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The trawl Fisheries of the western Bay of Bengal

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Introduction

The Western Bay of Bengal (WBoB) trawl fishery is typically a tropical multispecies mixed fishery with a history of commercial exploitation since early 1960s. The nature of fishing changed dramatically with the introduction of trawlers. In the last 50 years, trawlers have become immensely popular and have emerged as the most important fishing craft in the region. The trawl fishery extends from 8°N (off Kanyakumari on the south) to 22°N (off Sunderbans in the north), accessing fishing grounds between 10 m and 150 m depth, but often restricted to a maximum depth of about 70 m. Thus trawling by Indian fishermen has remained exclusively a coastal activity and deep-sea trawling is occasional. The main gear is the bottom otter trawl, with two variants, namely the shrimp trawl and fish trawl. The difference between the two variants is that the shrimp trawl scrapes through the bottom with more sinkers, and the fish trawl is hauled slightly off bottom with more floats. The fishery is complex with operation from craft varying in length and efficiency. All trawlers are mechanized, with the engine placed inboard. Being multispecies, the fishery exploits species that widely vary in their life history traits and habitats. Approximately 800 species of elasmobranchs, teleosts, crustaceans, molluscs and echinoderms are taken by the trawls, and at least 300 species contribute to the fishery.

With increasing importance over the years, the trawl fishery has emerged as the largest contributor to the catch, value and earnings from domestic and export trade in the marine capture fisheries sector in the WBoB. Trawlers were introduced in the southern part of the region, which gradually proliferated to the northern part. In the first 30 years, the fishery consisted of small wooden boats ranging in length from 9 m to 12 m, which accessed the nearshore fishing grounds undertaking single-day fishing per unit operation. By 1990, larger trawlers of more than 13 m length were added to the fleet, which enabled multiday fishing in relatively distant grounds. In the last five years, the efficiency of the fleet has further increased by induction of larger steel trawlers of 15 - 20 m length. The fishery also witnessed parallel improvement in the gear. From early 1980s, the headrope length and mouth opening of the trawlnet have been increased, thereby substantially increasing the volume of filtered water. The cod-end mesh size was reduced to 15 mm (stretched), enabling capture of juveniles. The other important side of the operation was use of electronic aids for gathering information on fish availability and use of acoustic instruments to find out grounds of higher fish concentration. The catch was brought to the deck by power winches requiring less human effort. These technological advances allow the fishermen to work with improved efficiency. The expansion and efficiency of the fleet had concomitant implications on the structure of the fishery.

While the fishery is multispecies, the trawlers target shrimps and high-value fish. The targets, however, change in response to the demand in the domestic and international markets. For example, demand for ribbonfish and squids in the Chinese market during 2005-2010 motivated the trawl sector to deploy the nets off-bottom, thereby substantially increasing the catches of midwater fish. Thus, over the years, the trawl fishery expanded in response to the demand and emerged as the most important contributor to fishery yields and returns in the region. It should be emphasized that the trawl fleet substantially contributed to increase the catches over the years, because the vessels could access fishing grounds farther away from the port and in relatively deeper waters, thus gaining access to stocks that previously had been unfished or underfished. These developments have helped increase revenue generation and occupation of a large number of stakeholders in the fishery.

Along with the development of trawl fisheries, concerns have been raised on the effect of the trawls on fish populations and coastal ecosystems. The concerns on harmful effects are the following: (i) Overfishing depletes the stock biomass and adversely affects the biodiversity. (ii) Trawls catch and discard large numbers of juveniles of species that, when larger, are targeted in other commercial fisheries. (iii) Trawling directly affects the sea bed habitat by scrapping, sediment resuspension; alter the physical structure of seafloor, and remove or scatter non-target benthos. Given the importance of the WBoB trawl fisheries to fish production, occupation and income generation on one hand, and concerns about the sustainability of catches and ecosystem impacts on the other, it is important to support a transition of trawl fisheries to more sustainable practices. This paper is intended to raise awareness on the generic structure and status of WBoB trawl fisheries, the attempts underway to regulate the fishery, the key experiences and the lessons learned. The purpose is to inform possible measures to perform future sustainability adaptation plans.

Background Information

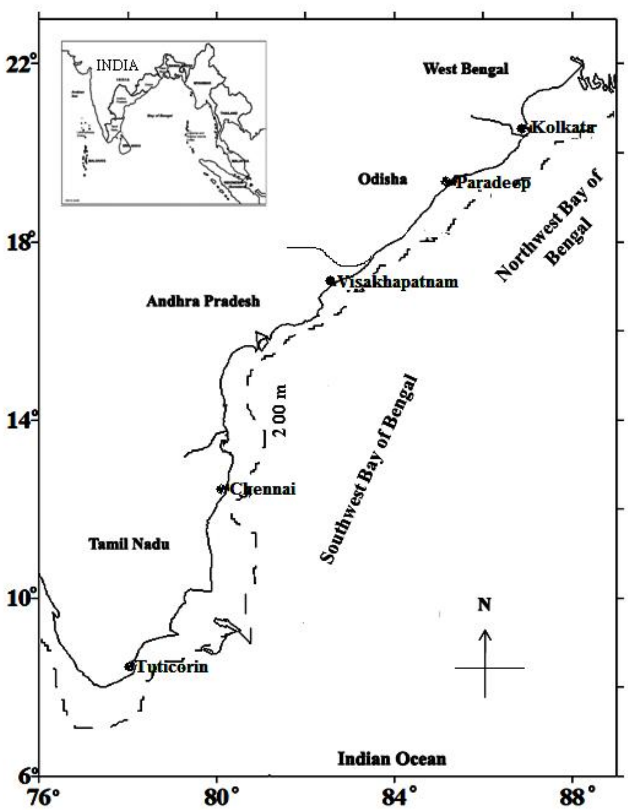
Oceanographic setting

The WBoB, bordered by 2746 km-long east coast of India, receives minerals and nutrients from several east-flowing rivers and two large brackishwater lakes. The major rivers, *viz*., the Ganges, Mahanadi, Godavari and Krishna drain 200 km^3 of water and 12 x 10^9 tonnes of silt during monsoon, which influence the ecosystem dynamics (Dwivedi and Choubey, 1998). The area of continental shelf of east coast of India is about 114,000 km^2. Two monsoonal seasons are distinguishable on the basis of wind, precipitation and current patterns than by temperature differences. The monsoon currents are seasonally reversing, open-ocean currents that flow between Arabian Sea and Bay of Bengal, the two wings of the north Indian Ocean. Dissolved nutrient levels in oceanic waters are generally low except in regions of upwelling. Oceanic plankton densities are also therefore generally low and relatively invariable seasonally. As in other tropical environments, predators are relatively more abundant (Johannes, 1978). This region is a home for rich biodiversity and diverse habitats. The unique biodiversity hotspots include the largest mangrove forest, the

Sunderbans, the large brackishwater lakes, namely the Chilika and Pulicat, the largest turtle rookery in Odisha, and Gulf of Mannar, home for coral reefs and endangered dugong.

Ecologically, the WBoB can be identified as two subsystems, namely the northwest Bay of Bengal (NWBoB) and southwest Bay of Bengal (SWBoB) (Fig. 1).

Fig. 1. Map of western Bay of Bengal (east coast of India)



The northern subsystem (northeast coast of India) consists of maritime states of West Bengal and Odisha, which is dominated by estuarine influence, caused by addition of freshwater and silt (Reemtsma et al., 1993). The shelf is wide (> 100 km in the Sunderban area), characterized by low saline, low O_2 and low temperature waters (Dwivedi, 1993).

The southern subsystem (southeast coast of India) consists of maritime states of Andhra Pradesh and Tamilnadu, and the Union Territory of Puducherry. It has a narrow shelf (as narrow as 10 km off Cuddalore) with little estuarine influence and higher salinity. The overall nutrient levels are generally high, particularly along the northern subsystem, but this is not reflected in high primary and secondary production as in the case of the upwelling areas of eastern Arabian Sea (southwest coast of India) (Dwivedi and Choubey, 1998). However, the productivity along the east coast is sufficient to support a large subsistence and industrialized fishing sector.

A wide variety of gears such as trawl, several variants of gillnet, hooks & line, longline, trammel net, boat seine, bag net, dol net and ring seine are operated along the entire coast. The catch consists of more than 50 commercially important species/groups of finfish, crustaceans, cephalopods, bivalves and gastropods (CMFRI, 2012).

Trawl fleet

The trawlers are of 12 – 20 m length, with engine power of 90 to 250 hp, with limited onboard storage. The catches are usually iced or frozen in fish-hold and a portion is deck-dried. The boats operate for 1 to 8 days at sea per fishing trip. Considering FAO classification of 24 m length as a benchmark, all the trawlers may be classified as smallscale fisheries vessels, but several tropical countries classify this type of vessels as semi-industrial. Most of these trawlers are owned by individual fishermen, but are generally regulated by fishermen associations. The fishers function under group organizational structure, which is headed by elected leaders from the village, who act as spokespersons with the government officials. The relationship between the associations and officials is usually gravitated into welfare measures and seeking other benefits from the government. The connection between fishermen groups and fisheries authorities ranges from weak to strong depending upon the issue.

Central Marine Fisheries Research Institute (CMFRI) has carried out marine fisheries census in India at irregular intervals from 1961 to 1998, and at regular interval of every five years from 2005 for the Ministry of Agriculture, government of India. The census shows that the number of trawlers has increased from 463 in the year 1961 to 10,137 in 2010 along the WBoB (Fig. 2). The rate of increase, which was fast until 1998, slowed down in the last 15 years. The number of trawlers has almost stabilized at around 7,400 in the SWBoB. However, the density of trawlers was higher in the SWBoB (102 per 1000 km^2 of continental shelf area) than in the NWBoB (65 per 1000 km^2) in the year 2010 (Table 1). While the number of trawlers tends to stabilise, the efficiency is increasing over the years. The exact horsepower of trawl engines over the years is not available, but considering mean horsepower of 40 in the year 1961 and 150 in 2010, the overall horsepower of trawl fleet in the WBoB could be estimated to have increased from about 18,520 hp in 1961 to 1,520,550 hp in 2010. Thus the number of trawlers increased by 22 times, but the efficiency increased four times faster than that, at approximately 82 times in 50 years. The efficiency has enhanced in the last 15 years, particularly when the density of boats began to stabilise.

