

Spatial and temporal differences in the coastal fisheries along the east coast of India

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Annual average fish landings along the east coast of India increased from 0.15 million tonnes during 1950-59 to 0.85 m t during 2000-06. The contribution of the northeast coast (NE) to the total landings along the east coast of India increased from 5.5% to 30.7% in the last five decades. There were remarkable differences in the catch composition between the NE and southeast (SE) coasts. Among the small pelagics, for instance, the hilsa shad *Tenualosa ilisha* and bombayduck *Harpadon nehereus* were dominant along the NE coast, but the oil sardine *Sardinella longiceps*, lesser sardines and Indian mackerel *Rastrelliger kanagurta* along the SE coast. Contribution of the fast growing, small-sized and low trophic level hilsa had increased from 0.5% during 1950-59 to 12.5% during 2000-06 along the NE coast, and the oil sardine (from 0.1% to 9.0%) and Indian mackerel (from 1.5% to 5.8%) along the SE coast. This has resulted in a decline in the mean trophic level of the catch by 0.077 and 0.041 per decade during 1950-2006 along the NE and SE coasts, respectively. This process of decline in the mean trophic level of the catch is caused due to substantial increase in the landings of species/groups that are low in trophic level, such as the small pelagics (oil sardine and hilsa), and penaeid and non-penaeid shrimps over the years.

[**Keywords:** east coast of India, coastal fisheries, spatial differences, Fishing Down Marine Food Web]

Introduction

The western Bay of Bengal, bordered by 2019 km-long east coast of India, receives minerals and nutrients from several east-flowing rivers and two large brackishwater lakes. The northern subsystem (northeast coast of India) consists of the maritime states of West Bengal and Orissa, which is dominated by estuarine influence caused by addition of freshwater and silt¹. 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)². However, the productivity along the east coast is sufficient to support a large subsistence and industrialized fishing sector. In 2005, about 0.5 million fishermen were actively engaged in marine fishing along the east coast of India by employing 21, 385 mechanized, 45, 391 motorized and 75, 626 non-motorized craft (CMFRI, 2006a). A wide variety of gears such as trawl, several variants of gillnet, hooks & line, longline, trammelnet, boatseine, bagnet, dolnet and ringseine are operated along the entire coast. The catch consists of more than

50 commercially important species/groups of finfish, crustaceans, cephalopods, bivalves and gastropods³.

Fish production or catch from natural sources is driven by three important factors, viz., (i) the innate environment and climate of a region, which determine the structure and functions of the ecosystems⁴ (ii) fishing^{5,6} and (iii) other human-induced interferences such as pollution, climate change etc on environment and climate, which were not conspicuous until a few decades ago, but are now leaving human footprints with dramatic influences⁷. The type and intensity of fishing are generally related to market demand. In recent years, however, a large portion is incidentally caught bycatch, which is not against consumer demand. A portion of this unintended catch also enters the market and is used as manure and feed for poultry and aquaculture farms. Nevertheless, these three drivers, either independently or in combination, influence the fish catch.

Considering the parameters such as temperature, salinity, wind, current, watermass movement, upwelling and sunspot⁸, concluded that spawning, recruitment and abundance of small pelagics in the northern Indian Ocean are driven, to a large extent, by

the climatic and oceanographic factors. In this paper an attempt had been made to analyze the spatial and temporal differences in the coastal fisheries and to delineate the impact of the three drivers on fish catch along the east coast of India.

Material and Methods

The data on fish landings are collected and published by Central Marine Fisheries Research Institute (CMFRI) for the last 60 years⁹. Census of marine fishermen population and number of fishing craft and gear has also been conducted by CMFRI periodically³. We analysed these data for this paper.

Results and Discussion

Two striking features characterize the fisheries along the east coast. The first is the difference in the development of the fisheries sector between the northeast (NE) and southeast (SE) coasts. Fisheries development along the NE coast is recent compared to the one along the SE coast. The fishery along the SE coast appears to have reached a plateau considering the stagnation in the catches in the last decade⁸. The second feature is the conspicuous differences in catch composition between the two subsystems.

Fish landings

Annual average fish landings along the east coast of India increased substantially from 1, 51, 367 tonnes during 1950-59 to 8, 46, 734 t during 2000-2006 (Fig. 1), *i.e.*, a 5.5 times increase in 57 years. This increase, to a large extent, was possible due to increase in the number and efficiency of fishing craft and gear. The number of mechanized craft (with inboard engine) increased from 1252 in 1960-61 to 21, 285 in 2005, and the motorized boat (with outboard engine), which was introduced in the mid-1980s, increased to 28, 124 in 1998 and 45, 391 in 2005 (Table 1). The size of the mechanized boats also increased, enabling multiday fishing, extension of fishing grounds, and fishing for pelagic, midwater and demersal resources in the coastal waters.

