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"The trawl fishery of the Eastern Arabian Sea" (A.P.Dineshbabu) presented at the APFIC Regional Expert Workshop on Tropical Trawl Fishery Management, 30th September - 4th October 2013, Phuket, Thailand

The trawl fishery of the Eastern Arabian Sea

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INTRODUCTION

India is bound by the Indian Ocean on the south, the Arabian Sea on the south-west, and the Bay of Bengal on the south-east. The east coast of India borders Western Bay of Bengal and the west coast borders Eastern Arabian Sea. Though these marginal seas occupy the same latitudinal range, water characteristics exhibit wide difference. This document deals with the trawl fishery of west coast of India, which is forming the eastern border of Arabian Sea. Marine fisheries is an important sector of the nation's economy supporting the livelihood of the millions of fisher-folk inhabiting the long coastline of India and those who are engaged in related activities. The marine fisheries sector in India has witnessed a phenomenal growth during the last five decades both quantitatively and qualitatively. The subsistence fisheries during the early 50's produced about 0.5 million tonnes annually. Indian marine fish production which was fluctuating between 2.3 to 3.3 million tonnes in 1990-2010 reached 3.9 million tonnes by 2012 (CMFRI, 2013). Technological intervention in the mechanized sector with more endurance in sea, better fish finding and geo-positioning equipment, better communication system, better storage facilities and better coverage of far off fishing grounds made its impact in marine fisheries production immensely. Contribution of mechanized sector (formed mainly of trawlers and purse seines) has dominated during last three decades. In the end of 1990s their contribution was around 50% which increased to 65% by 2000 and to 78% in 2012 (3.08 million tonnes).

The trawl catch is showing an increasing trend all along Indian coast, which is contributing highly to the economy of the country. Research programs are being conducted for resources conservation and sustainability of production in trawl fisheries. The changes in fishing technology and catch characteristics, like pelagic trawl introduction, introduction of high speed engines, bycatch issues and juvenile fishery are monitored and discussed in various forums organized by government of India. Such awareness and participatory programs are also yielding socially acceptable solutions for many of the issues. The closure of fishery during monsoon is earnestly followed by the trawl fishery. The debate is going on for introduction of new ban period and/ extension of existing ban period in various fora.

Participatory research program in trawl fishery is also found to yield encouraging results in which progressive fishermen are sharing the spatial data on fishing and catch which enable the researchers to have resource maps of the exploited resources. This also enables identification of critical fishing zones in terms of juvenile and brooder abundance, which in turn serves as an important tool for introduction of spatial restriction in future. Strengthening monitoring, compliance and surveillance (MCS) have been understood as the immediate requirement to monitor implementation of existing policies and new policies to manage marine fisheries. Steps are being taken up to introduce Vessel monitoring system (VMS) which is expected to boost the ongoing efforts for fisheries management.

BACKGROUND INFORMATION

Oceanographic setting

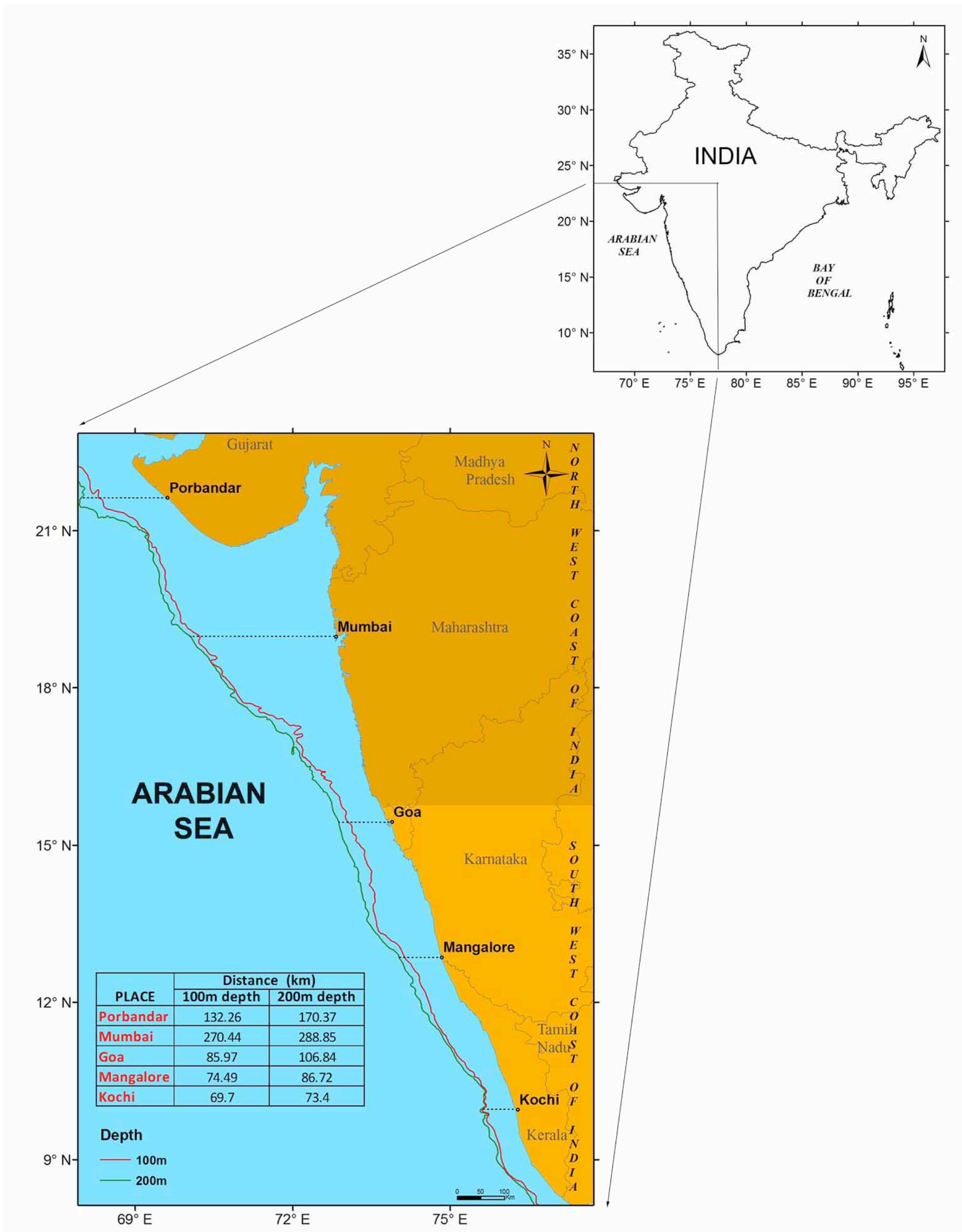
Coastal currents around India change direction with season. From November to January the current off Indian coast, the east India coastal current (EICC) is equatorward all along the cost. It bends around Sri Lanka to flow along the coast of Eastern Arabian Sea as poleward West India Coastal current (WICC). Wind pattern and water circulation in the Arabian Sea are unique when compared with the pattern of similar latitudes. There is a seasonal change in wind north of equator. Winds blow over the equatorial ocean between November and March causing northwest monsoon. From May to September, the system reverses and the southeast trade winds extend across the equator and blow across the northern Indian Ocean as the southwest monsoon. The large inflow of freshwater into the seas around India due to monsoon rainfall over the ocean and run off from rivers causes large changes in salinity.

Seasonal changes in winds induce an annual cycle of hydrographic events along the coast of Eastern Arabian Sea. During the monsoon, southerly currents spread over the entire continental shelf. Isolines of water temperature, salinity, dissolved oxygen (DO) and density lift to the surface (upwelling) and occupy the area between the southerly current and the coast. Consequently dense and cool water with low DO occupies the surface near the coast. During the post monsoon (October-January) there is a strong current with northerly flow. On the seaward side, there exists a southerly flow only in the southern region of the south west coast. During this period, low saline equatorial waters are advected northward causing sinking of high saline Arabian sea water between 10^{O}N and 12^{O}N. During the pre monsoon period (February-May), the northerly current disappears and the southerly flow constricts to the narrow belt. Apart from the upwelling season shelf waters are well aerated.

Physical features

The Indian coast along Eastern Arabian Sea is found to be more productive than the east coast in terms of fish production. Monsoon supported productivity is the major reason for overall high production from the coast. For trawl fishery the physical nature of the substratum is of advantageous nature. In the west coast the shelf break is almost parallel to the 100-200 m depth contour and is away from the coast in the northern part (except near Saurashtra) and close to the coast in the southwestern part of India. The most prominent feature adjacent to the western Indian margin is the Indus cone, one of the largest deep fans in the world. The shelf, having an area of about 310,000 km^2, is divided into two units: inner and outer shelf. The inner shelf is smooth or even with gently sloping topography (gradient 1:800). This even topography occurs down to 55-60 m depth in the north and narrows down to 25 m depth off Cochin. The width of the shelf ranged from 60 – 345 km and water depth at shelf break ranged from 60-140 m. The inner continental shelf off the Gulf of Cambay consists of 6 to 13 m high sand banks (at 8 to 30 m depth).

Fig.1. Physical features of the seas along the coast of Eastern Arabian Sea (west coast of India).

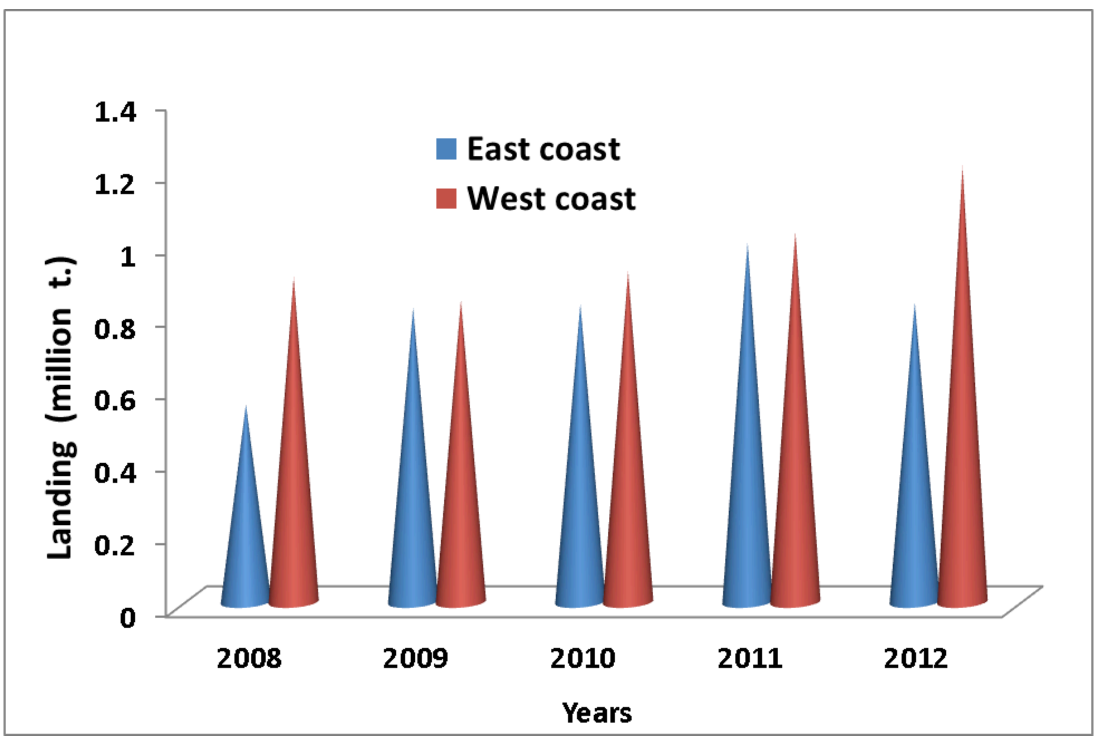


The shelf break is almost parallel to the 100-200 m depth contour and is away from the coast in the northern part (except near Saurashtra) and close to the coast in the south western part of India. Wider continental shelf, when compared with east coast, provides more area for trawling. Off Mumbai more than 270 km from the coast is having depth below 100 m. Figure 1 shows the area available for trawling within 100 and 200 m along the coast of Eastern Arabian Sea. The contribution of northwest coast of India to trawl fisheries production is higher than to that of southwest coast of India.