Fig. 2. Growth of trawl fleet in the western Bay of Bengal; NWBoB = Northwest Bay of Bengal; SWBoB = Southwest Bay of Bengal

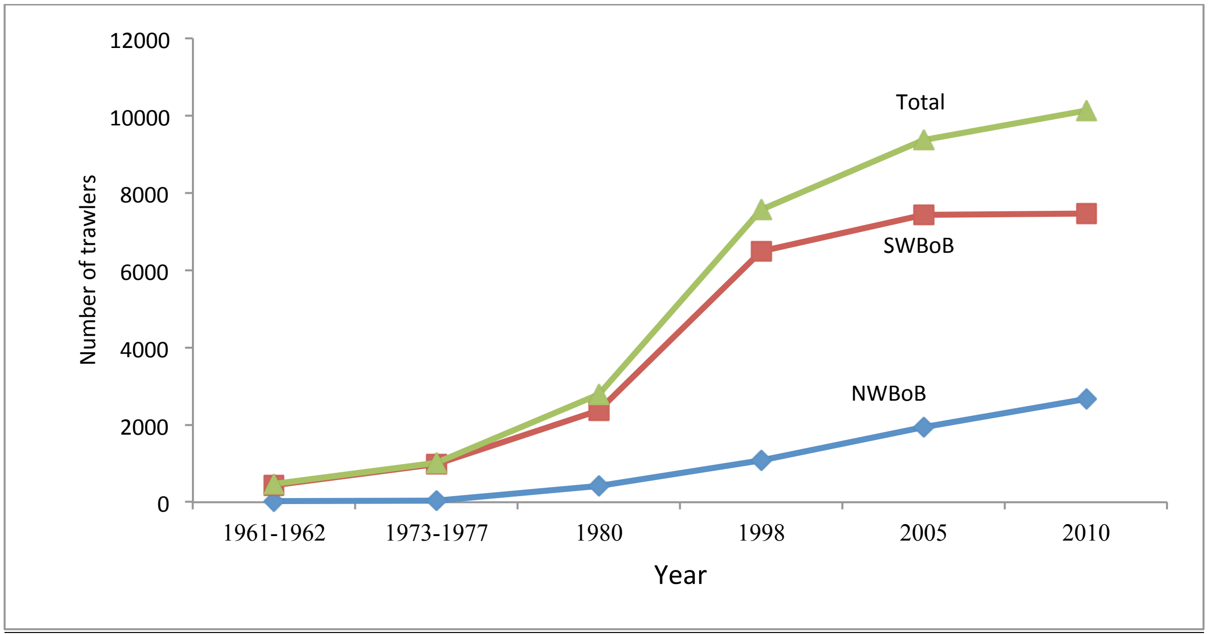


Table 1. Profile of east coast of India

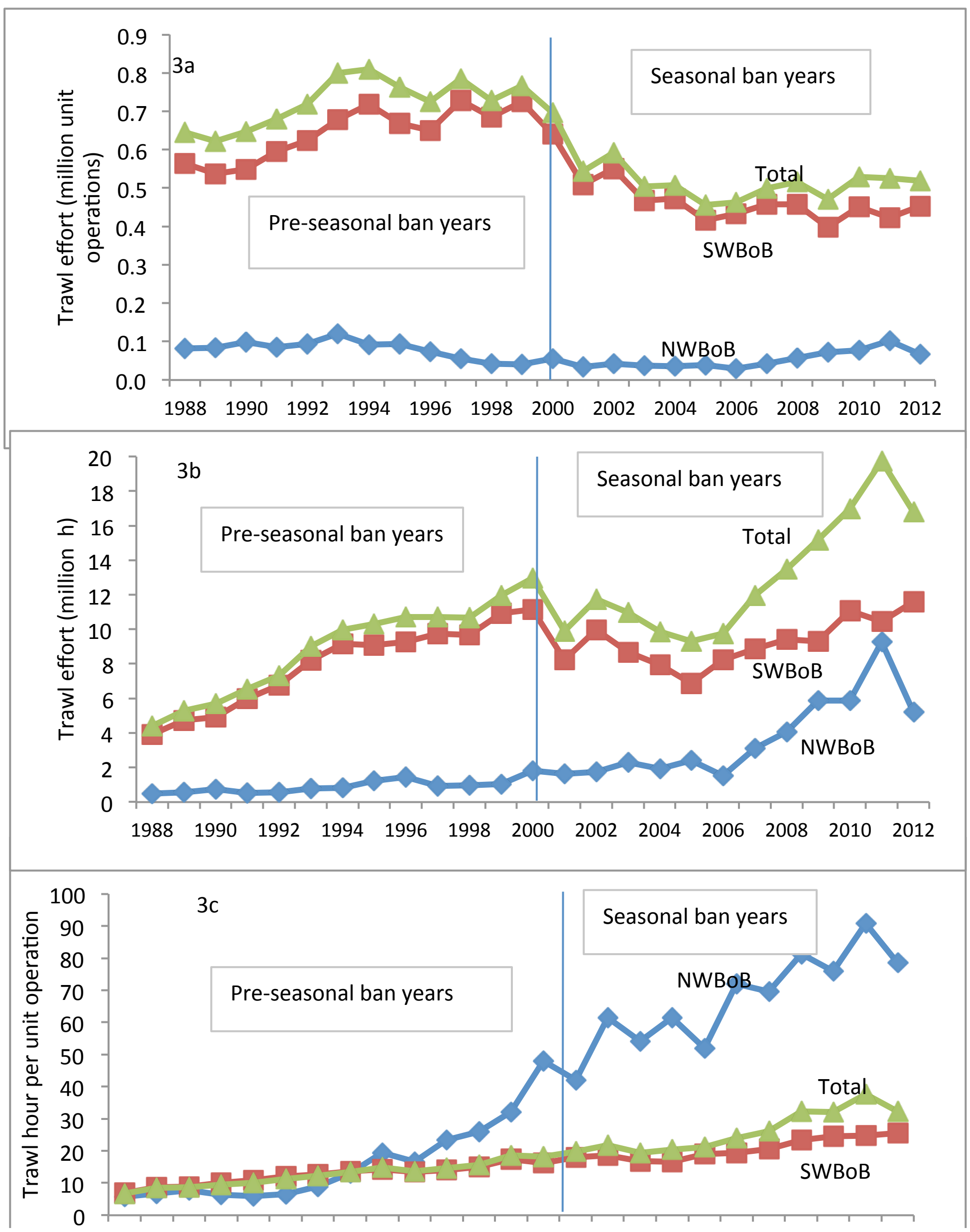
Character	NWBoB	SWBoB	Total
Coast length (km)	637	2,109	2,746
Continental shelf area (km^2)	41,000	73,000	114,000
Trawler density in 2010 (Vessels/1000 km^2)	65	102	89

The fishing unit operation (fishing unit = one fishing operation of a boat from departure to return to the base) in the WBoB stabilized at around 0.5 million units in the last 12 years, particularly after introduction of seasonal fishing ban (Fig. 3a). However, fishing hours, which declined in the first six years after introduction of seasonal fishing ban, increased substantially in the later six years, particularly in the NWBoB (Fig. 3b). In the WBoB as a whole, the annual trawl effort increased from 13.0 million h in 1988 to 16.8 m h in 2012, showing that the seasonal fishing ban for 45 to 60 days in the last 12 years did not help reducing the annual trawl effort in the WBoB. Compared to the SWBoB, more number of large trawlers were introduced in the NWBoB, enabling multiday fishing, thereby substantially the operation from 7.1 h/unit in 1988 to 78.6 h/unit in 2012 (Fig. 3c). Thus the development of trawl fleet started late in the NWBoB, but has been rapid in the last six years.

Catch trend

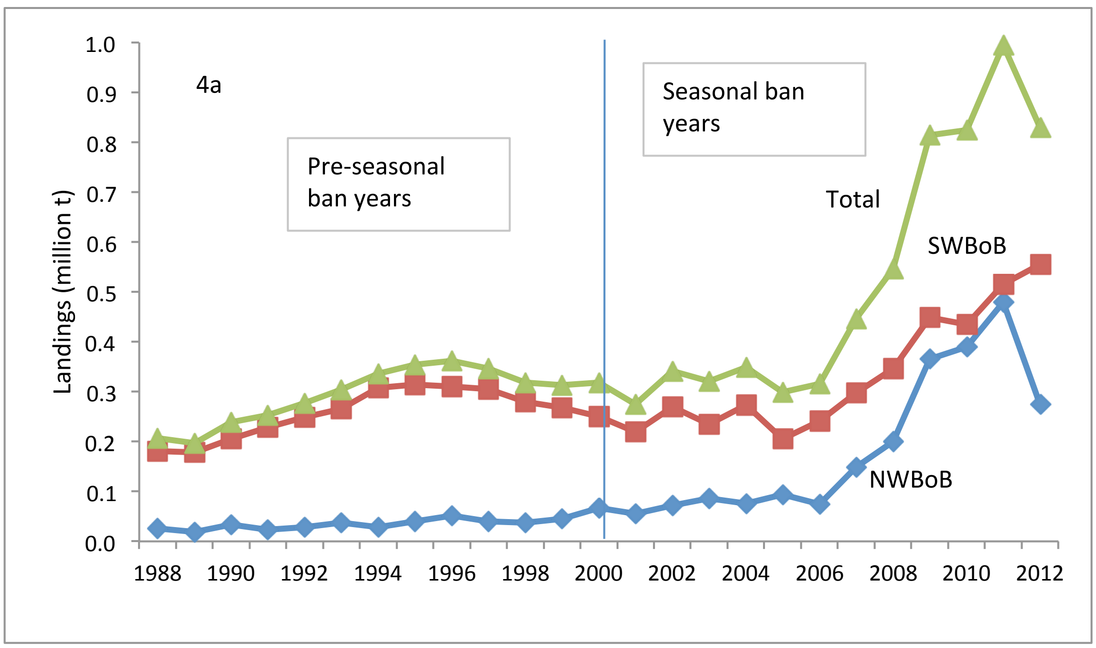
The annual average trawl landings along the WBoB increased from 214,112 t in the years 1988-1990 to 882,721 t during 2010-2012 (Fig. 4a), i.e., by over four times in 25 years. The rapid development of trawl fleet in the NWBoB was reflected in the catch too. While the landings increased by 2.6 times along the SWBoB, it increased by 14.6 times along the NWBoB. The contribution of NWBoB, which was only 14.3% to the landings in the region during 1988-1990, increased to 43.2% during 2010-2012.

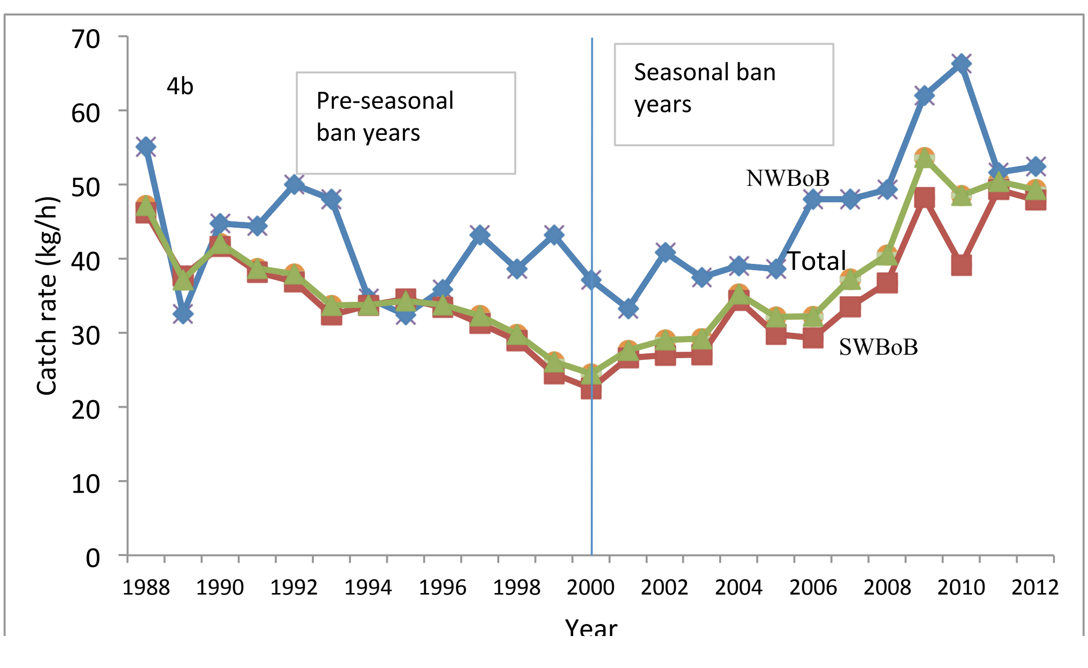
Fig. 3. Trawl effort in the western Bay of Bengal during 1988 - 2012; SWBoB = southwest Bay of Bengal; NWBoB = northwest Bay of Bengal; the vertical line indicates the year from which seasonal trawl ban was implemented