Through the decades, the landings along the SE coast were higher than that along the NE coast. During 2000-06, the annual average catch from the SE coast (8.0 t/km² of continental shelf area) was 40% more than that from the NE coast (5.6 t/km²). However, the landings along the SE coast were stagnant over the last 15 years as against a substantial increase along the NE coast. Consequently, the

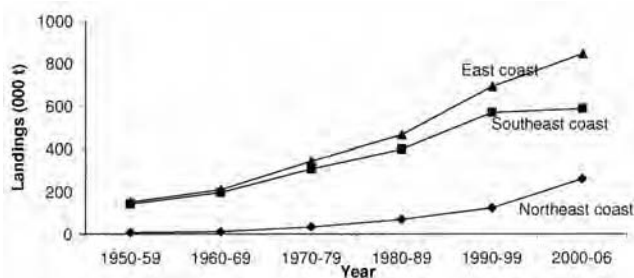


Fig. 1—Annual average fish landings along the east coast of India

Table 1—Numbering of fishing craft along the east coast of India during different time period

Year	Mechanized craft		
	NE coast	SE coast	Total
1961-62	65	1187	1252
1973-77	58	1998	2056
1980	1523	3383	4906
1998	6189	9955	16144
2005	10406	10879	21285
Motorized craft			
1961-62	0	0	0
1973-77	0	0	0
1980	0	0	0
1998	4152	23972	28124
2005	6495	38896	45391
Non-motorized craft			
1961-62	3569	49383	52952
1973-77	6667	58244	64911
1980	13789	81106	94895
1998	7558	44382	51940
2005	25485	50141	75626

contribution of the NE coast to the landings along the entire east coast increased from 5.5% during 1950-59 to 30.7% during 2000-06 (Fig. 2). The number of mechanized boats was increasing from 6,189 in 1998 to 10,406 in 2005 along the NE coast whereas it was almost stable at around 10,500 along the SE coast in the last decade (Table 1).

Differences in regional species mix

Based on the bathymetric distribution and body size, the catch could be broadly grouped into the following six categories: small pelagics, large pelagics, midwater fish and cephalopods, small demersal finfish, large demersal finfish and demersal crustaceans. Though fishes do not strictly restrict within this distribution regime, and freely move between the pelagic, epipelagic, midwater and demersal domain, for the sake of clarity, we have

grouped them into six categories in this paper. A comparison showed that the small pelagics (41.8% of NE coast landings) and midwater fishes (19.6%), which together contributed 61.4% along the NE coast, contributed only 48.2% along the SE coast (Table 2). Compared to the NE coast (21.2%), the SE coast supports more quantities of large pelagics, and small and large demersals (38.0%).

Within each category, the dominant species/groups were different between the NE and SE coasts. Among the small pelagics, for instance, the hilsa shad *Tenualosa ilisha* and bombayduck *Harpadon nehereus*, which contributed 26.9% to the NE coast landings during 1990-2006, contributed only 0.8% along the SE coast (Table 3). On the other hand, the lesser sardines, oil sardine *Sardinella longiceps* and Indian mackerel *Rastrelliger kanagurta*, which were dominant (25.8%) along the SE coast contributed only 4.4% along the NE coast. Among the midwater fishes, the catfishes and ribbonfishes were dominant along the NE coast, but carangids along the SE coast; among the small demersals, the sciaenids were dominant along the NE coast, but threadfin brems and silverbellies along the SE coast. The major peches such as the rockcods, snappers and emperors were conspicuously absent along the NE coast (Table 3). Evidently, each species/group has a strong habitat

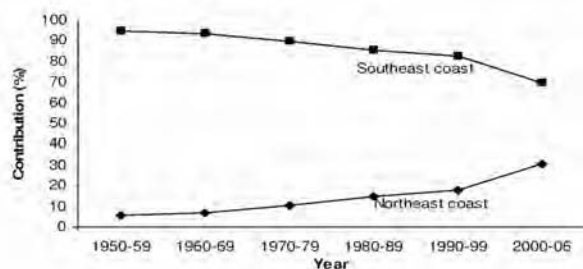


Fig. 2—Contribution of northeast and southeast coasts to the total landings

Table 2—contribution (%) of landings of different fish categories to the total landings of different fish categories to the total landings of respective coastal zones during 2000-06

Category	NE coast	SE coast
Small pelagics	41.8	35.2
Large pelagics	4.6	8.7
Midwater fishes	19.6	13.3
Small demersals	14.7	22.4
Large demersals	1.9	6.9
Crustaceans & Cephalopods	17.4	13.5

preference, which is driven mainly by the oceanographic features of the regions.