Mechanised fisheries sector

Trawl is the major mechanized gear being used in India. According to Marine Fisheries Census 2010 (CMFRI,2013), it was estimated that around 35,228 units of trawlers are operating in the country. During 2008-2012, more than 50 % of the marine fish landing in India was contributed by trawl fisheries. Trawl landings of India showed an increasing trend over that last few decades and in 2008-2012 the annual average trawl landing of India was around 1.8 million tonnes. Monsoon driven upwelling is attributed as major reason for this consistent dominance. In 2012 the contribution of the west coast was around 65%. Along the coast of Eastern Arabian Sea the number of trawl units operated crossed 25,000. In 2012 the landings by trawlers along west coast was estimated at 1.1 million tonnes.

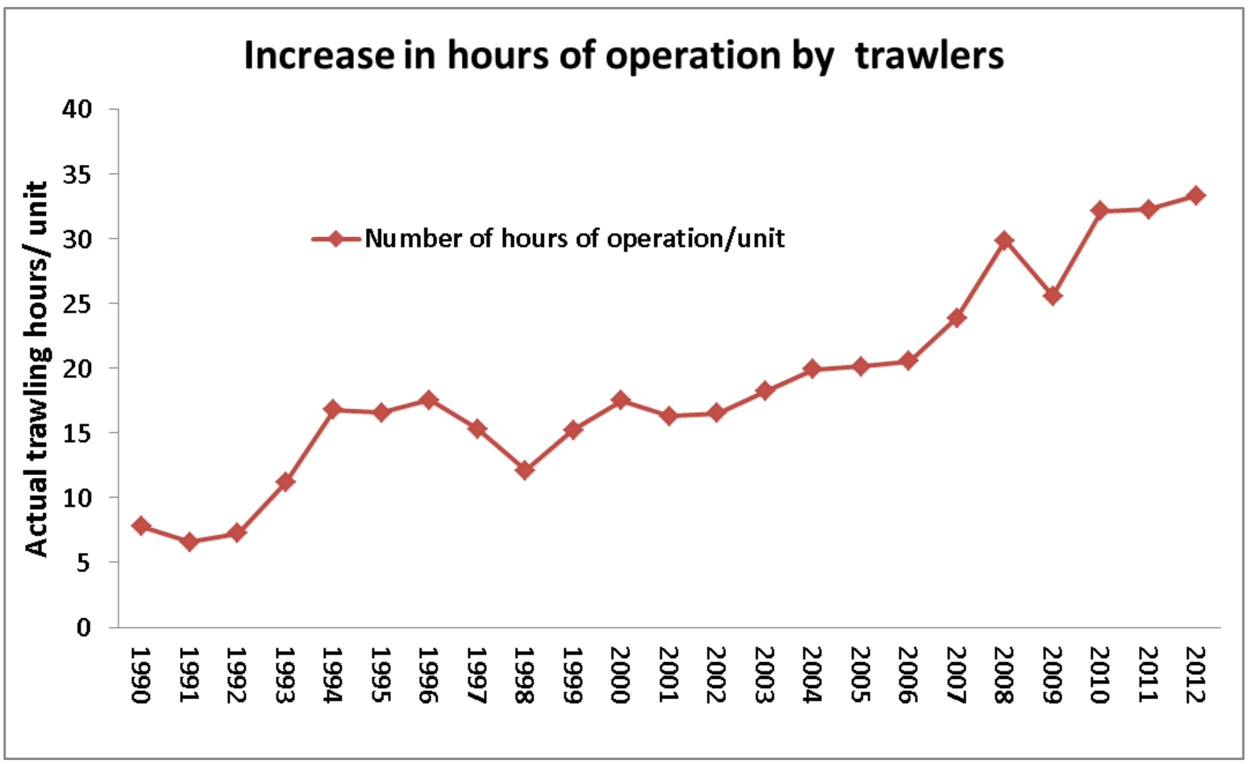
Fig.2. Trawl landings along the east and west coasts



Trawl fleet

The genesis of trawl fishery along the coast of Eastern Arabian Sea commences with the introduction of few boats by the erstwhile Indo-Norwegian project in 1953. During the last 60 years changes have occurred especially in the depth of operation, hours of operation per fishing trip and species composition of the landings. In southwest coast of India, in the early sixties the depth of operation was up to 10-20 m and during 1967-70 it extended up to 30 m. During 1970-80, the depth of operation further extended to 40 m and during 1980-85 the trawlers operated up to a depth of 55 m. During this period night trawling and multiday trawling also were introduced. By 1985-1995, the depth of operation extended up to 100 m and it further extended up to 150 m by 2000. Average fishing hours operated by trawler shows that during last 24 years the trawling hours per unit of the trawler operated increased from 7 hours in 1990 to more than 33 hours in 2012 (Fig. 3).

Fig.3. Increase in fishing hours of one unit operation by trawler



Detailed studies on the craft and gear operated for trawl fishery along southwest coast of Eastern Arabian Sea was carried out by Central Marine Fisheries Research Institute, Kochi, India. Studies showed that single day operation of the trawlers were coming down considerably and single day trawlers are getting phased out. For single day operation, old boats are being used and these boats are invariably made of wood with horsepower ranging from 68 hp to 100 hp running on diesel. The length of the vessel ranged from 32-42 feet. The average quantity of diesel used /day is 205 litres. There were no fish holds for these type of crafts. The average fishing hours was 3-5 hours per day. These boats fished in the depth range from 10 to 35 m. In recent years, steel trawlers are used in place of wooden trawlers and imported engines (Chinese make) with power of more than 300 hp are used in multiday trawlers. Average sea speed of normal boat is restricted by speed length ratio. Speed length -hull ratio of 1.1 to 1.25 is taken as upper limit for sustained speed. As per the speed length ratio the engine power required for 15 m (OAL) trawler ranges for 90 hp to 140 hp. Increasing the power beyond this ratio leads to high cost on fuel consumption. State Fisheries Departments have advised the trawl sector not to introduce excess power engines.

TRAWL FISHERY

Catch trend

The annual trawl landings along the Eastern Arabian Sea showed an increasing trend over the period of time. The catch trend was subjected to wide fluctuations in earlier years but from 2009 onwards catch showed a steady increase and reached 1.18 m tonnes in 2012 (Fig. 4) Technological advancements in trawl fisheries can be attributed as the major reason for this high production. Catch rate of trawlers fluctuated from 30 to 50 kg per hour (Fig. 5) during 1990-2007. From 2008, the catch rate increased and reached about 75 kg per hour in 2012. Introduction of high speed engines started after 2010 which may be one of the reasons for increase in catch rate.

Fig.4. Trawl landings along the coast of Eastern Arabian Sea during 2008-2012.

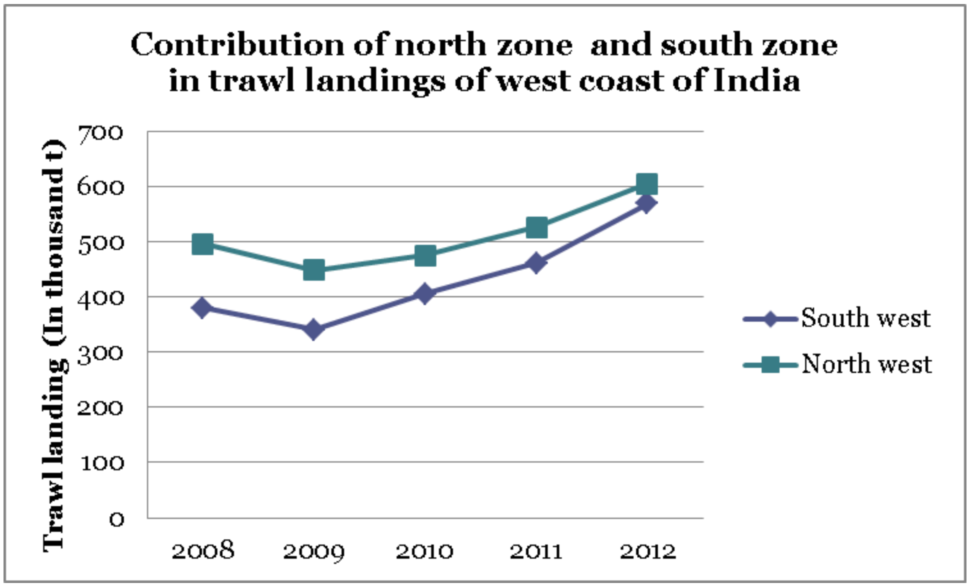
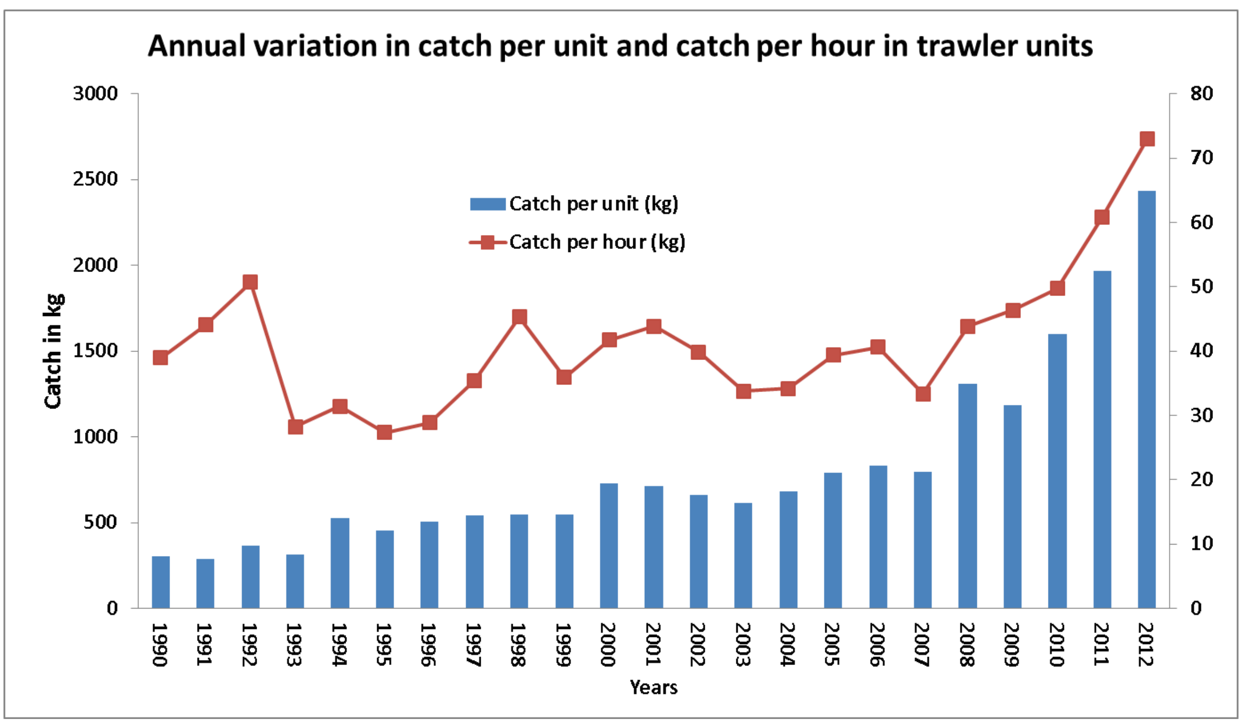