The catch rate, which was decreasing substantially from 47.2 kg/h in 1988 to 24.5 kg/h in 2000 in the WBoB, recovered to 49.3 kg/h in 2012 (Fig. 4b). The catch rate recovered in both the sub-regions in spite of increasing trawling hours. The catch rate in the NWBoB remained higher than in SWBoB through the period

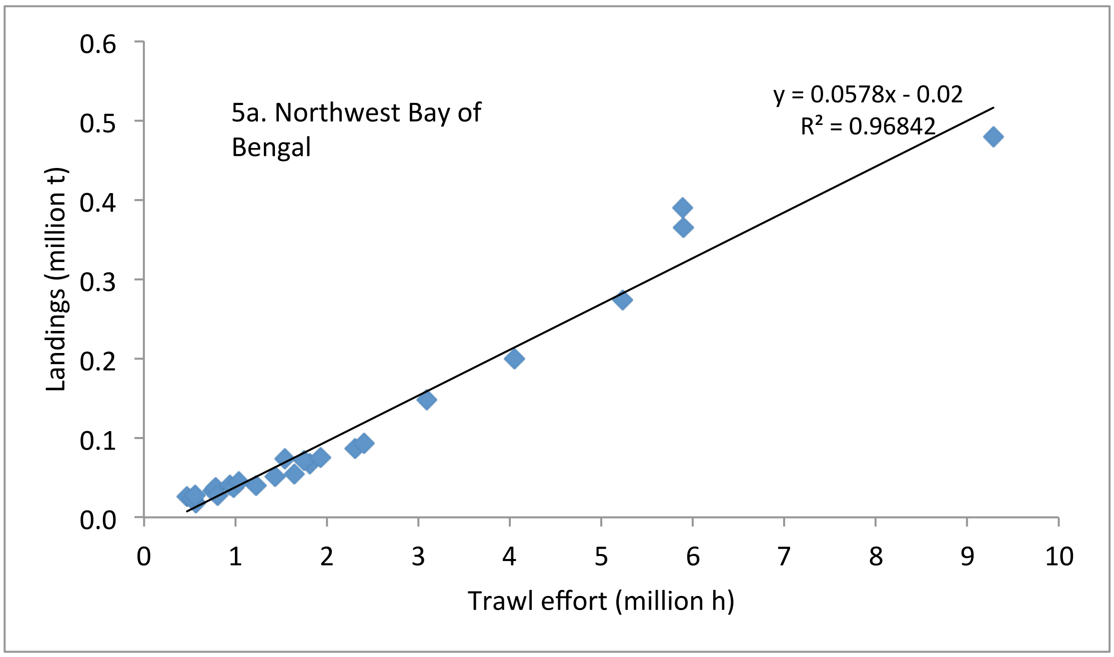
Fig. 4. Trawl landings and catch rate in the western Bay of Bengal during 1988 - 2012; SWBoB = southwest Bay of Bengal; NWBoB = northwest Bay of Bengal; the vertical line indicates the year from which seasonal trawl ban was implemented





While the annual catch increased linearly in relation to trawling hours in the NWBoB (Fig. 5a) as well as SWBoB (Fig. 5b), the catch rate did not display a definite trend. However, it is discernible from Fig. 6a & b that the catch rate indicated an increase in the NWBoB and a decrease in the SWBoB in relation to increasing trawl effort.

Fig. 5. Landings in relation to trawl effort during 1988 - 2012; the thin line is the trendline



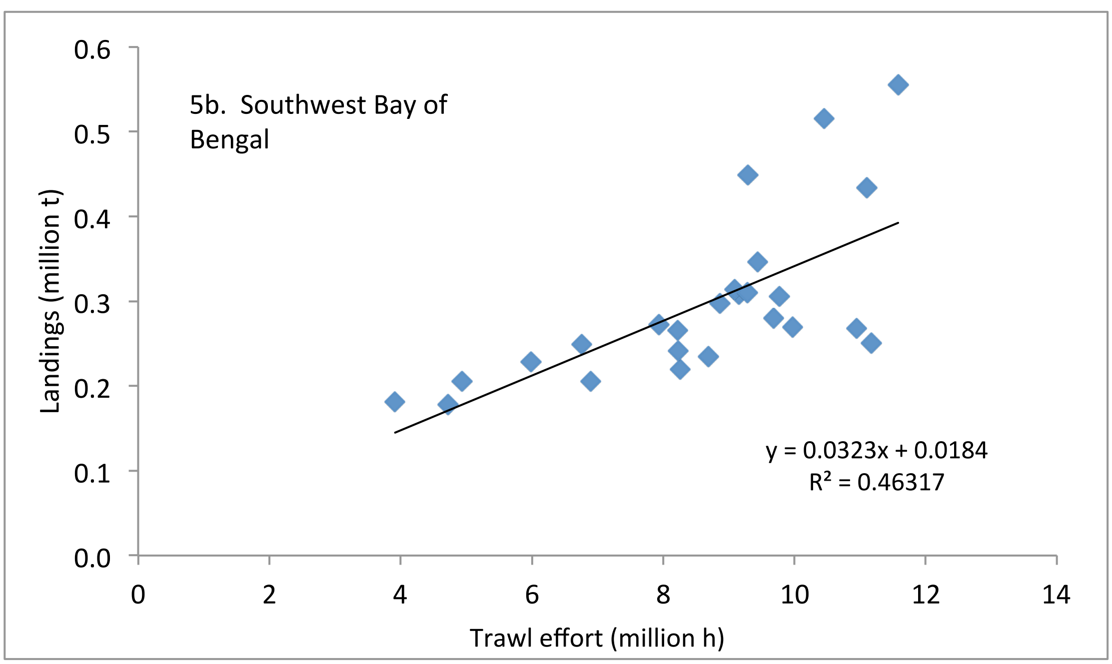
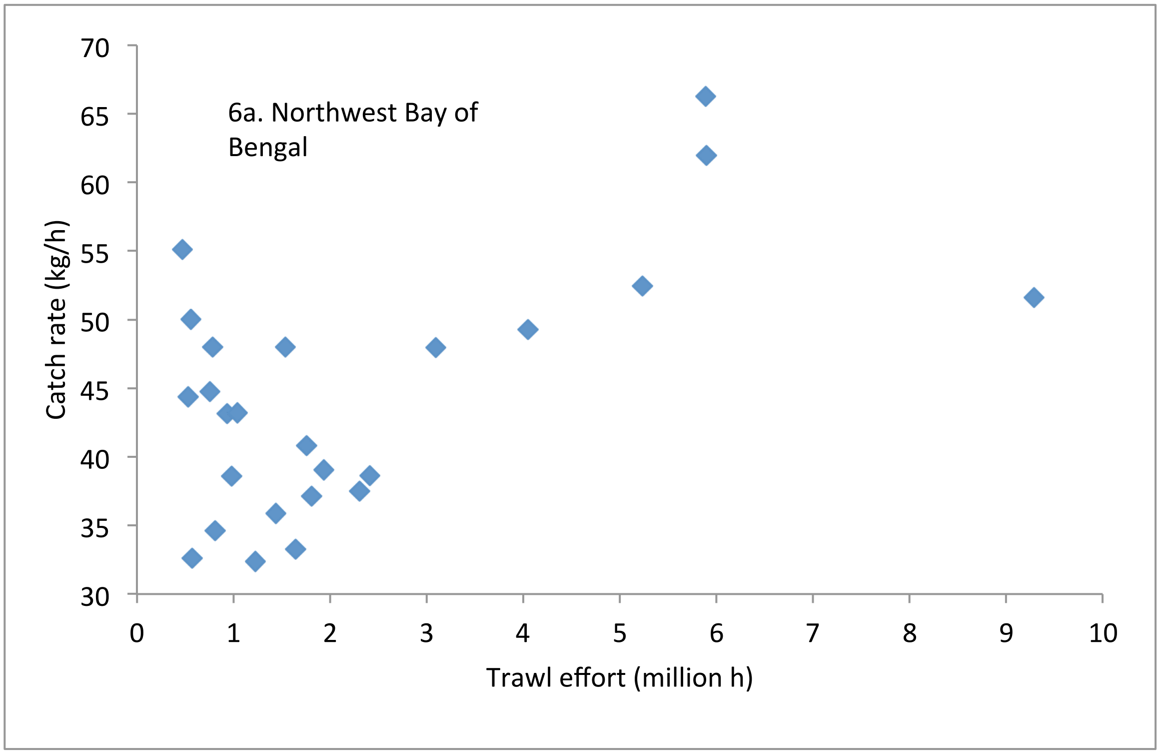
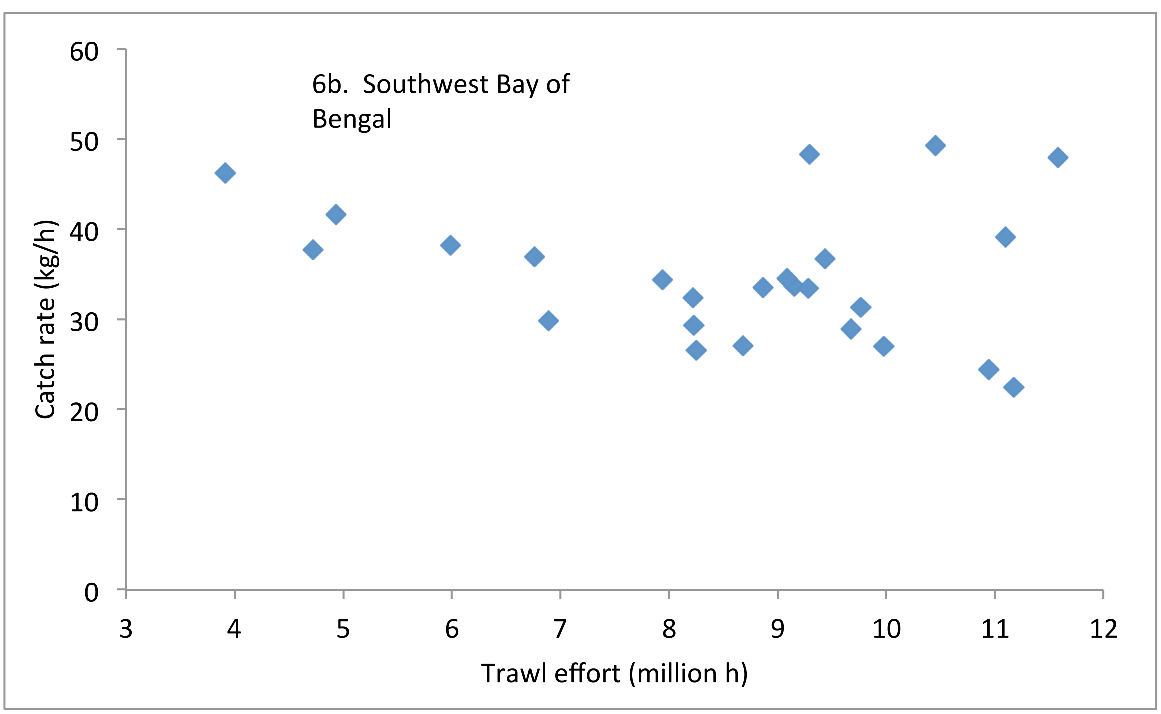


Fig.6. Catch rate in relation to trawl effort during 1988 - 2012





The trends in trawl effort, catch and catch rate indicate that the trawl efficiency has increased over the years, enabling approach to distant and relatively new fishing grounds, which were not accessed before. Consequently, the catch and catch rate have increased. Ban on trawling, which was introduced for 45 to 60 days during April – May from 2000, has helped reduce the rate of acceleration of number of boats, but could not prevent increase in efficiency. Increase in catches coincided with trawl ban period, but conclusions on actual benefits of trawl ban could be arrived at only after considering other indicators such as spawning stock biomass and recruitment strength.