Emergence of small pelagic fisheries along the east coast

The landings of the small pelagics, especially that of the hilsa shad, the oil sardine and the Indian mackerel have increased substantially along the east coast during 1960-2006. The annual average catch of the hilsa shad increased from 6, 600 t in the 1970s to 29, 694 t during the 2000s along the NE coast (Table 4).

The annual average oil sardine catch from the SE coast, which was only 81 t (0.04% of the all-fish catch along the SE coast) in the 1960s, increased to 58, 687 t (10.3% of the catch) during 1990-1999. Until 1989, about 90% of the oil sardine catch in the country was obtained from the SW coast (Kerala, Karnataka and Goa). By 1990, the oil sardine catch from the SE coast showed sudden increase and during 1994-1998, more than 50% of the total oil sardine catch was obtained from this coast.

Table 3—Contribution (%) of selected species/group to the total landings of respective coastal zones during 2000-06

Species/groups	NE coast	SE Coast
	Small pelagics	
Hilsa shad	13.7	0.5
Coilia	2.3	0.1
Setipinna	2.0	0.1
Bombay duck	13.2	0.3
Oil sardine	0.1	9.0
Lesser sardines	2.4	10.2
Indian mackerel	1.9	6.6
Whitebaits	0.5	2.8
Midwater fishes		
	Catfishes	1.6
	Ribbonfishes	2.8
	Horse mackerel	0.4
	Pomfrets	1.1
	Other carangids	4.4
Small demersals		
	Sciaenids	3
	Threadfin brems	5.7
	Other perches	2.8
Large demersals		
	Silverbellies	6.1
	Rays	2.8
Crustaceans & Cephalopods	Rockcods	0.7
	Snappers	0.8
	Emperors	1.3
	Non-penaeid prawns	1.0
	Crabs	3.6
Cephalopods		
	Cephalopods	2.4

Table 4—Annual average small pelagic landings (tonnes) along SE and NE Coasts; the values in parentheses refer to % in the all-fish landings of the respective coasts; NA refers to non-availability of data

Period	Northeast coast			Southeast coast		
	Hilsa shad	Oil sardine	Mackerel	Hilsa shad	Oil sardine	Mackerel
1960-69	NA	27 (0.1)	95 (0.7)	NA	81 (0.04)	4373 (2.2)
1970-79	6600 (18.8)	4 (0.01)	379 (1.1)	232 (0.1)	298 (1.0)	8861 (2.9)
1980-89	4447 (6.5)	84 (0.1)	827 (1.2)	485 (0.1)	4552 (1.1)	17324 (4.4)
1990-99	20458 (16.7)	198 (0.2)	840 (0.7)	796 (0.1)	58687 (10.3)	34592 (6.1)
2000-06	29694 (12.8)	403 (0.2)	3380 (1.5)	1498 (0.3)	51744 (8.8)	32762 (5.6)

The mackerel catch, which was only 4, 373 t (2.2% of the all-fish catch along the SE coast) in the 1960s, increased to 34, 592 t (6.1% of the catch) during 1990-1999. From 1961 to 1979, nearly 82% of the mackerel catch in the country was recorded from the SW coast, while the remaining was from the SE (~12%), NW (~5%) and NE (~1%) coasts. By 1990, the contribution of the SW coast to the all India mackerel catch gradually reduced to around 64%, whereas the contribution by the SE coast increased to about 25%.

Earlier researchers have reported widespread distribution of oil sardine and mackerel along the west coast of India especially in the Malabar upwelling zone^{10,11}. This is due to the high primary productivity associated with the seasonal coastal upwelling in the region¹². Recent studies have clearly established that the Arabian Sea is more productive than the Bay of Bengal (BoB) and there are several striking differences in the oceanographic features of these two basins^{13,14}. Recent studies using satellite derived chlorophyll *a* imageries have shown more phytoplankton growth in the southern part of BoB than in the northern part¹⁵. Generally, the northern BoB is less productive than the southern BoB due to the strong stratification driven by the immense fresh water flux and also due to the shallow euphotic zone created by the suspended sediment load¹⁶. The SE coast is found to be more productive than the NE coast with reference to the production of pelagic fishes.