Fig.5. Catch rate of trawlers during 1990-2012



Catch composition

Threadfin breams were the major species contributed to the west coast as a whole (13%) followed by ribbon fishes and penaeid shrimps. Of late cephalopods, squids and cuttlefishes together started dominating the trawl scenario and their contribution as a group formed around 12%.

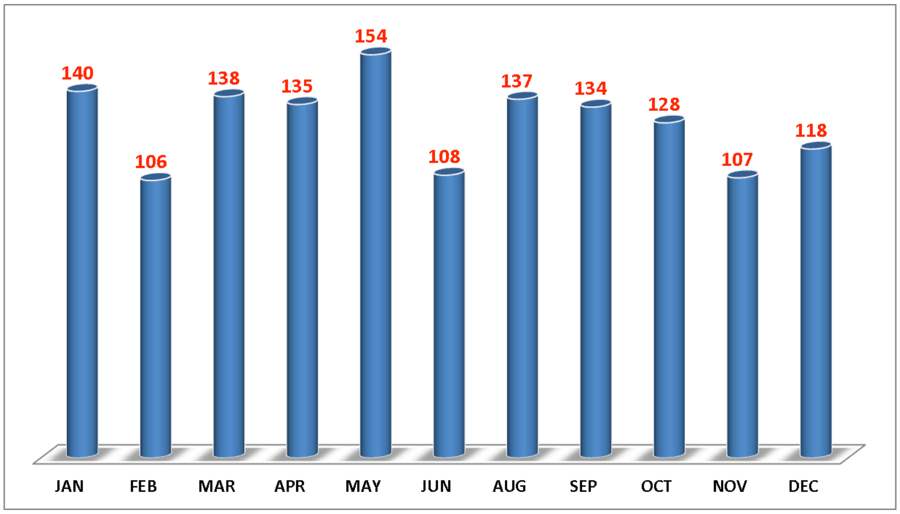
Introduction of mid water trawls and high speed engines increased the contribution of pelagic fishes in trawl landing. Indian Mackerel formed 3% of all India landing and in south west coast landings the contribution of the species was more than 5%.Threadfin breams formed the main stay of trawl fishery (Table 1) of the south west coast (19%).

Table 1. Composition of the trawl catch (ten major groups) along West- coast of India (Average 2008-2012)

Fish groups	Average (2008-12)	Percentage (2008-12)	Max. landing (2008-2012) tonnes
Threadfin breams	130,582	**13.4**	184,751
Ribbon fishes	104,477	**10.7**	146,498
Penaeid prawns	93,343	**9.6**	98,184
Sciaenids	64,186	**6.6**	72,224
Squids	59,205	**6.1**	73,835
Cuttlefish	53,494	**5.5**	67,539
Lizard fishes	41,745	**4.3**	55,109
Scads	34,865	**3.6**	55,109
Non-penaeid prawns	32,889	**3.4**	67,193
Indian mackerel	25,481	**2.6**	39,198

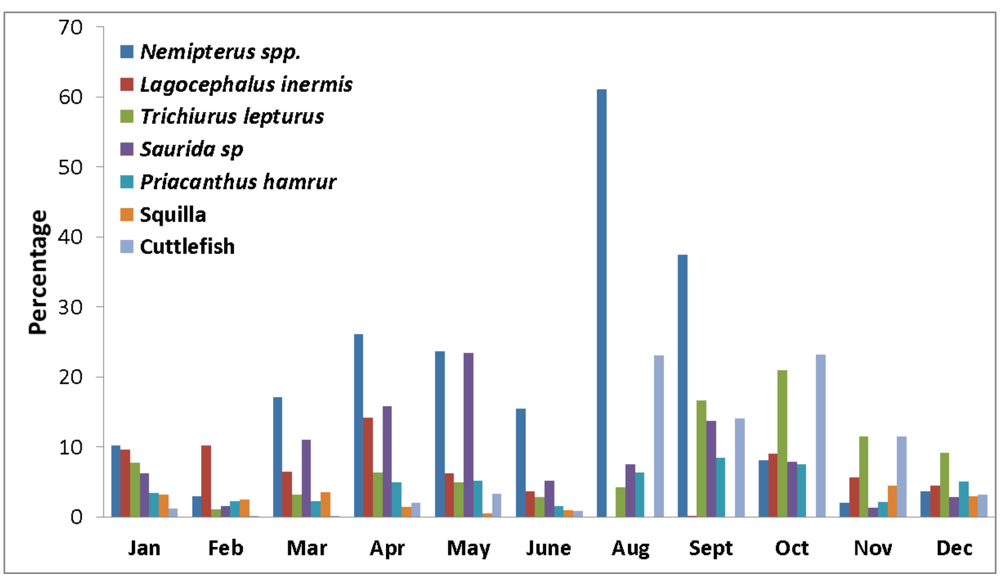
More than 800 species have been recorded from marine fish landings of south west coast of India. Analysis during trawl landings of 2008 and 2009 showed that, on an average, total number of species caught monthly in trawl fisheries of south west coast of India varied from 106 to 154. Maximum number was caught in May and minimum in February (Fig.6).

Fig.6. Number of species recorded from trawl fishery of south-west coast of India during 2008-2009.



Major resources caught were *Nempiterus* spp and other major contributors were cuttlefish, *Lagocephalus* sp, *Trichiurus lepturus*, *Saurida* spp., *Priacanthus hamrur* and squilla. Maximum landing of *Nempiterus* spp. was observed in August. Cuttlefish formed the major catch during post monsoon period (Fig.7).

Fig.7. Seasonal dominance fishery groups in the trawl fishery of south-west coast of India during 2008-2009.



JUVENILE COMPOSITION IN COMMERCIAL FISHERY

Over the years, fleet size of trawlers and trawling operation underwent qualitative and quantitative changes. This growth no doubt resulted in increased yields, employment and exports, but it has also lead to excessive fishing pressure as a result of which juveniles of various fishes are exploited in large scale.

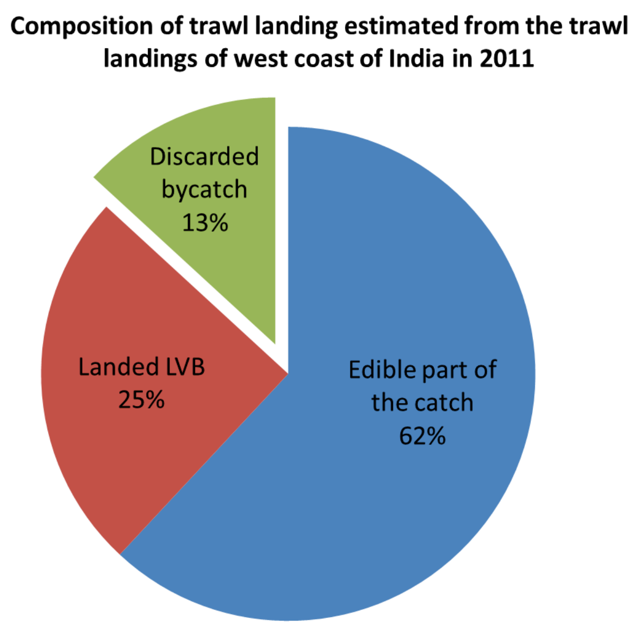
As the profitability from the trawl fishery declined due to stock related and market related high competition, there were indications that juveniles of some of the resources are becoming targeted fishery. Apart from forming incidental catches (the juvenile incidence in bycatch is dealt elsewhere in the document) the juveniles of many commercial fishes are being targeted for marketing.

Research organization like CMFRI have taken up research on impact of juvenile fishery and also came out with potential solutions to incorporate in marine fisheries policies in future. The results of the study showed that juvenile exploitation issue can be addressed by determining spatio-temporal distribution and abundance juveniles of various species. Management measures like seasonal effort reduction, seasonal fishing area restriction or protection of nursery grounds can be formulated and implemented to minimize the damages occurring to the commercial fishery due to juvenile exploitation.

BYCATCH FROM TRAWLERS

In the tropical fishery, when a trawl net is operated, it catches many species which have demand for edible purpose and some non-edible purpose. Hence, the concern of the trawler operator will be whether it would be economically viable to bring the species in a preserved condition during the period of voyage. Practically these criteria decide which is to be landed for edible purpose in best possible preservation and which is to be brought to shore without much preservation to land as "low value bycatch'' (LVB) and which is to be discarded for which bringing to the shore in any form may not fetch any additional return. Trawl landing in India showed a steady increase over the period of time but similar noticeable increase was not reflected in the edible portion of the landing during recent years (2008-2012). Studies conducted at major trawl landing centres of India showed that, edible portion of the fishery was fluctuating at around 300,000 tonnes and increase was contributed by non edible bycatch in the form of Landed low value bycatch. The non-edible portion of the landing steadily increased from 50,000 tonnes. in 2008 to 100,000 tonnes in 2011.

Fig.8. Contribution of trawl landing at important trawl landing centres along Eastern Arabian sea in 2011.



Overall analysis of the trawl landing at different centres of Indian coast showed that the LVB percentage in the total landed fish was 16% in 2008 which has increased to 27% in 2011 and discard percentage is coming down considerably. Total bycatch is showing an increase with heavy landing of low valued bycatch. The catch composition of trawler operated during 2011 along Eastern Arabian Sea showed that 25% of the catch formed by LVB (fig.8)

DISCARDS FROM TRAWL FISHERIES OF INDIA

The issue of discard is of great concern worldwide and extensive studies are carried out to understand its impact on the structure of marine communities and/or ecosystems (Alverson *et al*., 1994). Accurate estimates on discards is difficult without an observer on board. CMFRI has initiated participatory fisheries program with data sharing from progressive fishermen of South-west coast of India, in which the fishermen on board trawlers are trained to collect information regarding fishing operation and also to collect the samples of unsorted catch from each haul. The data and samples are handed over to researchers, who after the analysis make conclusions on the resource distribution and impacts of the trawl fishery. A workshop on "Bycatch-Its Impact on Marine Fisheries" was conducted at Mangalore in 2010 to appraise the results of such participatory research in formulating effective fisheries policies. A participatory research program with trawl operators and researchers was carried out at two centres in south west coast of India, namely Mangalore in Karnataka State (Province) and Calicut in Kerala State. The program with data sharing arrangement with trawl operators showed that there is considerable reduction in trawl discards and most of the bycatch are being brought to shore in recent years.