Catch composition

The catch consists of biologically diverse organisms. For example, the fishery along Coromandel coast, which is within the SWBoB, consisted of 750 species of finfish, crustaceans and molluscs (Sathianandan et al., 2012). On an average, 40 species are landed in every trawl haul. In trawl fishery, the species landed have been categorized into 55 groups/species by the CMFRI, which could be further grouped into small pelagics, large pelagics, demersal fish, crustaceans and cephalopods. Gastropods and bivalves are also recorded in the trawl catch, but these records are incomplete. In addition to these groups, several invertebrates such as jellyfish, starfish and sea urchins are also landed.

Changes in the fishing pattern over the years are reflected in catch composition. Considering two time periods, i.e., 1988-1989 and 2011-2012, it has been observed that the contribution of landings of 21 species/groups increased over the 24-year period; 9 decreased and 13 emerged as new fisheries in the NWBoB (Table 2). The major hikes in contribution were from clupeids, goatfishes, ribbonfishes, carangids and penaeid prawns. Substantial decreases were in the contribution of sciaenids and stomatopods. In the SWBoB, major contributions from 25 species/groups increased, 20 decreased, and 3 emerged as new fisheries. The major hikes were in the contribution of sardines, ribbonfishes, scads and Indian mackerel. The contribution of sciaenids and silverbellies to the total trawl landings substantially decreased. The striking observations in the two regions are the following: (i) In the SWBoB, 20 of the 55 groups, especially the demersal fishes, displayed decrease in their contribution to the trawl fishery. This trend reflects the response of demersals to perhaps, overfishing. (ii) In the NWBoB, 13 new fisheries have emerged indicating the developing state of trawl fishery. Thus the two regions are in two different states of exploitation.

Table 2. Composition (%) of groups/species to total trawl landings in two time periods in the northwest and southwest Bay of Bengal; SP = small pelagics; LP = large pelagics; DF = demersal fish; CR = crustaceans; CP = cephalopods

Group/Species	**NWBoB**		
	1988-1989	**2011-2012**	**Remarks**
Sciaenids (DF)	53.55	16.13	Decrease
Penaeid prawns (CR)	9.15	22.52	Increase
Miscellaneous	5.04	1.50	Decrease
Other major perches (DF)	4.07	1.56	Decrease
Catfishes (DF)	3.96	2.81	Decrease
Stomatopods (CR)	3.62	0.13	Decrease
Ribbonfishes (LP)	3.39	8.36	Increase
Other clupeids (SP)	2.33	5.65	Increase
Coilia (SP)	1.73	2.80	Increase
Eels (DF)	1.73	0.54	Decrease
Threadfin breams (DF)	1.72	1.44	Decrease
Lizardfishes (DF)	1.29	1.00	Decrease
Setipinna (SP)	1.27	2.24	Increase
Rays (DF)	1.19	0.24	Decrease
Soles (DF)	1.10	2.69	Increase
Goatfishes (DF)	0.90	3.26	Increase
Silverbellies (DF)	0.84	1.52	Increase
Bombayduck (SP)	0.82	1.68	Increase
Crabs (CR)	0.67	0.83	Increase
Non-penaeid prawns (CR)	0.30	2.68	Increase
Silver pomfret (DF)	0.23	1.33	Increase
Cuttlefish (CP)	0.20	1.07	Increase
Thryssa (SP)	0.20	0.99	Increase
Whitefish (DF)	0.19	0.74	Increase
Skates (DF)	0.15	0.00	Decrease
Other carangids (SP+LP)	0.11	5.04	Increase
Wolf herring (SP)	0.07	1.04	Increase
Stolephorus (SP)	0.05	1.11	Increase
Squids (CP)	0.05	0.38	Increase
Threadfins (DF)	0.03	0.31	Increase
Other shads (SP)	0.03	0.00	No change
Snappers (DF)	0.02	0.02	No change
Sharks (LP)	0.01	0.49	Increase

Indian mackerel (SP)	0.00	2.77	New fishery
Horse mackerel (SP)	0.00	1.53	Increase
Black pomfret (DF)	0.00	0.92	New fishery
Other sardines (SP)	0.00	0.77	New fishery
Indopacific seerfish (LP)	0.00	0.74	New fishery
Hilsa shad (SP)	0.00	0.28	New fishery
Chinese pomfret (DF)	0.00	0.26	New fishery
Barracudas (LP)	0.00	0.16	New fishery
Lobsters (CR)	0.00	0.13	New fishery
Leatherjackets (LP)	0.00	0.12	New fishery
Oil sardine (SP)	0.00	0.09	New fishery
Scads (SP+LP)	0.00	0.06	New fishery
Skipjack tuna (LP)	0.00	0.05	New fishery
Groupers (DF)	0.00	0.01	No change
Spanish seerfish (LP)	0.00	0.01	New fishery
Mullets (DF)	0.00	0.01	New fishery
Flying fishes (SP)	0.00	0.00	No fishery
Pigface breams (DF)	0.00	0.00	No fishery
Kawakawa (LP)	0.00	0.00	No fishery
Yellowfin tuna (LP)	0.00	0.00	No fishery
Halibut (DF)	0.00	0.00	No fishery
Flounders (DF)	0.00	0.00	No fishery
Gastropods	0.00	0.00	No fishery
Octopus (CP)	0.00	0.00	No fishery

Group/Species	**SWBoB**		
	1988-1989	**2011-2012**	**Remarks**
Silverbellies (DF)	22.23	15.95	Decrease
Penaeid prawns (CR)	10.96	8.13	Decrease
Miscellaneous	9.30	2.99	Decrease
Sciaenids (DF)	6.90	3.05	Decrease
Goatfishes (DF)	5.32	2.49	Decrease
Threadfin breams (DF)	4.18	3.17	Decrease
Other clupeids (SP)	3.75	2.35	Decrease
Rays (DF)	3.66	2.29	Decrease
Other carangids (SP+LP)	3.27	2.86	Decrease
Other major perches (DF)	2.95	3.44	Increase
Crabs (CR)	2.71	2.10	Decrease
Lizardfishes (DF)	2.46	1.89	Decrease
Thryssa (SP)	2.27	0.82	Decrease

Other sardines (SP)	2.00	8.87	Increase
Stolephorus (SP)	1.82	1.25	Decrease
Coilia (SP)	1.33	0.08	Decrease
Ribbonfishes (LP)	1.32	5.56	Increase
Soles (DF)	1.31	0.34	Decrease
Scads (SP+LP)	1.17	6.16	Increase
Squids (CP)	1.04	1.96	Increase
Cuttlefish (CP)	1.04	1.82	Increase
Stomatopods (CR)	1.01	0.34	Decrease
Indian mackerel (SP)	1.00	3.32	Increase
Other shads (SP)	0.97	0.95	No change
Catfishes (DF)	0.82	1.48	Increase
Barracudas (LP)	0.79	1.87	Increase
Silver pomfret (DF)	0.68	0.68	No change
Sharks (LP)	0.49	0.16	Decrease
Oil sardine (SP)	0.45	6.32	Increase
Eels (DF)	0.31	0.28	Decrease
Threadfins (DF)	0.29	0.27	No change
Pigface breams (DF)	0.25	0.99	Increase
Halibut (DF)	0.24	0.11	Decrease
Wolf herring (SP)	0.23	0.45	Increase
Bombayduck (SP)	0.20	0.09	Decrease
Setipinna (SP)	0.17	0.01	Decrease
Indopacific seerfish (LP)	0.16	0.14	No change
Non-penaeid prawns (CR)	0.14	0.50	Increase
Whitefish (DF)	0.12	0.08	Decrease
Spanish seerfish (LP)	0.11	0.48	Increase
Groupers (DF)	0.11	0.23	Increase
Black pomfret (DF)	0.09	0.91	Increase
Snappers (DF)	0.09	0.47	Increase
Skates (DF)	0.08	0.07	No change
Leatherjackets (LP)	0.06	0.16	Increase
Lobsters (CR)	0.04	0.05	No change
Horse mackerel (SP)	0.03	0.42	Increase
Chinese pomfret (DF)	0.03	0.08	Increase
Mullets (DF)	0.02	0.66	Increase
Gastropods	0.01	0.12	Increase
Kawakawa (LP)	0.01	0.09	Increase
Flounders (DF)	0.01	0.04	Increase
Octopus (CP)	0.00	0.20	Increase
Yellowfin tuna (LP)	0.00	0.19	New fishery

Flying fishes (SP)	0.00	0.12	New fishery
Skipjack tuna (LP)	0.00	0.07	New fishery
Hilsa shad (SP)	0.00	0.00	No fishery

An important change over the years is the emerging dominance of pelagics in the trawl fishery. The contribution of small pelagics and large pelagics jointly increased from10.0% during 1988-1989 to 36.0% during 2011-2012 in the NWBoB; and from 21.6% to 42.8% during the corresponding years in the SWBoB (Table 3). This substantial increase in pelagic fish contribution has been reflected as decrease in the contribution of demersal fish in both the sub-regions. The trawlers in the region operate exclusively bottom trawlnets. The mouth opening of trawlnet has been increased in the last 25 years, enabling access to midwater fishes. In recent years, more number of floats has been attached to the net, and trawl speed has been increased to > 3 knots, thereby effectively capturing fast moving large pelagics such as ribbonfishes, tunas and barracudas. These technical changes in fishing operation have enabled the trawl fishery to expand access to a large number of resources. The occurrence of large amounts of small pelagics in the trawls is a recent phenomenon, which Vivekanandan (2011) attributed as response of the fish to seawater warming. He suggested that with warming of seawater, the small pelagics such as oil sardine and Indian mackerel are at an advantage, which is reflected as extension of their area of distribution to deeper waters. Consequently, the SWBoB has emerged as a complex of small pelagics consisting of oil sardine, other sardines and Indian mackerel in place of demersals such as silverbellies and threadfin breams.

Table 3. Changes in contribution (%) of fishery groups to the total landings during two time periods

Group	**NWBoB**		**SWBoB**	
	1988-1989	**2011-2012**	**1988-1989**	**2011-2012**
Small pelagics	6.49	21.01	15.40	31.21
Large pelagics	3.52	14.99	6.20	11.59
Demersal fish	70.98	34.77	52.15	38.99
Crustaceans	13.73	26.28	14.86	11.12
Cephalopods	0.25	1.44	2.08	3.98

Penaeid prawns remain as the mainstay of trawl fisheries in both the sub-regions. While the contribution of prawns has substantially increased to 22.5% in the NWBoB, it remained stable at around 8.1% in the SWBoB (Table 2). For targeting penaeid prawns, a large number of sinkers is attached to disturb and scrape through the bottom.