The small pelagic fishes are short-lived, highly fecund, and spawn in all the months. These biological characteristics make them highly sensitive to environmental forcing and extremely variable in their abundance^{17,18}. Small pelagics also respond dramatically and rapidly to fluctuations in ocean climate^{19,20}. The oil sardine and mackerel fishery along the Indian coast is mainly supported by the 0-year class and therefore the success of the fishery

mainly depends up on their larval recruitment²¹. The spawning and recruitment strategies of small pelagics, especially clupeoids from the upwelling areas are adapted to the spatial and temporal patterns in the upwelling process of the region¹⁷. These fishes release their larvae into the annual production cycle at the best time to match with the large scale production of their food in those areas.

However, an optimal environmental window (OEI) consisting of nutrient enrichment (upwelling or mixing), concentration processes (convergence, stratification) and retention processes that maintain eggs and larvae in the suitable habitat are found to be crucial for the successful recruitment of the small pelagics²². Therefore, the recruitment success of most of these fishes whose spawning and recruitment cycle is matching with upwelling season depend upon several environmental parameters such as wind speed, turbulent sea conditions, upwelling intensity, rainfall, SST and dissolved oxygen (DO) content^{23,22} have reported that for Ekman type upwelling, the annual recruitment increases with upwelling intensity until wind speed reaches a value of approximately 5-6 m/s and decreases for higher values. They have also reported that for a non-Ekman type upwelling, the relationship between recruitment and upwelling intensity is linear. The anomalous oceanographic conditions in the Arabian Sea associated with positive Indian Ocean Dipole (IOD) in 1994 (data on IOD downloaded from www.jamstec.go.jp) have resulted in the collapse of oil sardine fishery along the SW coast and its proliferation along the SE coast (Fig. 3).

Fish catch and trophic level

Examined⁵ the fish landings along the Indian coast for 1950-2002 in terms of trophic levels (TL) of 707 species of fish, crustaceans and cephalopods. The TL is the functional position of a given species/group in the food web. Herbivorous fish are low in TL, and carnivorous fish are in higher trophic level. The analysis showed that the landings have shifted from

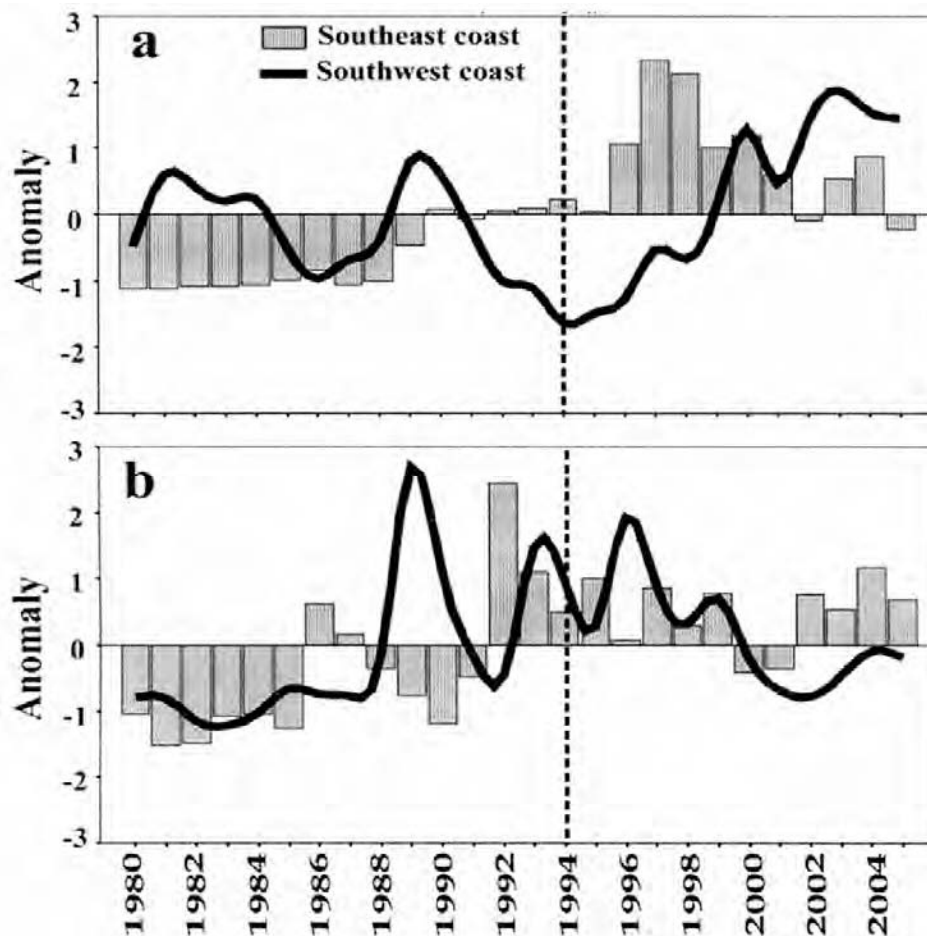


Fig. 3—Comparison of catch anomalies of (a) oil sardine and (b) Indian mackerel along the SE and SW coasts of India during 1980-2005; dashed vertical line indicates the anomalous oceanographic conditions in 1994 associated with positive Indian Ocean Dipole (IOD) event (information collected from www.jamstec.go.jp)