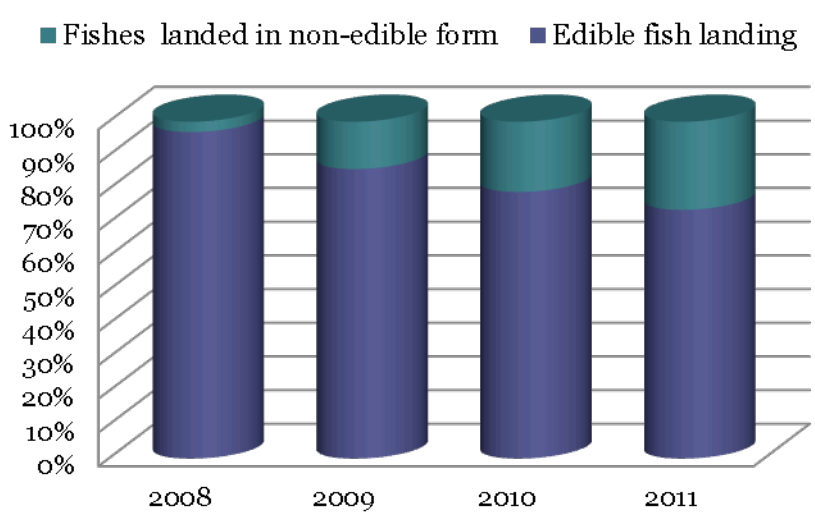
- In Mangalore the discard percentage of 22% in 2008 came down to 6% by 2011 and
- In Calicut, the discard percentage which was 17% in 2008 reduced to 4% in 2011.

LANDED BYCATCH FOR NON-EDIBLE PURPOSE

Trawlers generally discard non-commercial species (Van Beek, 1998) but ever since fish protein from sea became an important raw material for feed industries, the percentage of discards has come down substantially and low value bycatch from trawlers are used extensively to feed livestock/fish, either directly or through reduction to fish meal/oil (Funge-Smith *et al*., 2005).

The demand for fish meal increased with aquaculture development, which encouraged trawl operators to land all the catch as Low Value Bycatch (LVB). In India, the quantity of fish meal used for shrimp culture and Indian carp culture in 2001 was 41,000 tonnes and 200,000 tonnes respectively (Funge-Smith *et al*., 2005). Using these estimates and considering that the trend is likely to continue, about 270, 000 tonnes of low value/trash fish may be needed to produce fish meal for aquaculture in India by the end of the decade and this demand in turn would put increased pressure on ecosystem (FAO, 2010).

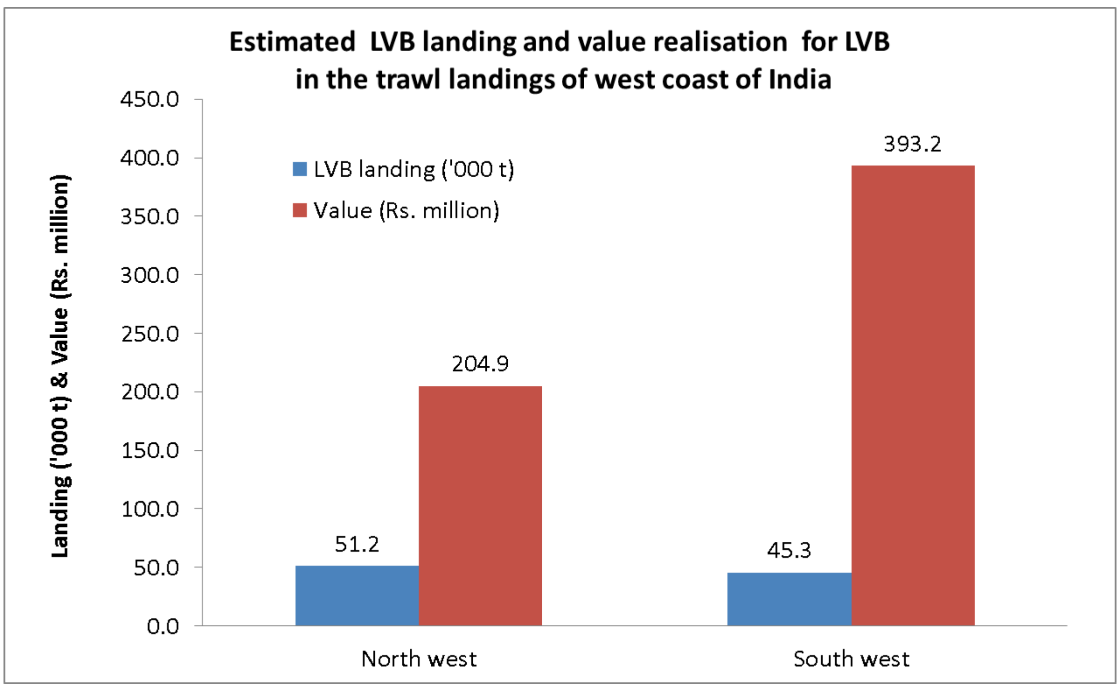
Fig.9. Edible and non-edible components of trawl landings at important trawl landing centres along Eastern Arabian Sea.



The economics of LVB marketing was studied by Aswathi *et al* (2011) who observed that there is an urgent need for comprehensive estimation of bycatch and discards from trawlers from all coastal states of the country for developing policies to reduce bycatch and discards.

Analysis of various trawl landing centres during 2008-2011 gave a clear picture of the LVB status in the country. Along northwest coast of India, it is a regular trend to land most of the fishes caught by trawlers and the LVB landing showed a steady increase from 24% to 33%. An efficient market chain exists in this part of the country for the LVB, which encourages trawl operators to bring as much LVB as possible for landing. The LVB landing was more than 50,000 tonnes in 2011.

Fig.10. Difference in value realization of the landed LVB in north west and south west coast of India.



In the southwest coast also a strong market chain exist for the LVB and the business is becoming a very prominent economic activity. In southwest coast LVB formed only 3% of the trawl landing in 2008 increased to 26% of the total trawl landing in 2011. Increase in LVB landing was the result of increased demand from fish meal plants operating in this region. The increase in trawl catch was found to be contributed by increasing percentage of LVB (fig.9).

Trawl operators decide landing fishes either in best possible preserved form or in semi-preserved state on the basis of value realization. Fishes with less preservation or no preservation are landed as LVB. In northwest coast, the market price of LVB was Rs. 4 ($0.07) in 2011 where as in the southwest it was Rs.9($0.15). Composition of the LVB and market demand are the major reasons for variation in value realization.

The finfish component in the LVB from the southwest coast of India is more than in northwest coast and the high fish composition is attracting higher prices as it is a better raw material for fish meal of good quality. Value realized for 45,000 tonnes of LVB in south west coast of India was around Rs. 390 million ($6.5 million) in 2011, whereas in north west coast the LVB landing of more than 50,000 tonnes fetched only Rs.205 million ($3.42 million)(Fig.10). The species composition of fishes from different centers is given in the Table 2.

Table 2. Composition of the Low Value Bycatch (LVB) landed at different centres (2011) along the coast of Eastern Arabian Sea.

Centres (No. of genera, species in LVB)	Major species	% in LVB	Centres (No. of genera, species in LVB)	Major species	% in LVB
Veraval	*Acetes indicus*	18.04	**Calicut**	*Decapterus sp*	8.7
	Lagocephalus inermis	6.76		*Saurida tumbil*	8.2
41 finfish species	*Epinephelus diacanthus*	5.54,	116 finfish species	*Lagocephalus inermis*	5.3
	Charybdis feriata	4.94		*Thryssa sp*	4.9
	Trichiurus lepturus	4.83		*Platycephalus sp*	4.8
13 crustacean species	*Plotosus lineatus*	4.04	19 crustacean species	*Trichiurus sp*	4.5
	Loligo duvauceli	3.37		*Opistopterus tardoore*	4.1
	Exhippolysmata ensirostris	3.37		*Caranx sp*	4.0
3 mollusc species	*Apogon sp.*	3.30	24 mollusc species	*Dusumeria acuta*	3.6
	Metapenaeus kutchensis	3.10		*Johnius sina*	2.5
	Metapenaeopsis stridulans	2.56		*Nemipterus randali*	2.2
	Solenocera crassicornis	2.45		*Stolephorus sp*	2.1
	Johnius spp.	2.38		*Saurida undosquamis*	2.1
	Decapterus russelli	2.26		*Nemipterus japonicus*	1.8
				Oratosquilla nepa	1.7
				Sardinella longiceps	1.6
Mumbai	*Oratosquilla nepa*	20.49	**Kochi**	*Oratosquilla nepa*	25.2
	Cyanoglossus arel	9.06		*Babylonia sp*	11.0
51 finfish species	*Coilia dussumieri*	7.26	25 finfish species	*Charybdis lucifera*	6.0
	Charybdis callinasa	5.09		*Bursa sp*	6.0
	Parapenaeopsis stylifera	4.24	16 crustacean species	*Sardinella spp,*	3.2
20crustacean species	*Trypauchen vagina*	3.58		*Cynoglossus*	2.3
	Apogon sp	3.53		*Lagocephalus inermis*	2.8
	Otolithes cuvieri	3.45	15 mollusc species	*Leognathus*	2.8
11 mollusc species	*Eupleurogrammus muticus*	3.18		*Johnius spp*	2.1
	Johnioeps vogleri	2.94		*Arius sp*	1.8
	Mene maculata	2.41		*Otolithus sp*	1.3
	Epinephelus diacanthus	2.40			
	Lactarius lactarus	2.36			

Centres (No. of genera, species in LVB)	Major species	% in LVB	Centres (No. of genera, species in LVB)	Major species	% in LVB
	Thryssa mystax	2.19			
Karwar 57 finfish species 10 crustacean species 10 mollusc species	*Oratosquilla nepa* *Sardinella longiceps* *Trichiurus lepturus* *Star fish* *Bivalves* *Lagocephalus inermis* *Nemipterus japonicas* *Charybdis cruciata* *Gastropods* *Cynoglosus macrostoma* *Sepia pharonias* *Sea urchin*	41.1 7.7 7.7 7.3 6.3 3.3 3.2 3.1 3.1 1.4 1.3 1.3	**Shakthikul-angara** 37 finfish species 18 crustacean species 28 mollusc species	*Doclea ovis* *Oratosquilla nepa* *Sardinella spp.* *Tibia* *Sciaenids* *Babylonia sp* *Bursa sp* *Cynoglossus* *Leognathus* *Thryssa mystax* *Lagocephalus inermis* *Parapenaeopsis stylifera*	12.0 8.0 8.2 8.5 7.6 7.3 6.8 6.2 5.8 5.0 4.2 2.0
Mangalore 95 finfish species 27crustacean species 20 mollusc species	*Lagocephalus inermis* *Saurida spp.* *Decapterus sp.* *Sardinella longiceps* *Nemipterus spp.* *Lesser sardines,* *Platycephalus sp* *Alepes sp.* *Rastrelliger kanagurta* *Dussumieria acuta* *Trichiurus lepturus* *Thryssa sps* *Eel* *Leiognathus spp .* *Charybdis spp.* *Cynoglossus macrosoma* *Oratosquilla nepa* *Other prawns* *Fistularia petimba*	12.80 11.70 10.63 8.59 8.56 5.93 4.06 3.88 3.64 3.49 3.41 3.25 2.46 2.21 1.79 1.64 1.56 1.32 1.31			

Management measures

Government of India has introduced various management measures in marine fisheries to assure sustainability of resources and also social security for the fisher folk. One of the most effective management measures is seasonal closure of mechanized fishery. Seasonal closure of the fishery was introduced as a measure of reducing the impact of the mechanized fishing along Indian coast.