Potential yield estimates

The Department of Animal Husbandry, Dairying and Fisheries (DAHDF), Ministry of Agriculture, Government of India has been engaging working groups from time to time to estimate the potential yield (PY) of exploitable fishery resources of the Indian EEZ. The Working Group constituted in 1991 arrived at an estimated potential of 3.9 million tonnes for the Indian EEZ, which was revalidated as almost the same in the year 2001. After ten years, the working group revised the estimates for the Indian EEZ as 4.42 m t (DAHDF, 2011). The potential of the NWBoB and SWBoB has been estimated as 0.61 and 0.36 m t, respectively (Table 4). In both the sub-regions, about 85% of the potential yield is from the coastal waters at depth below 100 m. Comparison of potential yield and catch indicates that the catch has exceeded the PY in the SWBoB, indicating overfishing. The report has also indicated that the number of trawlers in the SWBoB has exceeded the estimated optimum fleet capacity. In the NWBoB, however, there is scope to increase the catch, not by increasing the fleet strength, but by extending fishing to distant grounds.

Table 4. Potential yield estimates (mt) in different depth zones in the NWBoB and SWBoB (DAHDF, 2011)

Group	**NWBoB**			
	< 100 m	**100-200 m**	**200-500 m**	**Total**
Small pelagics	40,517	5,437	0	45,954
Large pelagics	22,179	3,860	18	26,057
Demersal fish	378,541	52,824	11,770	443,135
Crustaceans	72,906	14,233	3,164	90,303
Cephalopods	2,292	339	118	2,749
Total	516,435	76,693	15,070	608,198

Group	**SWBoB**			
	< 100 m	**100-200 m**	**200-500 m**	**Total**
Small pelagics	108,311	2,348	0	110,659
Large pelagics	36,576	2,679	50	39,305
Demersal fish	123,046	16,995	7,941	147,982
Crustaceans	35,093	10,582	2,360	48,035
Cephalopods	12,560	85	45	12,690
Total	31,5586	32,689	10,396	358,671

Bycatch and discards

The FAO Code of Conduct for Responsible Fisheries calls for the sustainable use of aquatic ecosystems, which requires that fishing be conducted with due regard for the environment. It also promotes the maintenance, safeguarding and conservation of the biodiversity of ecosystems by minimizing the impacts of fisheries on non-target species and ecosystem in general. By-catches can affect biodiversity through impacts on top predators, the removal of individuals from many species, or by elimination of prey (Hall et al., 2000). Thus not only the stocks of bycatch and discarded species are affected, but the entire trophic webs and habitats may be disrupted at the ecosystem level. Given the continuing concern that excessive bycatch and discard may threaten the long-term sustainability of many fisheries, a major project was undertaken by CMFRI to assess the low-value bycatch and discards arising from fishing, especially from trawl fisheries. Several countries have considered species other than shrimps as bycatch in shrimp trawl fishery. However, as shrimp and fish trawls are employed interchangeably in the fishery, and several fish groups are also targeted, all species other than shrimps cannot be considered as bycatch. Considering this, the CMFRI has assessed the bycatch that is of low-value and not directly used for human consumption.

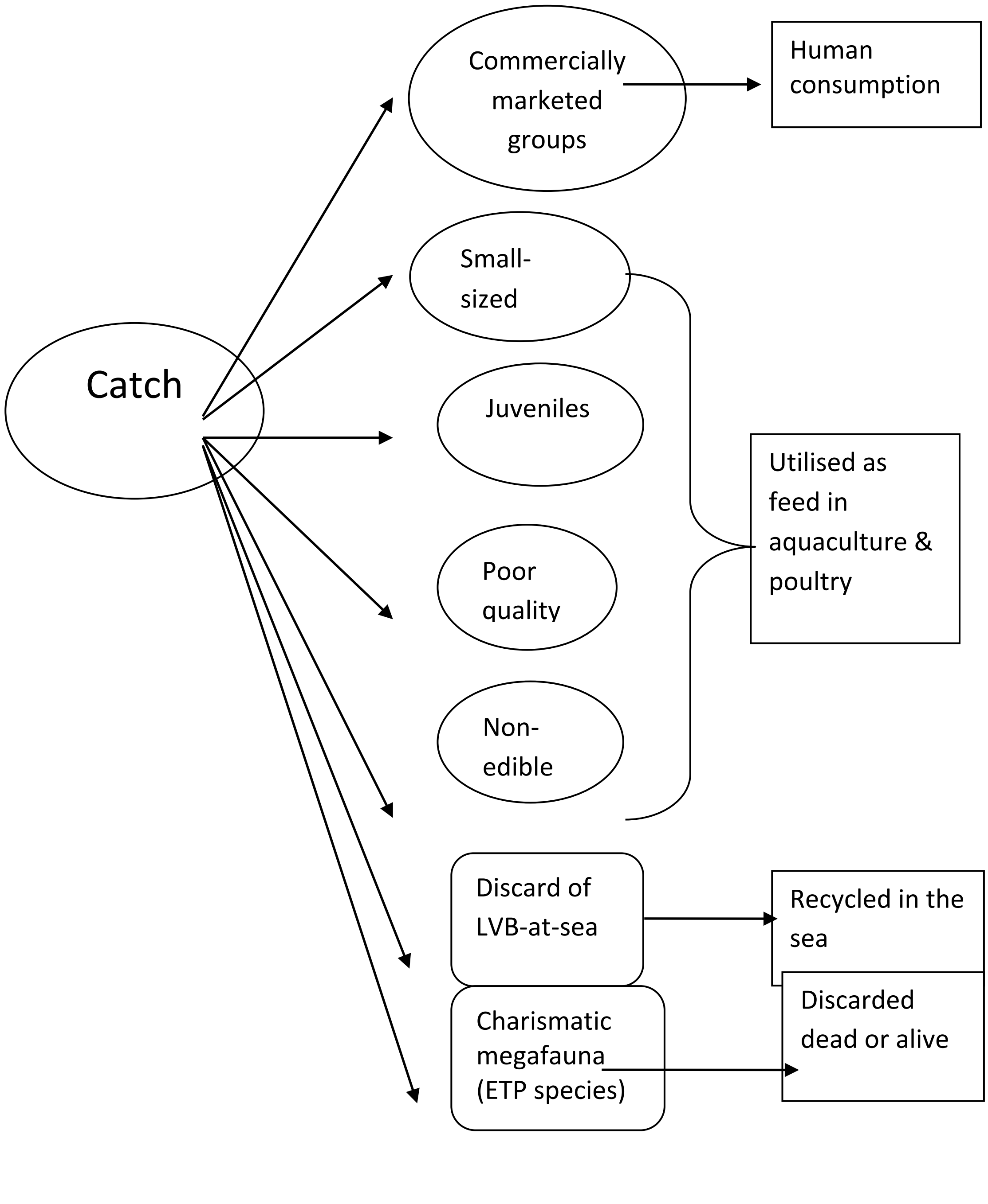
The trawl catch consists of the following three categories: (i) commercially important fish groups, which is directly utilized for human consumption, (ii) low value-bycatch, and (iii) discard-at-sea (Fig. 7). The low-value bycatch (LVB) is defined as the catch that is landed, segregated and sold at the landings centres for a low price. A large portion of the LVB is generally not suitable for human consumption and the remaining is non-edible biota. The LVB consists of:

(i) small-sized, commercially low-value organisms such as few species of cardinalfishes, silverbellies, crabs and non-penaeid prawns;
(ii) juveniles of commercially important fishery groups;
(iii) poor quality fish, which would have fetched higher price had they been properly preserved, and
(iv) non-edible biota such as starfish, sea urchin, sponges, few species of bivalves, jellyfish and pufferfish.

Discard is the portion of the catch that is thrown overboard and not landed. This may consist of:

(i) LVB, which could not be stored in fish hold due to lack of space; and
(ii) incidentally caught megafauna such as dolphins and turtles, which may be discarded dead or alive.

Fig. 7. Composition and fate of trawl catch in WBoB



In Chennai Fisheries Harbour, the trawlers landed an estimated annual average of 16,164 t during July 2005 – June 2008. Of this, 17.5%, i.e., 2829 t were LVB (Lakshmi Pillai et al., 2009). The LVB widely fluctuated between months from 1.9% to 21.2% of trawl landings. Fishes contributed the maximum (60.0%) to the LVB, followed by crustaceans (34.2%) and molluscs (4.6%). Other groups like echinoderms and sponges formed 1.2%. Among fishes, silverbellies, cardinalfishes and clupeids were the major constituents of LVB (Table 5).

Table 5. Composition (%) of low value by-catch of trawlers of Chennai Fisheries Harbour during 2006-2010 (re-calculated from Lakshmi Pillai et al., 2009; CMFRI, 2011)

Group	Composition (% of LVB landings)
FISH	
Silverbellies	14.5
Cardinalfishes	11.5
Flatheads	4.8
Scorpianfishes	3.6
Lizardfishes	2.8
Whitbaits	4.2
Other clupeids	1.8
Carangids	2.1
Threadfin breams	2.4
Pufferfishes	2.1
Flatfishes	1.8
Dragonets	1.5
Glasseyes	1.5
Rays	0.9
Eels	0.9
Filefish	0.8
Goatfish	0.8
Others	2.0
Crustaceans	
Crabs	17.9
Stomatopods	7.5
Shrimps	6.3
Lobsters	2.5
Molluscs	
Gastropods	3.3
Bivalves	0.7
Cephalopods	0.6
Miscellaneous	
Echinoderms	0.4
Sponges	0.4

Others	0.4

The bulk of crabs in the LVB were juveniles of commercially important species like *Portunus sanguinolentus, P. argentatus, P. gladiator, Charybdis lucifera* and *C. hoplites.* Others include *Calappa* spp., *Dorippe frascone, Arcania heptacantha* and *Liagore rubromaculata*. Shrimps in the LVB were mainly constituted by the juveniles and damaged adults of *Metapenaeopsis stridulans* and *Parapenaeus longipes*. Stomatopods, another important constituent in the LVB, were represented by several species like *Oratosquilla nepa, O. woodmasoni, O. gonyptes, Harpiosquilla harpax*, *H. annandeli* and *H. raphidae.* Lobsters consisted of the scyllarids *Petractus rugosus* and *Thenus orientalis*. The cumulative number of species of all groups in the LVB was 232. On an average, 50 to 55 species contributed to the LVB every month.

The value of LVB was determined by its composition, quality and market price of the overall landings in the harbor. Some of the constituents on a specific day would have found place in the LVB on days of good landings. Depending on the quantity of landings and demand, the LVB is sold for Rs 5 to Rs 15 per kg (1 US$ = Rs 65). The annual average value of the LVB landed at Chennai Fisheries Harbour was approximately Rs 20 million (= 0.31 million USD). Had the constituents of the LVB been allowed to grow to a larger size and used for human consumption, the value would have been at least three times higher.

The causes of occurrence of low-value bycatch are (i) use of small sized cod-end mesh, (~15 mm which is only half of the recommended size of 35 mm), (ii) availability of juveniles of several commercially important species throughout the year due to prolonged spawning of tropical fishes, and (iii) realization of better price in recent years from trades related to aquaculture and poultry feed, and use in fertilizer manufacture.

