observations revealed that off Goa, intensive prawn fishing commenced in November/ December and their catches increased up to April/ May. The pre-monsoon catches (during February – May) were marked with a

high proportion of juveniles including those of *M. dobsoni* and *P. stylifera*. On the other hand, the post-monsoon catches comprised of juveniles as well as mature adults of *M. dobsoni* and *M. affinis*.

The life cycle of a penaeid prawn spans two years and comprises of an adult stage which breeds and spawns in the inshore waters. Post-hatching, the planktonic larva undergoes several metamorphoses and attains the post-larval stage, which enters estuarine waters and develops into a benthic juvenile stage²⁸. The juvenile grows in estuarine nurseries, develops into sub-adult stage, which then emigrates back offshore and undergoes further sexual development *i.e.* adult stage²⁹. During the present study, the occurrence of high proportion of juveniles of *M. dobsoni* in the trawl catches suggested that it is a frequent breeder along the Goa coast. Goswami & Goswami³⁰ reported perennial presence of protozoa and mysis larvae of this species in the Mandovi and Zuari estuaries. The above fact suggests that this species breeds in the inshore coastal waters off Goa beyond 30 m depth, and that most juveniles and sub-adults were captured by the trawl net while migrating to breeding grounds from the estuarine nurseries as evident by the size class (45 – 80 mm Total Length (TL)). In the case of *P. stylifera*, catches were dominated by juveniles and small sized adults (45 – 70 mm TL) during the pre-monsoon season as

fishing activity is confined to less than 20 m depth in this season. Intermittent occurrence of mature adults (75 – 90 mm TL) during late January – April suggested that it breeds mostly during pre-monsoon³¹. This species was however not observed in trawl catches during pre-monsoon 2007. This is because *P. stylifera* breeds in the 20 – 30 m depth zone off Goa³¹, whereas during February – May, 2007 much of the trawling activity was restricted to less than 15 m depth. In the case of *M. affinis*, occurrence of mature adults (90 – 110 mm TL) during November – January suggests that it breeds mainly during the post-monsoon season (October – January). On the other hand, the dominance of juveniles during February – May suggests recruitment to the coastal waters (65 – 80 mm TL) during the pre-monsoon season (February – May).

The stomatopods (*M. nepa*) were the second most abundant faunal group and comparatively higher catches were observed in February and December 2006; November 2007 and January – February 2008. During these months, their catches were dominated by sub-adults and large sized adults. In addition, transparent alima larvae were observed during February and March months.

The life span of mantis shrimps comprises of brooding adult, a pro-pelagic larval or burrowing phase, followed by a pelagic larval phase, which subsequently develops into a post-larva. The post-larva settles to the bottom substrate and further develops into juvenile, sub-adult (possessing partially developed reproductive organs) and adult (sexually matured) stages to complete the life cycle³². The life span in stomatopods is highly species specific, and in *M. nepa* it is estimated to be approximately two years³³. This species is known to spawn in the coastal waters during December – October, with peaks during February – April and September – October³³. Subsequently, the alima larvae last for about six months until settlement to substratum³³. Against this background, the occurrence of sub-adults in trawl catches during November – February indicates recruitment to the fishery. Simultaneously, the occurrence of large sized adults suggests aggregation in the coastal waters for spawning. Further, the above aspect is supported by the occurrence of alima larva in February and March.

Remainder of the by-catch fauna comprised mostly of small sized individuals. Abundance peaks of silver bellies and anchovies during the pre-monsoon season

coincided with periods of juvenile recruitment to the coastal waters³⁴. The pre-monsoon season is characterized by a secondary peak in zooplankton production in the coastal waters of Goa³⁵, and the enhanced secondary production attracts a wide array of planktivorous fishes. Moreover, anchovies are known to prey heavily upon juvenile prawns³⁶ that are abundant during the pre-monsoon. On the other hand, abundance peaks of sea stars probably coincide with spawning aggregations in the coastal waters³⁷.