Seasonal closure of fishery

The regulations for "closed season were notified for the Eastern Arabian Sea from 1988 onwards (Table 3).

In Kerala State south west coast of India, seasonal fishing ban was introduced in 1988. The analysis of impact of trawl ban during 25 years along Kerala (Mohamed *et al.*2013) showed that there is a positive impact on fishery yield in Kerala after the introduction of the trawl ban from 1988. Seasonal fishing ban and its positive peak persisted for a short period (9 years) after which catches came down and reached a steady level by 2000.

Vivekanandan *et al.* (2010) analyzed the impact of seasonal closures and found that the seasonal closure was useful in arresting the growth of fishing effort. Seasonal ban helps the fish grow, there by increase its production and value.

There is an improvement in recruitment of dominant demersal species immediately after the ban. A combination of other regulatory measures such as minimum/maximum size at capture, mesh size regulation, licensing, regulation of operation of motorized boats during the ban period and capping the number of boats in addition to seasonal ban has been suggested for long term sustainability of the stocks.

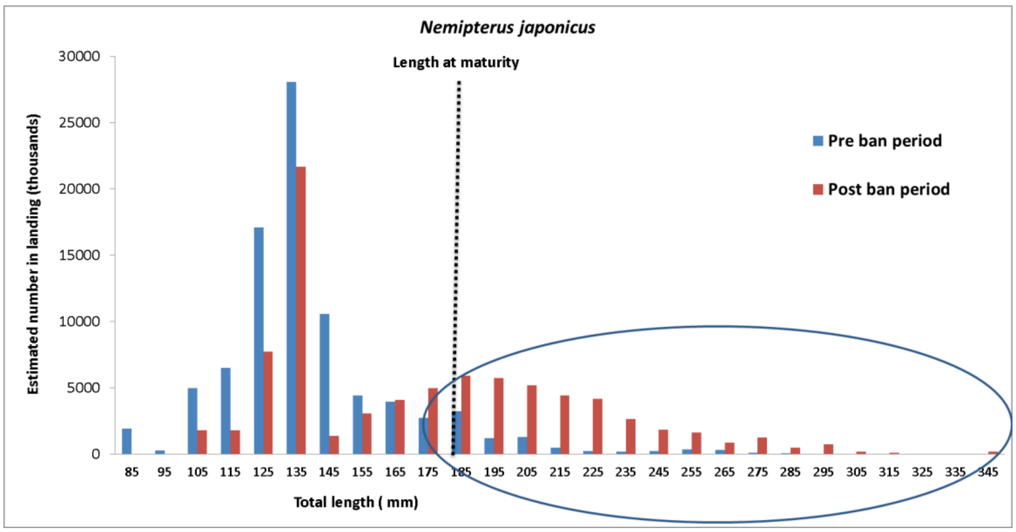
Table 3. The closed season notified for the Eastern Arabian Sea (Source: Vivekenandan 2010)

State/Union Territory	Year of introduction	Notified period	Days	Type of fishing banned	Type of fishing permitted
Gujarat	1998-1999	10 June- 15 August	67	All craft	Nil
Maharashtra	1990	10 June- 15 August	67	All craft	Nil
Daman & Diu		1 June- 15 August	75	Trawlers, gillnetters and dol netters	Motorised and traditional craft
Goa	1989	10 June- 15 August	67	All craft	Nil
Karnataka i)Dakshina Kannada ii) Uttara Kannada	1989	15 June-10 August 15 june- 29 July	57 45	All except motorised OBM/IBM vessels up to 25 hp engine	Motorised up to 25 hp engine
Kerala	1988	15 June- 31 July	47	Mechanised vessels/motorised craft>10 hp engine	All traditional and motorised craft of OBM/IBM up to 10 hp engine

Analysis of impact of trawl ban on stock renewal of important fishery resources

Among demersal fishes, threadfin breams are the major targeted group for trawlers along south west coast of India due to its high demand in local market and also for "*surimi*" preparation.

Fig.11. Comparison of length-frequency of threadfin bream, *Nempterus japonicus* prior to closure of mechanised fishing (Pre ban period) and during the start of the following trawl season (postban period), 2012.

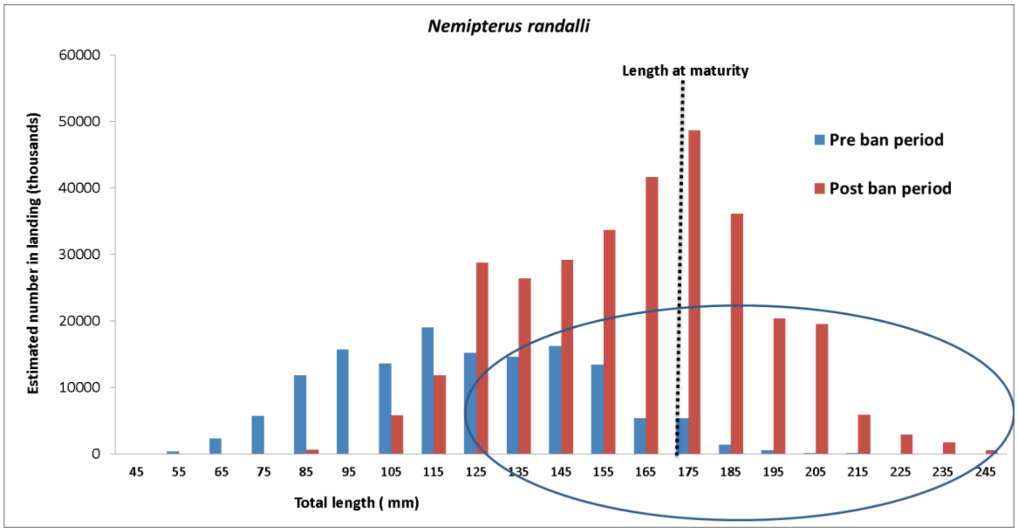


Among shrimps, *Metapenaeus monoceros* is the major shrimp targeted by multiday trawler fleets. The mean sizes of these resources in the catch reduced during the progress of the trawling . In pre monsoon months, the mean size of shrimps in the landing reduced below length at maturity. The introduction of trawl ban was found to make significant impact on the improvement of spawning stock biomass of several species.

The length frequency analysis of the landings of threadfin breams (*Nemipterus randalli* and *N. japonicus*) and penaeid shrimp *Metapenaeus monoceros* during 2012 was carried out to understand the impact of trawl ban on the fishery related characteristics of these species. For the analysis the length frequency distribution of the three months before trawl ban, March, April and May and those of post trawl ban period August, September and October were used.

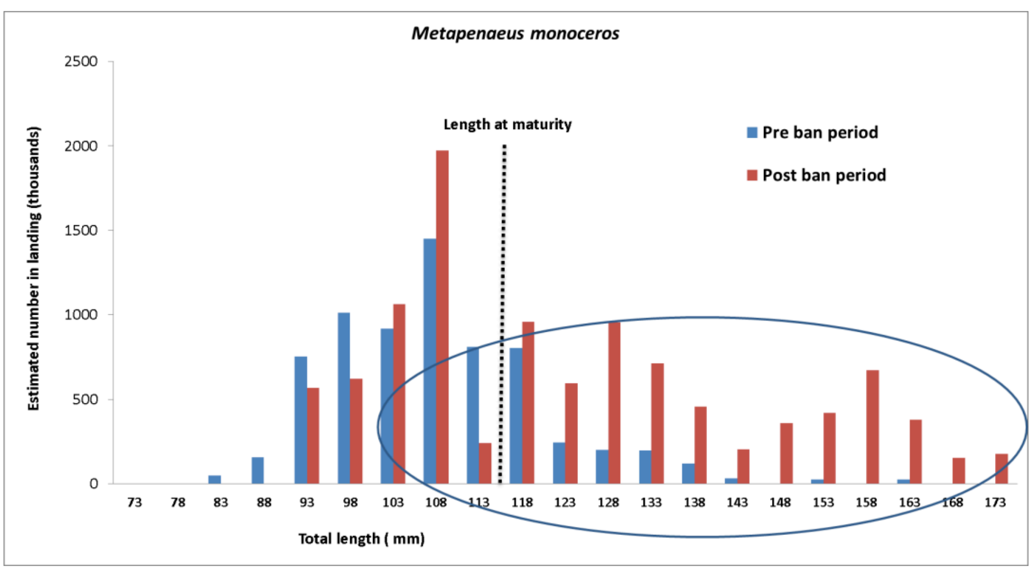
In *N. japonicus,* the higher length range 165 mm to 345 mm was seen predominantly in post ban period (fig. 11) and in *N. randalli* similar domination of higher length range (125 to 245) was observed during post ban period (fig.12). This indicate there is a significant improvement in spawning population as a result of closure of fishing.

Fig.12. Comparison of length-frequency of threadfin bream, *Nempterus randalli* prior to closure of mechanised fishing (Pre ban period) and during the start of the following trawl season (postban period), 2012.