While good estimates on the LVB are available, similar estimate on discard is not available. From fishermen interviews, it has been reported that about 3.3% of the overall trawl catch is discarded.

Incidental mortality of long-lived species with low reproductive rates is a conservation problem affecting marine mammals, sea turtles and other endangered, threatened and protected species. Analysing the available information, Rajagopalan et al. (2006) reported that of the total incidental mortality of sea turtles along the Indian coast during the years 1998-2003, only 18% was contributed by trawls, 78% by gillnets and the remaining by lines. Turtle Excluder Device (TED) was recommended for installation in the trawlnet for escape of turtles that entered the net. The TED is an effective device for turtle escape especially off the turtle mass-nesting site in Odisha (NWBoB). However, the fishermen are reluctant to use the device and often complain loss of fish trapped in the cod-end through the device. Observations on dolphin incidental capture in three major landings including Chennai and Visakhapatnam in the SWBoB during 2006-2008 showed that gillnets contributed 69% to the capture, trawls 18% and lines 12% (Yousuf et al., 2008). Midwater trawls have a greater potential to capture cetaceans and turtles than bottom trawls. As the nets operated in the WBoB are bottom trawls, the capture of these megafauna by the trawls is not in great numbers.

There appears to be considerable potential for reducing the LVB. Use of bycatch reduction devices, gear modifications and regulation of fishing operations may reduce the LVB. A careful analysis is required to ensure that a proposed measure will achieve the desired objective at an acceptable cost (Hall and Mainprize, 2005). Use of 35 mm in place of the currently used 15 mm is likely to reduce the LVB, but would eliminate capture of small-sized adults like a few species of silverbellies, cardinalfishes and non-penaeid prawns, even if they are abundant. This would be a loss to the fishery.

Trawling impact on bottom habitats

Trawling directly affects sea bottom by scraping, sediment re-suspension, physical destruction of bedforms and removal or scattering of non-target benthos. While the effect of one passage of trawlnet would be relatively minor, the cumulative effect and intensity of trawling may generate long-term changes in benthic communities (Collie et al., 1997). Collecting benthic samples from grab before trawl passages off Cuddalore in the SWBoB, Murugesan et al. (2013) reported 126 species of benthic invertebrates, of which 86 were polychaetes, 20 crustaceans, 7 bivalves, 6 gastropods, 2 species each of stomatopods, echinoids, asteroids and 1 scyphozoan. After three trawl passages each lasting for one hour, the number of species reduced to 75 and the population density reduced by about 25% . The concentration of important nutrients, namely total phosphorous and total nitrogen significantly reduced in the sediments after trawling (Muthuvelu et al., 2013). During trawling the turnover of sediments was higher and the availability of sediment nutrients got dispersed, resulting in lower values after trawling (Sreedevi, 2008). The silt content in the sediment increased in the first hour after experimental trawling due to settling of suspended particles. However, the change was temporary, as one day after trawling, the surface sediment had grain size pattern analogous to that before trawling. In areas of tide and current, the re-suspension of sediments was of short duration and the effects of sediment re-deposition were not permanent. Similarly, the removal of macrobenthos had variable effect depending on the depth. In shallow waters, if the damage was intermittent, recolonisation occurred quickly. However, if the trawling was intense, the damage was permanent. In depths beyond 200 m, the effects could be severe and recovery will take long time (Jones, 1992).

Ecosystem impacts

To find out the fishing impact on marine ecosystem, Vivekanandan et al. (2005) estimated the annual mean trophic level (TrL) of marine fish landings consisting of 53 exploited species/ groups along the Indian coast for the period 1950–2002. They detected that increase in the landings was associated with decrease in mean TrL in the WBoB, particularly in the SWBoB. The decadal trend indicated that the mean TrL has decreased in the SWBoB, from 3.53 during 1953–1962 to 3.32 during 1993–2002, i.e. at the rate of 0.04

per decade. Further analysis by Vivekanandan and Krishnakumar (2010) showed that the mean TrL decreased from 3.220 during 1990-1999 to 3.205 during 2000-2006 in the NWBoB as well, at the rate of 0.077 per decade. Using an index developed by Pauly et al. (2000), which indicated whether a fishery is balanced (FIB) in ecological term or not, they found that the increasing trend of the FIB index ceased in the last 5–10 years in the SWBoB. A backward-bending signature in the landings versus TrL plot for the SWBoB in the last 6 years indicates fishing-induced changes in the ecosystem owing to low productivity of the coastal waters and high density of fishing craft. The landings of several large predators increased, but higher removals appear to have helped proliferation of their prey, the mid-level carnivores.

One of the major changes in the fisheries in the SWBoB is the incursion of the oil sardine (trophic level: 2.5). The oil sardine, which did not contribute substantially to the fishery during 1950–1988 (annual landings in all gears: 0 to 4533 t), started emerging as a fishery by the end of 1980s, and since then, continued to increase in the landings, and reached 111,540 t in 1997 and further to 155,000 t in 2012. The emergence of a fishery for the oil sardine has reduced the mean TrL of the fishery. Vivekanandan (2011) suggested that increase in sea surface temperature and chlorophyll a concentration have driven increase of oil sardine population from the late 1980s. In the NWBoB, the landings of other groups with low-TrL such as the penaeid prawns and clupeids increased in the last two decades, reducing the mean TrL of the fishery.

Thus fishing down the food web has been influenced by environmental fluctuations, advanced fishing technologies, and market-driven, deliberate fishing on low-trophic level invertebrates such as the penaeid prawns. Based on their analysis, Vivekanandan and Krishnakumar (2010) arrived at the following conclusions for the WBoB regions: (i) The species mix, especially that of small pelagics, is different between the two sub-regions. (ii) Oil sardine and Indian mackerel catches along the SWBoB and hilsa shad along the NWBoB showed an increasing trend after 1990 due to climate-driven changes. (iii) Fishing down food web is driven by climatic and fishing factors. (iv) The climate-driven, low-trophic level, low value clupeids, and the fishery-driven, low trophic level, but high-value penaeid prawns play major roles in determining the quantity and value of the catch. (v) Due to climate-driven proliferation of small pelagics, which are characterized by fast growth, small body size, quick generation turnover and large interannual variabilities, predictions on future trend in the ecosystem effects based on fishing down food web alone may not be realistic.

Tools used to assess resources

Concerned about the status of marine fish stocks in the Indian EEZ, the country has put in place institutional mechanisms to monitor and forecast fishery yields.

Collection of temporal and spatial data on commercial fish catch and effort

Realising the importance of a reliable database in fish stock assessment and fisheries management, the CMFRI initiated the process of collection of data on catch and effort of commercial fishing boats along the coastline of mainland of India based on a scientific sampling technique in 1947. Data on marine fishing villages, landing centers, craft and gear were collected that could form a frame for developing an appropriate sampling design. The first attempt in that direction was made in 1948 to collect marine fish catch statistics. Pilot surveys were conducted in different regions of the country between 1950 and 1955 (Banerji and Chakraborty, 1972). Initially the surveys were based on a three-stage stratified sampling. From 1959, the CMFRI is following a multi-stage stratified sampling design along the west coast of India, and a full-fledged sampling along the west and east coasts became operational since 1961. Considering the changing scenario in the fisheries sector, the sampling is periodically updated with enhanced scope and coverage.

The sampling design enables estimation of landings by resource (fish groups/species) and area (maritime state). In this design, the stratification is over space and time (Srinath et al., 2005). The number of fishing units landed on the days of observation, length of craft, type of gear, date and time of departure of units from the landing centre, number of hauls, depth of hauls, duration of actual fishing, manpower employed, weather and sea state are recorded. Thus the fishing efforts in terms of number of units, number of hauls and fishing hours are available, and it is possible to calculate catch rate in terms of number of units and fishing hours. As the observation has spatial and temporal coverage, the catch and effort of directed and non-directed fisheries of all types that are landed along the mainland of India are covered in the database.

Although the taxonomic resolution of the data collected is high, there is considerable data reduction during the data processing to facilitate easy reporting. Consequently, the catch data records which have more than 1000 species names have been reduced to 83 species/groups for reporting purpose. To enable the reporting of actual species caught (fished taxa biodiversity), the original data records are being re-entered from the original field data sheets using appropriate software and estimates are made and stored in MS ACCESS by developing an estimation software in C++ and Visual Basic code for exporting data.

Status of stock assessment

Assessments for coastal stocks are made from commercial fish catches by CMFRI and for oceanic stocks from exploratory surveys by Fishery Survey of India (FSI). Since 1991 the Department of Animal Husbandry, Dairying and Fisheries (DAHD&F), Ministry of Agriculture is estimating the potential yield of Indian EEZ in collaboration with CMFRI and FSI every 10 years. These organizations are also undertaking marine fishery census periodically and the last census was in 2010. The next census is proposed to be taken up in 2015.

Since its establishment in 1947, the CMFRI is monitoring the biological characteristics of fish resources caught along the Indian coast. In the last 30 years, the focus of capture fisheries research has expanded to stock assessment of commercially important species of small and large pelagics, demersal finfishes, crustaceans and molluscs. The stocks are continuously monitored through resource, gear and region-based research projects. The technical activities of these projects include monitoring spawning, fecundity, recruitment, diet composition, growth, mortality and status of exploitation to estimate biological reference points, MSY, spawning stock and standing stock biomass and developing predictive models. The results are consolidated in the institute's annual reports and published from time to time in research journals. The findings of the projects are also shared with government fisheries departments to facilitate developing fisheries management policies and acts.

An analysis of literature shows that the methodology of stock assessment has remained almost uniform through the time period. As a thumb rule, growth parameters are estimated by length frequency method. Total mortality (Z) is estimated mostly by length converted catch curve method and natural mortality by the empirical relationship derived by Pauly (1980). In recent years, the standing stocks and spawning stock biomass have been estimated by length-based virtual population analysis (VPA); and prediction models have been developed using Beverton and Holt method (1957) and Thompson and Bell method (1934).

There is scope to improve the stock assessments by validating growth estimates by reading growth rings in hard parts; by employing acoustic surveys and tagging programmes, and by strengthening the deep sea surveys. In spite of availability of a large amount of data on fish stock estimates and oceanographic parameters (collected by National Institute of Oceanography), only a few models exist to understand the relationship between physical, chemical and biological oceanographic parameters, and fish distribution and abundance. Delineating the impacts of climatic and oceanographic factors and anthropogenic interventions (other than fishing) from fishing impacts remains to be addressed.

Ecosystem models

Diet compositions have been estimated for several species in the last five decades, but most of the earlier records were qualitative. Recently, quantitative diet compositions have been recorded for estimating index of relative importance (IRI) for deriving trophic levels. Ecopath model is under development for the Gulf of Mannar (located in the SWBoB), which is a biodiversity hotspot. The interim trophic model for Gulf of Mannar consists of 32 ecological groups ranging from phytoplankton and detritus to dolphins and whales. Fishery groups constitute about half of the total number of groups. Using the model, a scenario has been built in Ecosim with increasing effort at the rate of 10% per year for a period of ten years. It was observed that effort increase resulted in substantial reduction in stock biomass, and therefore effort reduction has been suggested for the Gulf of Mannar ecosystem (CMFRI, 2011).