Low correlation between faunal abundance and SST as well as chlorophyll suggests that the occurrence of demersal fish is determined by a combination of several environmental parameters³⁸. Moreover, long-term intensive fishing activities combined with enormous anthropogenic inputs in the coastal regions may probably affect the occurrence and distribution of demersal species irrespective of oceanographic conditions.

Long-term bottom trawling can potentially alter the composition and structure of demersal marine communities³⁹. In view of this, a comparison of the present trawl catch data with earlier published data¹⁰ suggested that yield of trawl catches is reduced substantially mainly due to increased effort in terms of number of mechanized fishing vessels operating in the region¹³. Available data for Goa for the period from 1969-2005^(ref. 26) (Fig. 6) suggested that elevated fishing efforts by mechanized vessels had augmented the marine fish production during the first twenty years (1969 – 1989). In the later phase from 1989 – 2005, there were several fluctuations in fish landing trend and the overall production decreased. Moreover, the increased fishing effort enabled to surpass the Maximum Sustainable Yield (MSY) of 74208 mt in the 1990's¹³. This has invariably resulted in reduced CPUE despite the enormous increase (by 40 times) in the number of mechanized fishing vessels (Fig. 6). Furthermore, after 1994, there has been a significant reduction in the contribution of crustaceans, including penaeid prawns and stomatopods, to the total marine landings of Goa (Fig. 7) that emphasizes the deleterious effects of bottom trawling on groundfish⁴⁰ and crustacean stocks⁴¹.

The presently observed decline in the yield of most of the fish groups across the marine trophic spectrum suggests that elevated fishing efforts during the post-mechanization era by a large fleet of mechanized trawlers had induced changes in the coastal demersal ecosystem⁴². This is evident from the reduced MTI

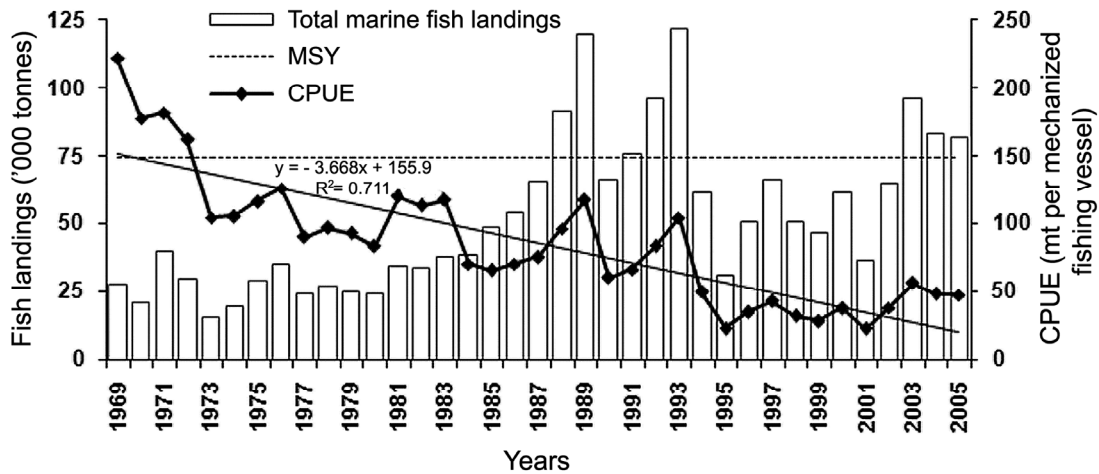


Fig. 6 — Trends of marine fish landings and CPUE (mechanized fishing vessels) for Goa from 1969 – 2005