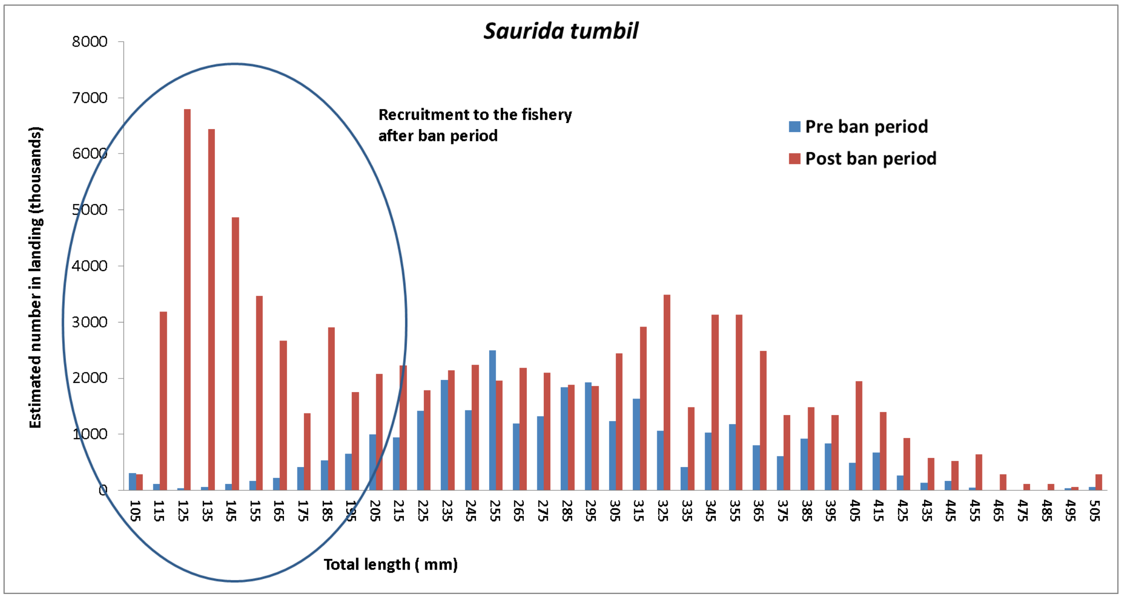
In the case of *M. monoceros*, the domination of spawning population(>118mm) was seen during post ban season period (fig.13). High percentage of spawning population indicates that fishes got opportunity to grow beyond the length at maturity during closure of fishery and ensure the recruitment success in following years.

Fig. 13. Comparison of length-frequency of penaeid shrimp, *Metapenaeus monoceros* prior to closure of mechanised fishing (pre ban period) and during the start of the following trawl season (postban period), 2012.



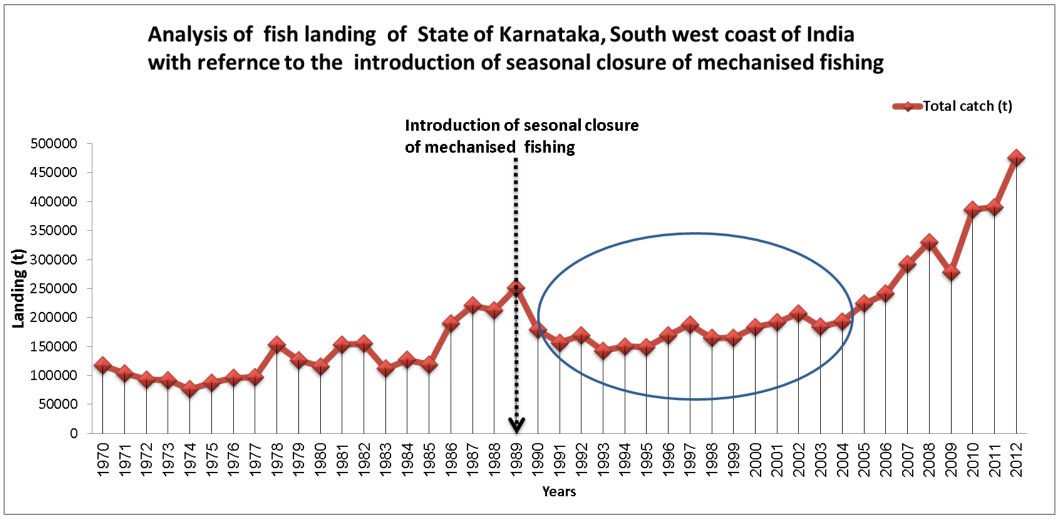
In lizard fishes, the impact of the trawl ban in the recruitment is evident from the length frequency analysis. Very significant increase of recruitment size (105-165mm) was observed in the species during the post ban period (fig.14)

Fig.14. Result of the length frequency analysis of the landings of lizardfish, *Saurida tumbil* during 2012



The analysis of fish landings of the State of Karnataka (southwest cost of India) during 1970 to 2012 showed wide fluctuation in marine fish landings from late seventies. With introduction of seasonal closure of mechanized fishing in 1989, the fishery did not show sharp fluctuations and was maintained around 200 thousand tonnes (Fig. 15).

Fig.15. Analysis of the fish landings of the State of Karnataka (South west coast of India) during 1970 to 2012 in connection with the introduction of seasonal closure of mechanized fishing.



The consistency in fishery during the period 1990 to 2005 may be attributed to the availability sufficient number of spawners in the population which may be resulting in successful recruitment.

Mesh size regulation and minimum legal size

Minimum mesh size for different species were recommended for avoiding juvenile bycatch. Diamond mesh size of 35 mm showed that it provides better opportunity for the juveniles to escape and it is recommended for cod end of trawls (Mohamed *et al,* 2013). Along with mesh size regulation minimum legal sizes (MLS) for landing is also suggested. The recommendations on minimum mesh size and MLS have failed to become operational due to the multi-species, multi-gear nature. To make these regulations effective, monitoring and surveillance are necessary.

Table 4. Legal size suggested for some of the commercial fishes of Eastern Arabian Sea (Source: Pillai *et al*, 2009)

Species	Common name	MLS (cm)	MLW (g)
CEPHALOPODS			
Uroteuthis duvauceli	Squid	8	25
Sepia pharaonis	Cuttlefish	11.5	150
Octopus membranaceous	Octopus	4.5	15
LOBSTERS			
Panulirus homarus	Rock Lobster	-	200
Panulirus polyphagus	Rock Lobster	-	300
Panulirus ornatus	Rock Lobster	-	500
Thenus orientalis	Sand Lobster	-	150
FINFISH			
Sardinella longiceps	Oil sardine	14	-

Rastrelliger kanagurta	Indian mackerel	16	-
Euthynnus affinis	Little tunny	40	-
Auxis thazard	Frigate tuna	30	-
Katsuwonus pelamis	Skipjack tuna	44	-
Thunnus albacares	Yellowfin tuna	70	-
Decapterus russelli	Scad	14	-
Megalaspis cordyla	Horse mackerel	22	-
Trichiurus lepturus	Ribbonfish	56	-
Scomberomorus commerson	King seer	75	-
Nemipterus japonicus	Threadfin bream	14	-
Nemipterus mesoprion	Threadfin bream	12	-
Cynoglossus macrostomus	Sole	11	-
Lactarius lactarius	Whitefish	13	-
Epinepheleus tauvina	Grouper	72	-
Parastromateus niger	Black pomfret	30	-
Pampus argenteus	Silver pomfret	-	200

Table 4. Major policies and programmes for marine resource conservation and management under various legislations brought by various agencies.

Year	Relevant Acts, programmes and policies	Salient features and Amendments
1972	Wildlife Protection Act	Offers protection to marine biota
1978	Marine fishing Regulation Act	A model act, which provides guidelines to the maritime states to enact laws for protection to marine fisheries by regulating fishing in the territorial waters.
1980	Forest Conservation Act	Protection to marine biodiversity
1991	Deep Sea Fishing Policy	Allows foreign fishing vessels into Indian waters beyond 12 nautical miles
1995	UNCLOS	A new international order established for oceans Provides a comprehensive legal framework for integrated treatment of issues relating to oceans and seas
1998	Integrated Coastal and Marine Area Management (ICMAM Project)	Aims at integrated management of coastal and marine areas.
2000	The Biodiversity Bill	With an aim to protect and conserve biodiversity and sustainable use

Research in resource management

India made considerable progress in capture fisheries resources assessment and fisheries management. Considering the vastness of the coast, indigenously designed methodology (Multi-Stage Stratified Random Sampling techniques) was used for the estimation of marine fish production along the Indian coast. Species-wise catch efforts are recorded continuously from 1947 onwards from all along the coast. Data base on the fishery biological characteristics of exploited stocks of resources like croakers, threadfin bream, silver bellies, catfish, lizardfish, goatfish, oil sardines, anchovies, mackerel, prawns, crabs, lobsters, bivalves, cephalopods and oceanic cephalopods *etc.* were prepared based on regular studies. Based on these studies management strategies for conservation of most of the exploited resources were suggested for policy making.

From Eastern Arabian Sea stock assessment was carried out in most of the commercial species exploited by trawlers. Important species are, *Nemipterus japonicas, Nemipterus mesoprion, Rastrelliger kanagurta, Cynoglossus semifasciatus, Lieognathus* spp.*, Saurida tumbil, Carax* spp.*, Tachysurus thalassinus, Thalassinus tenuispinis, Tachysurus serratus,Tachysurus caelatus, Protonibea diacanthus, Otolithes argenteus, Otolithes cuvieri, Johnius glaucus, johnius vogleri, Johnius sina, Johnius macrorhynus, Pseudosciaena coibor, Polynemus heptadactylus, Penaeus indicus, Penaeus merguiensis, Metapenaeus dobsoni, Metapenaeus affinis, Metapenaeus monoceros, Parapenaeopsis stylifera, Parapenaeopsis hardwickii, Solenocera crassicornis, Solenocera choprai, Sepia pharaonis* and *Loligo duavuceli.* Similarly the spawning season for more than thirty species has been identified. The list of species and their spawning season is given in table 5.

Table 5. Spawning season of different species from Eastern Arabian Sea.

Species	Locality/ Area	Spawning season
Rastrelliger kanagurta	West coast	June-Aug; Oct-Dec; Mar-July; Oct.
Sardinella longiceps	West coast	June-Nov.
Nemipterus japonicus	Cochin	June-Jan.
	Mangalore	Nov-Apr
	Bombay	Jan-Dec.
	Veraval	Feb-May; Sep-Jan.
Nemipterus mesoprion	Cochin	June-Jan.
	Bombay	Throughout the year peak: June-Aug.
	Veraval	Feb-May; Sep-Jan.
Cynoglossus semifasciatus	Calicut	Feb-May; Oct-Jan.
Psettodes erumei	Bombay	Sep-Oct.
Lieognathus bindus	Calicut	Feb-Apr.
Sillago sihama	Karwar	Aug-Feb.
Saurida tumbil	Karwar	Oct-Jan.

Species	Locality/ Area	Spawning season
Harpodon nehereus	Bombay	Apr-July; Nov-Dec.
Carax kalla	Calicut	May-June; Dec-Jan.
Tachysurus thalassinus	Cochin	Sep-Jan.
Thryssa dussumieri	Cochin	Dec-Feb.
	Calicut	Dec-Feb.
	Mangalore	Dec-Feb.
Thalassinus tenuispinis	Cochin	Sep-May.
	Calicut	Sep-May.
	Mangalore	Sep-May.
	Veraval	Feb-May.
Tachysurus serratus	Cochin	Sep-Dec.
	Calicut	Sep-Dec.
	Mangalore	Sep-Dec.
Tachysurus caelatus	Veraval	Jan-Apr.
Protonibea diacanthus	Bombay	June-Sep.
Otolithes argenteus	Mangalore	Oct-Jan.
Otolithes cuvieri	Cochin	Feb-May; Sep-Jan.
	Veraval	Feb-May; Sep-Jan.
	Bombay	May-July; Nov-Dec.
Johnius glaucus	Veraval	Feb-May; Sep-Jan.
johnius vogleri	Bombay	June-July; Nov-Dec.
	Veraval	June-Aug; Sep-Jan.
Johnius sina	Cochin	Jan-Dec.
Johnius macrorhynus	Bombay	June-July; Nov-Dec.
Kathala axillaris	Cochin	Feb-May; Sep-Jan.
Pseudosciaena coibor	Calicut	May-Aug.
Polynemus heptadactylus	Bombay	Mar-June; Aug-Nov.
Penaeus indicus	SW coast	Throughout the year peaks: Oct-Nov; May-Jun.
Metapenaeus dobsoni	SW coast	Throughout the year peaks: Oct-Dec; Apr-May.
Metapenaeus affinis	NW coast	Throughout the year peaks: Sep-Jan; Feb-May.
Metapenaeus monoceros	SW coast	Throughout the year peaks: July-Aug; Nov-Dec.
	NW coast	Throughout the year peaks: Feb-Aug.
Parapenaeopsis stylifera	SW coast	Throughout the year peaks: Nov-Dec; Mar-Apr.