Decision support systems for management of trawl fisheries

Bayesian estimation method has been used to study time series catch and effort data for trawlers in Tamil Nadu (SWBoB) and West Bengal (NWBoB). Schaefer's non-linear model was considered for arriving at estimates of biomass and Maximum Sustainable Yield (CMFRI, 2012).

The algorithm used was Markoc Chain Monte Carlo using WinBUGS software version 3.0.3. The final estimates of MSY for the trawl fishery were 211,000 t and 46,510 t for Tamil Nadu and West Bengal, respectively. The annual average landings by trawlers during 2001-2010 was less than the estimated MSY. These estimates, and estimates on optimum fleet size have cautioned on the overcapacity of fishing fleet, especially of the trawl fleet in the WBoB.

Development of Vulnerability Index

Vulnerability Index is a risk assessment tool that relies on life history characteristics of a stock (productivity potential) and its susceptibility to fishing and environmental characteristics. Vulnerability is expected to differ between stocks based on life history characteristics and susceptibility to the fishery. Taking advantage of the availability of data in different publications in peer-reviewed journals and grey literature on the biological characteristics, exploitation status and population parameters for 120 species of finfish, crustaceans and molluscs in the Indian seas, an interim sustainability index has been developed (Vivekanandan et al., 2009).

This semi-quantitative and rapid risk assessment tool relies on the life history characteristics of the stocks and their sustainability. The Index has been determined by assigning scores ranging from 1 (low) to 6 (high) for a standardised set of attributes. The approach is to rank the species based on 13 attributes under 4 broad categories, viz., biological, exploitation, distribution and habitat productivity. This is a tool similar to Productivity and Susceptibility Analysis (PSA; NOAA, 2010), but with a difference in selection of attributes and assigning scores within each attribute.

Based on the sustainability index, the data were recalculated to arrive at Vulnerability Index (VI) of 120 exploited species in the Indian seas. The interim VI estimated for 60 exploited species in the SWBoB showed that in the score of 1 to 6, the VI ranged from 2.67 to 5.32 (Table 6). Among the top ten in the list of vulnerability are mainly large pelagics, namely two species of sharks, two barracudas, two carangids and two seerfishes in addition to one catfish. The large body size, slow growth, high trophic level and high market value make these fishes vulnerable to fishing.

Table 6. Interim results on vulnerability assessment (VI) of exploited species in SWBoB sub-region; higher the VI, higher the vulnerability; modified from Vivekanandan et al (2009)

Species	**VI**
Carcharhinus sorrah	5.32
Sphyraena picuda	4.92
Ablennes hians	4.89
Rhizoprionodon acutus	4.67

Caranx ignobilis	4.64
Sphyraena jello	4.58
Tachysurus dussumieri	4.55
Scomberomorus lineolatus	4.42
Scomberomorus commerson	4.38
Selaroides leptolepis	4.38
Turbinella pyrum	4.33
Trichiurus lepturus	4.25
Caranx carangus	4.08
Thunnus albacares	4.08
Scomberomorus guttatus	4.06
Sepia aculeata	4.05
Tachysurus thalassinus	4.02
Euthynnus affinis	3.95
Otolithes ruber	3.92
Johnieops aneus	3.91
Sardinella gibbosa	3.90
Saurida undosquamis	3.89
Leiognathus bindus	3.87
Stolephorus waitei	3.85
Sphyraena obtusata	3.83
Anadara granosa	3.82
Secutor insidiator	3.81
Leiognathus dussumieri	3.79
Stolephorus devisi	3.77
Upeneus taeniopterus	3.77
Loligo duvauceli	3.75
Rastrelliger kanagurta	3.75
Sepia pharaonis	3.75
Tachysurus tenuispinis	3.75
Penaeus monodon	3.74
Upeneus vittatus	3.73
Penaeus semisulcatus	3.72
Kathala axillaris	3.70
Nibea maculata	3.69
Upeneus sulphureus	3.69
Ariomma indica	3.64
Sardinella longiceps	3.62
Placenta placenta	3.60
Johnius carutta	3.54
Auxis thazard	3.50
Katsuwonus pelamis	3.50
Portunus sanguinolentus	3.46
Leiognathus jonesi	3.45

Decapterus russelli	3.42
Sardinella albella	3.38
Metapenaeus dobsoni	3.35
Nemipterus delagoae	3.31
Nemipterus japonicus	3.25
Portunus pelagicus	3.25
Sardinella sirm	3.23
Caranx leptolepis	3.18
Pennahia macrophthalmus	3.18
Metapenaeus monoceros	2.95
Oratosquilla nepa	2.81
Parapenaeopsis maxillipedo	2.67

While there are many qualitative risk analyses currently used by fisheries scientists and managers, the VI analysis is a particularly useful methodology for tropical stocks. The output from this relatively simple and straightforward tool enables the managers understand how vulnerable their managed stocks are becoming overfished. It also provides guidance to determine the needed strength of conservation measures and the degree of precaution to apply in management measures.

Governance systems

Fisheries within 12 nautical miles (territorial waters) are governed by provincial/ state administration in India. As majority of commercial fishing vessels are coastal, fishing licenses, regulation, compliance and welfare are governed by the state governments. Beyond territorial waters and within the EEZ, the Ministry of Agriculture of the central government administers fisheries. The responsibility of regulating large vessels which fish in the offshore waters, though not many in numbers, is retained by the central government. Often, the central government coordinates with the state governments on matters related to fishing regulations to arrive at uniformity. Funding is essentially from central government's centrally-sponsored schemes, which are used for infrastructure development such as harbour construction, providing subsidies (for example, purchase of outboard motors for artisanal craft), strengthening data collection system etc. In addition, the state governments spend on fisheries, mostly on welfare measures (for example, monetary compensation to the fishermen during trawl ban period).

National and state legal frameworks are in place, but implementation of harvest controls, other than seasonal closure, is weak. Lack of manpower in state ministries, and strong negotiations by stakeholders prevent effective implementation of management measures. The strength of the Indian system is the research institutions, which are producing appropriate advice to the policy makers.

Several advisory committees in the last few years have suggested harvest control measures and capacity reduction recommendations, after consultations with the stakeholders, but much headway has not been made. Initiatives are taking place on co-management. Management is taking place under the Marine Fishing Regulation Act, which includes provision for ecosystem approach to fisheries. Other acts relevant to fisheries governance are Indian Fisheries Act 1897, Indian Wildlife (Protection) Act 1971, Maritime Zones Act 1976, Forest Conservation Act 1980, Coastal Regulation Zone Notification 1991, Deep Sea Fishing policy 1991 and Biological Diversity Act 2002. The Indian Fisheries Act 1897 was created mainly to offer protection to fisheries against dynamites or explosives. The Indian Wildlife (Protection) Act offers protection to marine biota and creates conditions favourable for in situ conservation of fauna and flora. The act was amended in 2001 to include several species of fish and sea shells, all species of corals, sea cucumbers, marine turtles and marine mammals in Schedule I and III. Whale shark is placed in schedule I of the act. The Marine Zones Act 1976 describes various zones such as territorial waters, EEZ, continental shelf etc, and the Coastal Regulation Zone notification 1991 regularises various activities in the coastal zone. Marine biodiversity is protected under the Forest Conservation Act 1980, which was amended in 1988. The Biodiversity Act 2002 was created with an aim to protect and conserve biodiversity and sustainable use of its components.

Marine Fishing Regulation Act, 1978

MFRA is 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. The measures include regulation of mesh size and gear, reservation of zones for various fishing sectors and also declaration of closed seasons. These laws are framed and amended from time to time by the maritime states. The regulatory measures formulated under this act cover prohibition of exploitation by destructive gears, explosives and poison. The other regulatory measures followed are: (i) restriction of number of fishing boats, (ii) restriction of number of fishing gears which exploit juveniles in the backwaters; (iii) mesh size regulation; (iv) minimum length at capture; (v) seasonal ban on fishing; (vi) restriction of fishing areas; (vii) protection of endangered species; and (viii) implementation of marine protected areas.

Licensing

All mechanized boats are registered either with the fisheries department of state governments, and the larger ones with government of India. Almost in the entire WBoB, the number of fishing boats has been stabilized either under the MFRA or at the initiative of fishermen. Fishermen associations, especially those on mechanized fishing, have self-imposed restriction and do not allow introduction of new boats. Old boats may be replaced, but there is no restriction on size and engine capacity of the newly introduced boats. Consequently, the number of trawlers has not increased, but the efficiency and capital investment on fishing have increased. Several technical advancements also have been introduced over the years. In this situation, the fisheries management approach may have to involve rationalization of capital investment in fishing. For this, the aggregate gross tonnage or horsepower of fishing vessels operating from a fishing harbor may form the basis upon which the number of licensed vessels may be regulated. To ensure that the total operational efficiency of a fishery does not exceed the prescribed ceiling, plans for enlargement of vessel size have to be carefully coordinated. To implement this method of limited entry on fishing capacity, the system of licensing may have to take into consideration prevention of overcapitalization.

Mesh size regulation

The cod-end mesh size (CEMS) of trawls is uniformly small at < 15 mm (stretched, from knot to knot). The MFRA suggests CEMS of 30 to 35 mm, but it is difficult to implement the minimum CEMS in the region, which typically represents multispecies tropical fisheries. In trawl fishery, each haul catches, on an average 40 species of different body size and shape. The body shape is one of the important factors that determines gear selectivity. The body shape, measured as depth ratio (standard length/maximum body depth) ranges from 1.0 (*Drepane punctata*) to 45.0 (the eel, *Thyrsoidea macrura*). There is, therefore, no single mesh size, which is optimum for all the species. However, the recommendations on optimum mesh size treat the multispecies fishery as a single stock. Recommending larger mesh size leads to underexploitation of several smaller species. The suggestions on optimum mesh size should consider finding a balance between different species. Perhaps optimum mesh size can be computed for different groups using yield per recruit analysis. Alternatively, a summation function may be formulated so that the aggregate yields per recruit for all the species are maximized for a given overall mesh size (Sainsbury, 1984). Nevertheless, the regulation of CEMS is difficult to enforce unless a regular observer monitoring programme is put in place.

Restriction of fishing areas

In the context of persistent conflicts between artisanal and mechanized vessels in the inshore waters, the state governments have delineated the areas of operation of these two sectors. Under this act, the mechanized boats have been banned from fishing in inshore areas, which have been assigned exclusively to the artisanal craft (Table 7). However, as the density of fish and shrimp biomass is higher near the shore, the mechanized boats do not comply with the restriction. Moreover, the depth in different locations widely differs. For instance, at a distance of 5 km from the shore, the depth may be only 10 to 15 m in Palk Bay, but 100 m in locations few kilometers north of Palk Bay in SWBoB. To address this issue, some governments amended the act by including depth factor into the act. As demarcation of fishing areas is basically meant for protecting the interests of artisanal fisheries, the trawlers are at a disadvantage as they are denied access to the richer shrimping grounds in the nearshore waters. Nevertheless, in the absence of surveillance, encroachment of mechanized boats into the waters demarcated for artisanal boats is common.