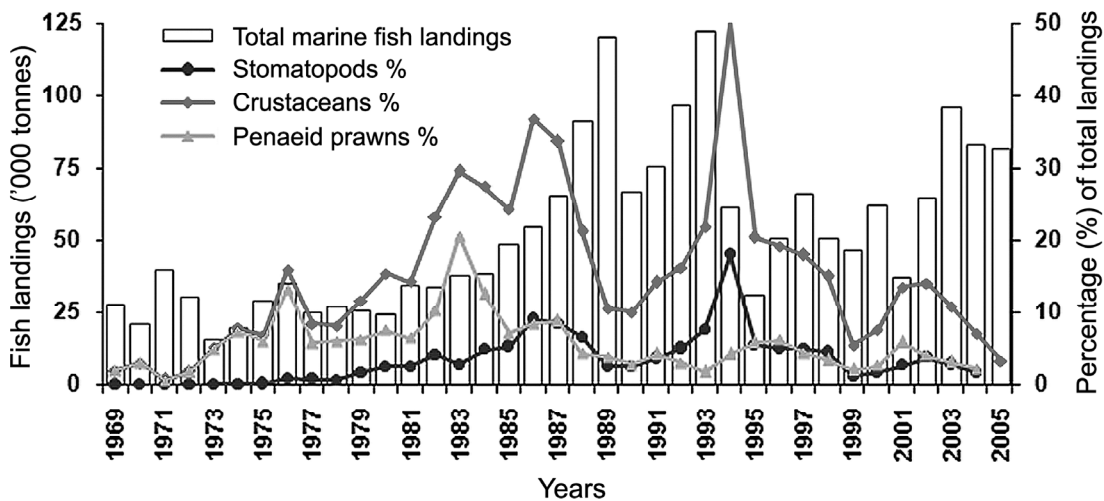


Fig. 7 — Trends of marine fish landings for Goa during 1969 – 2005 along with percentage contribution of crustaceans (including prawns and stomatopods)

and FiB ratios. Bhathal & Pauly²² suggested that a decrease in the FiB index (< 0) reflects large-scale fishery-induced removal of biomass resulting in the impairment of ecosystem function. This implies that sustained fishing pressure over the next few decades could lead to decline of top predators like elasmobranchs (*pers. comm.*) causing profusion of less valuable, opportunistic, mid trophic level organisms. This could be exemplified by the occurrence of large quantities of the pufferfish *Lagocephalus spadiceus* hauled in 2007. This species is a voracious generalist feeder of Indian mackerel, demersal fishes and invertebrates and breeds perennially with two peaks during February – March and September – November⁴³. Further, it is known to contain the toxic compound Tetrodotxin⁴⁴ and is highly unpalatable,

which is an effective deterrent for several predators. Moreover, catches of its wide-mouthed predators such as shark, catfish and cobia are steadily decreasing along the west coast of India⁴⁵. The above condition is extremely favorable for pufferfish as it proliferates and preys on the abundant prey items. Opportunistic species, in the absence of top predators, would probably exert unrestrained predation on low trophic level fishes, thus affecting their stocks⁴⁶.

Conclusions

The present observations suggested that the temporal variations in the trawl catches were largely determined by CPUE. Further, a noticeable change was observed in the yield, catch composition and the trophic level of trawl catch with long-term

consequences for the fishers and policy makers alike. These alterations have undoubtedly arisen from activities such as increased rates of exploitation (mechanized fisheries), coastal pollution (discharge of untreated sewage and mining effluents), habitat destruction and moreover, alterations in land use pattern are rapidly undermining the influence of environmental factors (rainfall and SST) on the coastal ecosystems. The most apparent manifestations of these disturbances are recurrences of extensive harmful algal blooms⁴⁷ and jellyfish aggregations (pers. comm.) in the inshore and estuarine waters of the region. The inferences drawn in this study are based on three years of intensive sampling surveys. Hence, it is suggested that further studies involving long-term monitoring of the trawl catches are necessary to improve the current understanding of the issues pertaining to ecological responses of coastal demersal communities to climate change and increased exploitation.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical Statement

All the authors mentioned in the manuscript have agreed for authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript. The manuscript in part or in full has not been submitted or published anywhere. There is no dataset associated with this manuscript. The study did not involve experiments on live animals.

Author Contributions

VPP: Conceptualization, formal analysis, methodology, and writing; AC: Formal analysis, validation, and writing; and CUR: Conceptualization, formal analysis, funding acquisition, investigation, project administration, resources, supervision, writing - original draft, review & editing.

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