Species	Locality/ Area	Spawning season
	NW coast	Throughout the year peaks: Feb-May.
Parapenaeopsis hardwickii	NW coast	Throughout the year peaks: June-Aug.
Solenocera crassicornis	NW coast	Throughout the year peaks: Sep-Jan.
Solenocera choprai	Mangalore	Throughout the year peaks: Nov-Dec

FISHERIES EXTENSION PROGRAMMES

Fisheries development is closely related with the improvement in the ability of the fisherman's adoption of sustainable fishing. Extension agencies are facilitating transfer of useful and practical information emerging from research activities and inform the scientific community of the problems of fishermen for finding suitable solutions. In this approach the technology generation and frontline extension activities come under the mandate of research institutes as well as State Agricultural Universities, while grassroot level extension is carried out by State departments. In marine fisheries sector extension workers are involved in creating awareness among fishermen of adverse effects of juvenile bycatch, exploitation of brooder, conservation of endangered species and fragile marine ecosystems, improvement of quality in harvest and post harvest sector *etc*., which will definitely yield good result in coming years. Mechanized fishing operated by progressive fishermen , who are adopting state of art technologies. The awareness programs conducted along south west coast of India revealed that trawl operators are aware of consequences of bycatch and juvenile exploitation. Many of them are concerned about the fishery in future and this provides a good opportunity for the extension agencies to impart their ideas in "sustainability", "responsible fisheries" etc., There are a series of sustainability related awareness programs being conducted by Fisheries Survey of India, Central Marine Fisheries Research Institute, Regional government bodies, National Fisheries Development Board, Non-governmental organizations *etc*. The following recommendations were made in the workshop.

No.	Regulatory measures	Implementation
1	Temporary closure of zones where a high proportion of juveniles are observed.	Declaration of zones is possible only on the basis of 'realtime' data on juvenile abundance in the fishing grounds.
2	Obligation for vessels to move to another fishing zone when their catches exceed a maximum acceptable limit of bycatches.	There is no fixed quota for bycatch that can be brought to the shore in India.
3	Reducing fishing pressure by limiting number of vessels	The optimum number of trawlers for each maritime state is to be estimated.

No.	Regulatory measures	Implementation
4	Adoption of modified fishing gear fitted with BRDs.	The gear modification demands a sizeable initial investment for fishermen, subsidies to procure such devices may be provided. Production of smaller, diamond-mesh cod-end may be discontinued.
5	Use square-mesh cod ends that allow smaller sized fishes to escape; adopt cod-end mesh size stipulated in the MFRs.	Square-mesh cod-ends should be made available to fishermen and gradually discontinue production of smaller mesh-sized cod-ends. In a multi species tropical fishery adult of a commercial species may be smaller than juvenile of another commercial species and therefore target specific nets may be used.
6	Improved handling, storage and landing of bycatch to make it suitable for human consumption.	Permission for landing of bycatch should not encourage uncontrolled fishing of bycatch circumventing the rules.
7	Experts have to work into possible market out-lets for landed by-catches, whether it could be marketed for human consumption or for processing into fish feed or oil to be decided.	Value addition to low value bycatch and quality standards to be prescribed for efficient utilization of bycatch.

On the basis of the regulatory measure No.1., recommended in the awareness workshop some of the trawl operators from south west coat of India volunteered to provide GPS based real time data in data sharing mode with Scientist of CMFRI (Central Marine Fisheries Research institute). With the participatory research CMFRI could come out with temporal and seasonal resource maps of more than 200 species of marine fauna caught by trawlers. Study enabled to identify the seasonal grounds of juvenile abundance of more than 50 commercial species off the coast in the form of GIS maps. This maps can be propagated to fishermen to make them understand the grounds of juvenile abundance and the importance of their data sharing in fisheries management. The awareness is being made in the grass root level in appreciable manner but now the thrust should be on monitoring, compliance and surveillance(MCS). Along with co-management, MCS system has to be strengthened for better management of trawl fishery along Indian coast.

GOVERNANCE

Need for participatory management

With past experiences in fisheries management it is becoming increasingly clear that governments alone cannot solve all fishery problems. Local communities have to take more responsibility for solving the problems. The concept of co-management has gained acceptance among governments, development agencies and development practitioners as alternative fisheries management strategy.

Inter departmental co-ordination

In National level, fisheries is being governed primarily by Ministry of Agriculture and ministries of commerce and food processing are concerned with export, value addition, respectively. In addition, several other departments are also stakeholders in terms of natural resource exploitation, transportation, tourism, natural resource conservation, coastal protection etc. For implementing a fisheries policies there need to be a synergy between these organizations/ministries. There is a need for national level coordination among the various departments involved in fisheries.

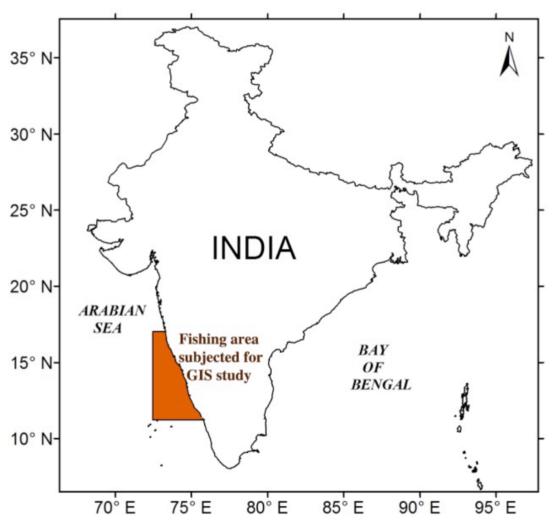
Table 6. Major stakeholders involved in decision making in marine fisheries.

Organization	Responsibilities
Ministry of Environment and Forests	Management of resources in the coastal water
Ministry of Earth Sciences	Scientific monitoring of the marine environment, management of resources in the high seas
Ministry of Agriculture	Development of fisheries, aquaculture, fish processing
Ministry of Commerce	Export
Ministry of Food processing	Fish processing
Ministry of Surface Transport	Ports, shipping etc.
Ministry of Petroleum and Natural Gas	Offshore installation, coastal refineries, pipelines etc.
Ministry of Tourism	Tourism activities in coastal regions
Ministry of mines	Mining activities in coastal regions
Ministry of home	Coastal protection

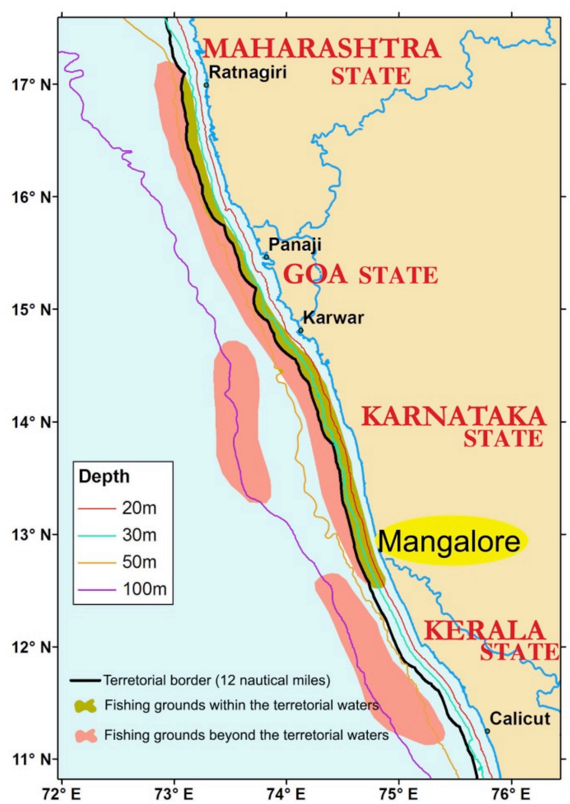
Need for zonal fisheries management bodies

The administration of marine fisheries is primarily with the respective State (Province) fisheries departments (SFD). In recent years, the trawlers are fishing away from the jurisdiction of the state. If the trawlers cross the territorial limit, the area of operation of the trawl is beyond the administrative control of the respective states. For example the studies conducted along South west coast of India (fig.16) shows that trawlers from Karnataka operated in the territorial waters of adjacent States Kerala, Goa and Maharashtra and this is the case with almost all multiday trawlers from different states. It is also seen that more than three fourth of the catch landed by multiday trawlers of Karnataka is from the waters beyond territorial waters of different maritime States. To have regulation on the fishing activity in Indian EEZ, beyond territorial waters of each state, zonal fishery regulation bodies under the auspices of Central Government may be necessary.

Fig.16. Map showing operation area of trawlers beyond territorial boundary each Province (State) along south west coast of India.



Map showing the area which was subjected for GIS based spatio-temporal study



THE WAY FORWARD

Seasonal and spatial restrictions in trawl fisheries

The use of design based selection technology in reducing the incidental catch of non-target species from the fishing ground in tropical waters was found to be less effective due to various reasons. In tropical fisheries, where various species at different phases of their life cycle co exist, mesh size regulation and similar design based restrictions have lot of practical difficulties. It is suggested that the design based BRDs in association with area closures and temporal closures of trawling will be the best option for the bycatch reduction in tropical waters.

The report of the FAO Expert Consultation on International guidelines for bycatch management and reduction of discards (FAO, 2010) suggested that closure of nursery/spawning grounds or areas of special biological significance can reduce bycatch and such spatially based measures help in the creation of marine protected areas, marine parks, zones reserved for traditional fishing activities for sustaining the biodiversity and for improving marine fisheries production.

GIS mapping of spatio-temporal distribution of all fishes, commercial and non commercial, and the different life stages and sizes of the fishes distributed in specific area can form important background information for spatial restriction of fishery to reduce bycatch. This multilayered information on different species, different size groups different maturity stages, will enable the researcher and policy makers to assess the fishing grounds under their jurisdiction in terms of resource conservation and resource exploitation. Fishing area closure and effort controls provide conservational benefits for vulnerable habitat and vulnerable species. Operational restrictions in fisheries management will help curtailing fishing operations in certain areas of biological significance designating as marine protected areas (MPA).

Data requirement for the recommendations for seasonal and spatial restrictions in trawl fishery.