Table 7. Demarcation of fishing areas in the WBoB

State	Demarcated fishing areas
West Bengal(NWBoB)	Boats < 15 m OAL: beyond 5 km Boats > 15 m OAL: beyond 10 km
Odisha(NWBoB)	Boats < 15 m OAL: beyond 5 km Boats > 15 m OAL: beyond 10 km
Andhra Pradesh(SWBoB)	Boats < 20 m OAL: beyond 10 km Boats > 20 m OAL: beyond 15 km
Tamil Nadu & Puducherry(SWBoB)	Mechanised boats beyond 5 km

Seasonal ban on fishing

Seasonal fishing ban (SFB) is one of the instruments which is systematically followed every year. In thus instrument, fishing by mechanized boats is banned for 47 to 60 days during April – June every year (Table 8). Protecting the spawners during peak spawning season, reducing fishing effort and giving respite to the benthic fauna from intense trawling are the goals of SFB. However, SFB has been generating controversies since inception. There are questions about the efficiency of SFB in long-term sustainability and enhancement of fish stocks. A section of fishermen complain loss of employment during the ban period. After inception of the ban, several committees were formed from time to time to review the efficiency, period, duration and impact of ban. Barring one or two, all the committees have advocated continuation of the ban as a measure of conserving the fishery resources and to aim at sustainable harvest. To find out the impact of SFB, the CMFRI analysed the relevant data pertaining to pre-ban years and the years of ban implementation. The conclusions of the analysis are as follows (Vivekanandan et al., 2010): (i) The increase in catches along the Indian coast is essentially due to increase in the efficiency of craft and gear and extension of fishing to offshore regions. (ii) There is an improvement in recruitment of several demersal species into the fishery immediately after the ban, but for a short duration of one to two months. (iii) SFB has not helped long-term recovery of stocks. However, removal of seasonal fishing ban may result in spurt in fishing effort, which is detrimental to fish stocks. (iv) Many species have a prolonged spawning season lasting for 6 to 7 months, with peak spawning at least twice a year. As spawners of different species of fish, crustaceans and molluscs occur almost in equal strength (Table 9), spawning period could not be considered as the sole criterion for fixing the period or duration of closure. (v) Boats with outboard motors with different engine capacity have become dominant in the fishery. While ban exists for larger boats, removal of large quantities of spawners by craft with outboard motor is evident. Seasonal ban on fishing by boats with any form of motorization is necessary. (vi) Effective implementation of a combination of several other regulatory measures such as minimum/maximum legal size at capture, mesh size regulation, licensing, regulation of operation of motorised boats and capping the number of boats are necessary along with seasonal closure for sustainability of fish stocks.

Table 8. Seasonal fishing ban in the WBoB

State	Year of introduction	Notified period	Days of Closure	Vessel types included in fishing ban
West Bengal (NWBoB)	1995	15 April - 31 May	47	All mechanised boats
Odisha (NWBoB)	2000	15 April - 15 June	60	All mechanised boats & boats with >25hp outboard motor
Andhra Pradesh (SWBoB)	2000	15 April - 31 May	47	All mechanised boats & boats with >25hp outboard motor
Tamil Nadu & Puducherry (SWBoB)	2001	15 April - 31 May	47	All mechanised boats & boats with >25hp outboard motor

Table 9. Number of species spawning by month in the WBoB (n = 55 species; from Vivekanandan et al., 2010)

Month	Number of species
January	25
February	29
March	28
April	30
May	33
June	27
July	27
August	27
September	22

October	20
November	21
December	21

Fishermen interviews indicated that they are convinced on the importance of fishing regulations. They agreed for longer duration of ban period, if it helps increase their catches in the fishing period.

Protected species

Several species are protected under Wildlife Protection (1971) Act (Table 10). Capture or trade on these species is prohibited under the act. Releasing sharks after finning is prohibited under a notification. Under this act, fishing for whale shark is prohibited.

Table 10. Species protected under Wildlife (Protection) Act 1971

Species/group	Number
Elasmobranchs	10
Grouper	1
Molluscs	24
Sea horses	All species
Sea cucumber	All species
Sponges	All species
Corals	All species
Sea turtles	All 5 species
Cetaceans & dugong	All 27 species

Marine Protected Areas (MPA)

The first MPA in India was designated in 1967 for the protection of wetlands and migratory birds, even before a specific legal framework was put in place. Currently, there are 31 MPAs along India's coastline that have been officially declared for conserving and protecting coastal and marine biodiversity (SCBD, 2006). Except four, all other MPAs are located in the east coast of India (WBoB) and in the Andaman & Nicobar Islands. The MPAs in the east coast of India include Gulf of Mannar Biosphere Reserve, Wildlife sanctuaries of Corringa, Gahirmatha and National Park of Sunderbans and Bhitarkanika.

Most of the MPAs were designated during 1980s and early 1990s. They were notified either as 'national parks' or 'wildlife sanctuaries' under the Wild Life (Protection) Act (1971), where, in most cases, no extractive activity is allowed (Ramya, 2008). While these are progresses towards positive direction, provisions in MPA legislation that support the rights and occupational interests of communities are yet to be implemented. Given this situation, fishing communities do not subscribe to the concept of MPA. The case study undertaken by Ramya (2008) also shows that fishing communities have either taken up, or are willing to take up, management initiatives to minimize the impact of their fishing activities. However, such initiatives from communities have not received adequate support, and have not yet been incorporated into the management plans for the areas.

In 2013, the MoEF, in association with GIZ (Germany), has initiated a project to design and implement participatory models for conservation and management of biodiversity at selected existing and potential MPAs in India. The overarching goals of the project are the protection of biodiversity and the improvement of livelihoods of the local communities.

Despite growing awareness, there is a need for site-specific action, research oriented to problem solving (e.g. socio-cultural aspects, participation), and integrating the research findings into management system and policies for coastal and marine biodiversity conservation and fisheries sustainability. Such management systems have to enable participation of local communities and other actors to ensure that both conservation goals and sustainable livelihood aspirations of local communities are met.

Suggestions for improvement of governance systems for sustainability

It is being increasingly realized that fishing may be unsustainable under the existing management regime because (i) rapid growth of human population drives increasing demand, (ii) development of mechanized fishing technologies damage the environment and fisheries, and (iii) quicker transportation to fishing grounds makes even the distant fish populations vulnerable to exploitation. The management objectives of trawl fisheries should be to sustain the health of the target resources, ensure that ecosystem impacts are low, and ensure that fleets are able to sustain catch levels (Banks and Macfadyen, 2011).

Traditional systems of management, which have tended to focus on individual stocks or species, have not achieved this objective. For sustainability, legislation requires effective fisheries management plans, bycatch management plans, collaboration among various stakeholders, ecosystem approach to fisheries and quick responses to changing fishery conditions and research findings. The objective of trawl fishery management should be to ensure that resources are managed with an ecosystem approach, and to ensure long-term sustainable livelihoods of fishers and fishing communities.

The trawl fishery management in WBoB has so far targeted input (or fishing effort) control measures such as seasonal closure, restricting the number of trawlers etc. Output (or catch) control measures, which may limit the tonnage or number of fish caught in a specific period of time, have not been attempted, except ban on capture of a few protected species.

There is scope to improve technical regulations relating to fishing craft and gear such as regulating boat size, mesh size and use of bycatch reduction devices.

Input controls

Effective implementation of access control measures requires the use of different capacity reduction schemes to address excess levels of fishing effort and fleet capacities. Fleet control measures and effort limitations should be addressed at an early stage. Failure to do so results in difficulties in reducing the capacity. Buy-back schemes to reduce capacity have not taken roots, but could be attempted with a target of reducing the number of boats within a specific period. The governments have to find enough funding sources and initiate detailed debates with the fishing communities.

Along with the efforts to reduce fishing effort and/or capacity, statutory craft and gear restructuring tools are required. For instance:

- Use excess engine capacity (400 hp) for 15 m trawlers and trawling at a high speed of about 5 knots not only decimates several midwater stocks, but also considerably increases fuel consumption and CO_2 emission.
- Reducing the trawling speed by installing speed governors is advocated by fisheries research institutions in India.
- Prevention on use of heavy otterboards, reducing the headrope length in the entire fishery and reducing the mouth opening of trawlnet could be the other gear restructuring tools, which would effectively reduce the destructive effect of trawling.

India encourages diversification of fishing, especially conversion of trawlers into tuna longliners. By giving subsidy to the conversion, several trawlers have been converted, which increased yellowfin tuna catches in the WBoB. India also encourages deep sea fishing, but the fishermen are not inclined to undertake the venture. Deep sea trawling up to 400 m depth for shrimps was prevalent for a short period every year by employing the same vessels engaged in coastal fishery, but as the catch dwindled after a few seasons, the fishermen are no longer interested in this fishery. Nevertheless, this did not reduce the overall fishing capacity.

Output controls

Output controls are not in place except the minimum legal size for export of lobsters and pomfrets. However, there is no restriction on minimum or mean size at landing. Fishermen-monitored initiatives on total allowable catch may be attempted on a trial basis. Use of bycatch reduction devices and turtle excluder devices may be promoted. Comprehensive analysis on management options centred on economic efficiency has to be made for each option on output control. The cost and benefits, identified strengths and weaknesses of the output control measures should be identified.

A framework for sustainable trawl fisheries may consider the following (see also Macfadyen et al., 2013):

(i) To create management framework to set appropriate control measures and to safeguard the ecosystem;
(ii) To ensure a robust compliance system and facilitate participation of stakeholders in decision making;
(iii) To establish monitoring and evaluation system;
(iv) To develop business drivers that will link to improved fishing practices.

A Trawl Management Advisory Council may be established in which fisheries manager, representatives from fishermen associations, processing industry and traders, fisheries scientist, economist and NGOs will be the members.

<u>Ecosystem approach to fisheries management</u>

The living aquatic resources are an integral part of the ecosystems and management of ecosystems is a prerequisite for the well being of fisheries resources. It has been widely recognized that fisheries management should adopt a broad-based spatial management strategy with the management of living resources and temporal restrictions such as closed fishing season appropriately integrated into the management regime depending upon the conservation needs of the ecosystems.

In the WBoB, Coastal Regulation Zones have been identified under the Integrated Coastal Zone Management. Marine Protected Areas and no-fishing zones are also in place. These regulations are implemented considering various users of the coastal areas, and hence, there is scope for initiating EAF. The fishing communities are dispersed all along the coast, and they are dependent on marine ecosystems that are close to them.

The nature of the ecosystems is an important determinant of many cultural characteristics, including the social and economic organization and the fishing gear and technologies that are utilized. The communities develop intimate, detailed and function-oriented knowledge about the marine ecosystems. They are also easily vulnerable to resource depletion. The question is how we are prepared to adopt EAF. The traditional approach will have to be embedded within the domain of the EAF by involving all stakeholders. A carefully planned protocol and implementation of EAF within a logistic time frame is expected to contribute to the protection of fisheries.

Conclusions

The increasing catches and catch rates mask several issues connected with trawl fishery in the WBoB. In spite of observance of seasonal trawl ban, the fishery is experiencing increasing fishing effort and efficiency, and considerable quantities of low value bycatch.

Long-term trends in catch composition and risk assessment indicate that many species, especially demersal finfish and large pelagic are vulnerable to fishing. Potential yield and optimum fleet size estimates have indicated overcapacity of fishing fleet especially in the SWBoB and that the catches are approaching the potential yield. These indicators emphasise the need for efficient management system for an improved sustainability. The lessons learned from other countries and the best practices may be followed for developing a trawl fishery management plan. Experience suggests that single tools seldom suffice achieving fisheries management. As multiple objectives exist in the region, multiple management tools related to input and output controls, and ecosystem approach are required.

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