Data on spatio-temporal distribution of spawners and juveniles are important requirements for suggesting seasonal and spatial restrictions. For Indian fisheries, time series data is available on peak spawing season of most of the commercial species in Eastern Arabian Sea, some of them are listed in the table 3 in the annexure. This provides an insight into the seasons of spawning, juvenile abundance of different species.

GIS based resource mapping of juvenile and spawner abundance along Indian coast will provide database for the spatial and temporal closure or restriction in trawl fishery. GIS is found to be very handy tool for fishery resource mapping.

The most important feature of the GIS maps is that, information on each separate group/species/juveniles/adults layers can be individually or collectively separated by queries and the layers can be studied in terms of its importance. GIS arranges the data collected periodically in different layers which can be retrieved as per the projections required and each layer can be analyzed individually.

The utility of the layer character of GIS in bycatch reduction is that, if some juvenile exploitation in a specific species makes considerable impact on the stock position and economics of commercial species, effort restrictions can be imposed in that fishing ground and season with illustrative justifications. Studies on the repeatability of the juvenile abundance in these particular fishing grounds will help in identification of critical fishing ground where seasonal and spatial closure of trawl fishery can be implemented to improve the fishery production in long run.

Similar spatio-temporal management of fisheries to reduce juveniles in the catch was suggested by Dunn *et al* (2011) in USA to reduce by-catch of finfish or protected species. They also found that such measures are helpful in ecosystem-based management approaches. More fisheries can be managed through multispecies, multi-objective models with spatial component. The resource maps can be used as an excellent tool for the policy makers to weigh each fishing ground in terms of commercial value and juvenile abundance so that the policy making process will be much transparent. Illustrated maps with seasonal/ fishing ground wise distribution of juveniles and commercial fishes, will help as a useful tool in awareness programs to extend the research findings to the stake holders.

Here are some of the examples of mapping grounds of peak spawning and juveniles abundance of the commercial species which could be used as information base for suggesting seasonal and spatial closure of the fishery. Fig. 17 shows the fishing grounds and month of abundance of spawners and Fig.18 shows the fishing grounds and month of abundance of juveniles.

Fig.17. Seasonal peak spawning grounds identified for *N. randalli, M. monoceros, S. tumbuil* and *T. lepturus* based on the GIS studies during 2008-2009. Peak spawning months and area of occurrence is indicated in the map.

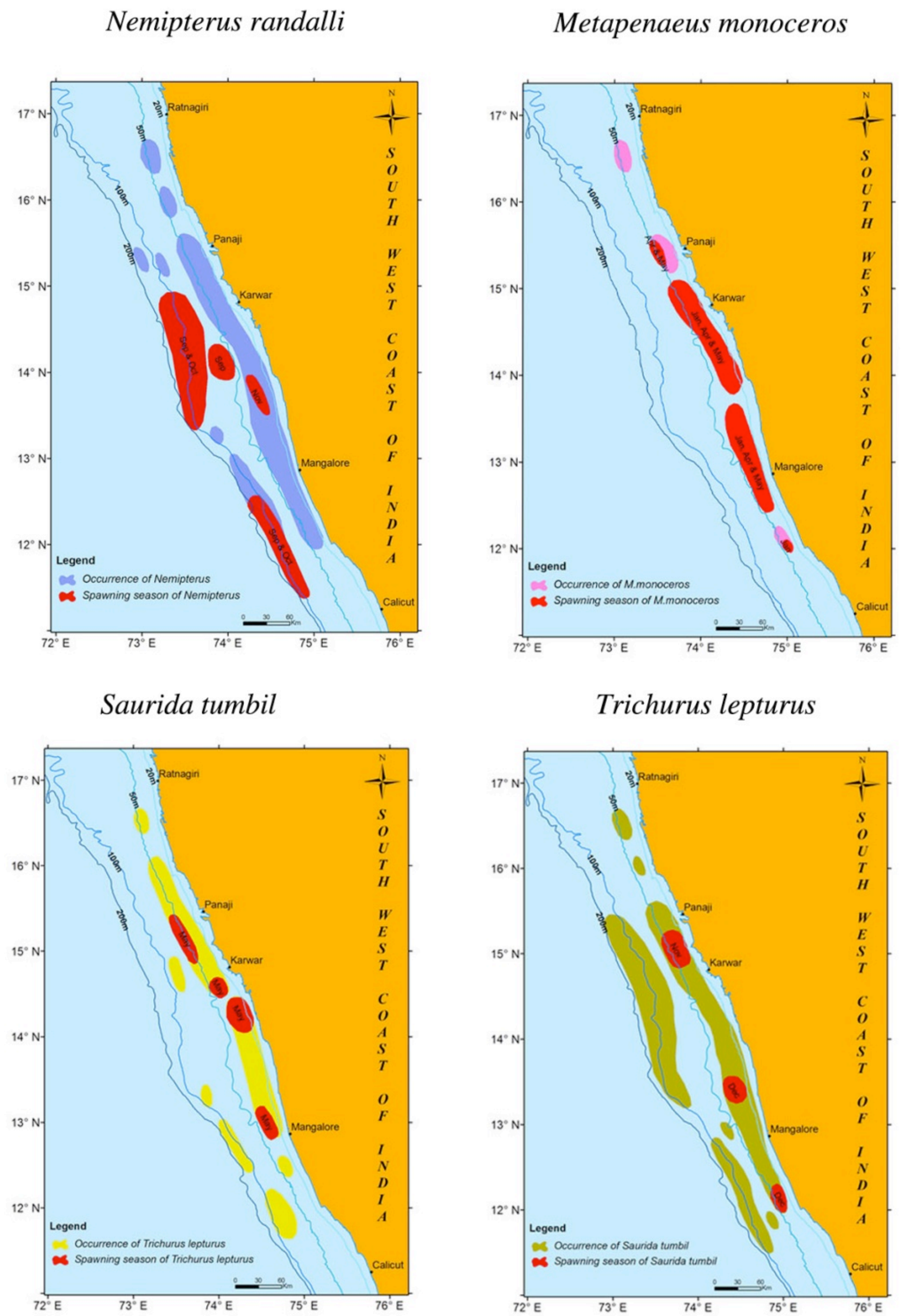
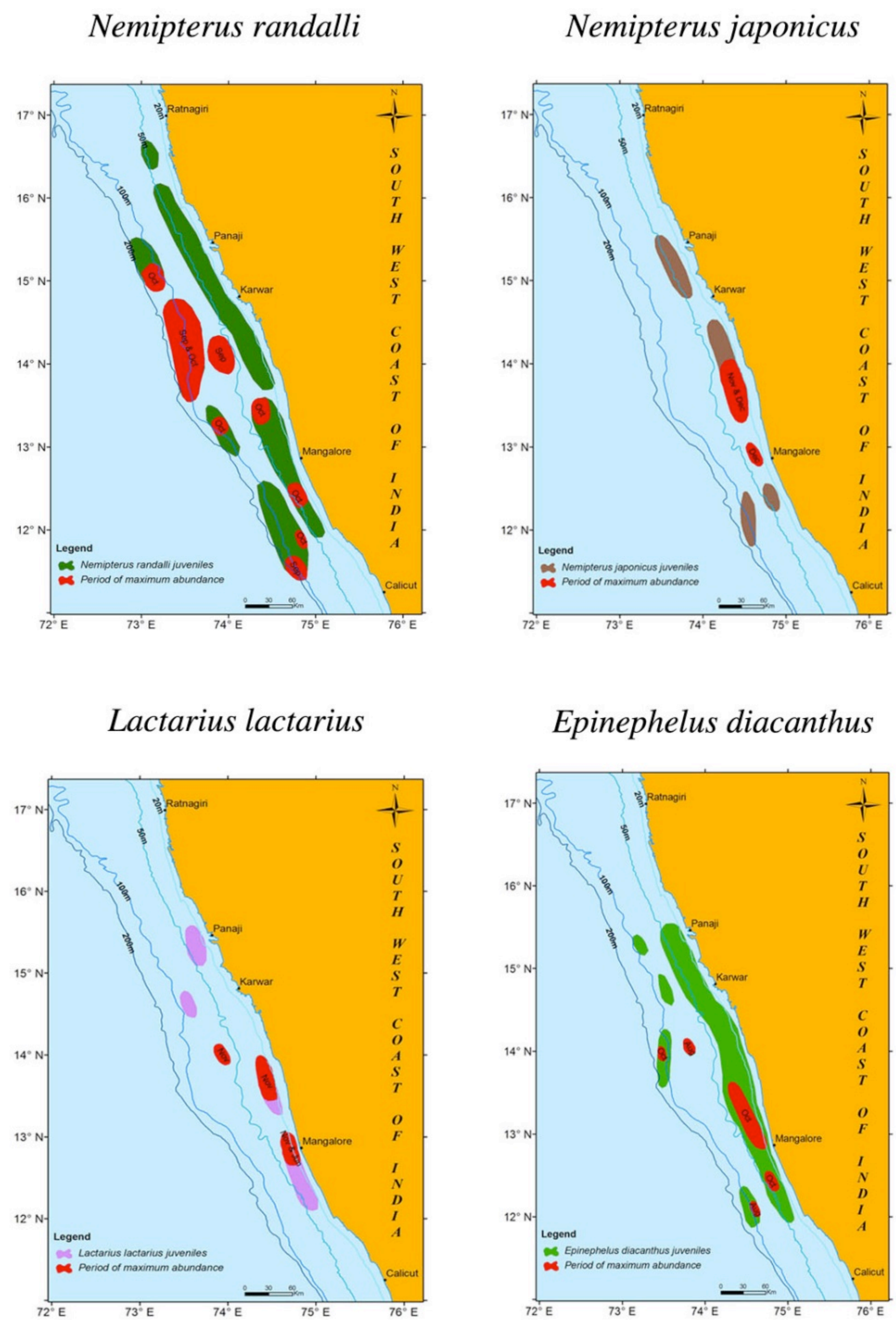


Fig.18. Seasonal juvenile abundance grounds identified for *N. randalli, N. japonicus, L. lactarius* and *E. diacanthus* based on the GIS studies during 2008-2009. Months of juvenile abundance and area of occurrence is indicated in the map.



MONITORING, COMPLIANCE AND SURVEILLANCE

On the basis of strong data base being created in spatio-temporal platform with help of GIS, research program for development of GIS and RS supported VMS (Vessel monitoring System) is in active consideration in Indian waters. This is proposed for helping conservation of the marine fisheries resources and to ensure fishermen safety.

Development of VMS is an extension of spatio-temporal assemblage studies of fishery resources and is considered as most practical MCS activity for marine fisheries management. In the present day fishing which is extended to deeper waters, VMS is essential for ensuring safety of fishermen in sea. Vessel monitoring system (VMS) is proposed as the mechanism and infrastructure for monitoring, control and surveillance activities to strengthen fisheries management. Infrastructure facilities for monitoring compliance and surveillance has to be made to implement these scientific findings and policies. Since the resource studies are taken up in GPS platform, VMS is an essential development to follow. Along with introduction of VMS, training the fishermen for seamanship and operation of electronic gadget for fishing and security is also essential.

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