large piscivorous fishes toward small invertebrates and planktivorous fishes along the east coast, a process called by²⁴ as “fishing down marine food web (FDFW)”⁵. detected that increase in the landings along the east coast was associated with decrease in the mean exploited trophic level (TrL) of 0.04 per decade particularly along the SE coast. They expressed concern that this trend may not only affect the value of fisheries, but may cause significant problems in the structure and function of marine ecosystems²⁴. We revisited this data for the east coast by adding landings data for four more years (2003-2006). The mean trophic level of the landings (TrL) for a given year was estimated by multiplying the landings by the trophic levels of the individual species/groups, and by taking a weighted mean. The objective was to find out (i) if any change has occurred in the fishing down trend, and (ii) whether the fishing down trend is driven by climatic, fishery or market factors.

The analysis shows that the mean TrL of the landings continues to decline from 3.220 during 1990-99 to 3.205 during 2000-06 along the NE coast, and from 3.338 to 3.317 along the SE coast (Fig. 4). On a longer time scale, the rate of decrease was 0.077 per decade along the NE coast (from 1980-89 to 2000-06) and 0.041 per decade along the SE coast (from 1960-69 to 2000-06). Thus the trend has set-in along the SE coast much ahead, but the current decline is steeper along the NE coast. The plot of mean TrL against the mean landings clearly indicates that the catch can be increased only against lower TrL (Fig. 5). For a decrease of mean TrL of 0.1, the landings increased by 87, 000 *t* and 1, 95, 000 *t* along the NE and SE coasts, respectively.

To identify the species/groups that cause the FDFW, we subjected the data for further analysis. The decrease/increase in the annual average landings of each species/group between 1990-99 and 2000-06

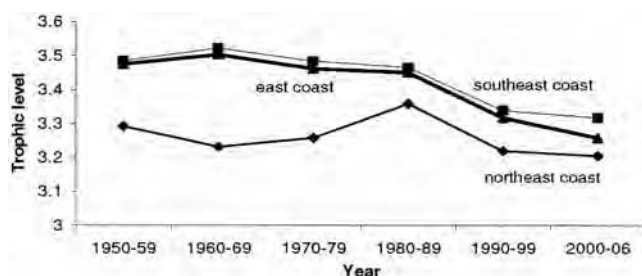


Fig. 4—Mean trophic level of landings along the east coast of India during 1950-2006

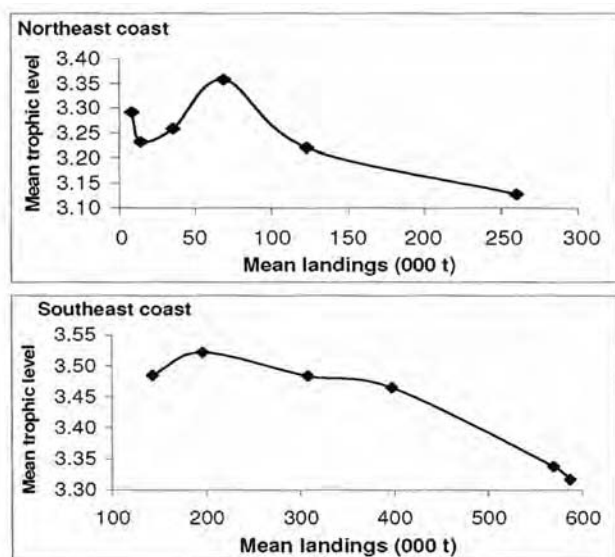


Fig. 5—Relationship between decadal mean landings and trophic level along the NE and SE coasts of India during 1950-2006

was plotted against the respective mean TL (Fig. 6). Though there was no specific trend in the plots, it was found that the landings of 34 of 42 species/groups increased along the NE coast. As there was increase in the landings of three groups with low TL, viz., *Hilsa* shad (TL: 2.00; increase in the landings: 11,900 tonnes), penaeid prawns (TL: 2.51; 9,711 t) and non-penaeid prawns (TL: 2.51; 14,584 t), the mean TrL decreased along the NE coast during 2000-06. The increase in the landings of these groups was 36,195 t, which accounted for one third of increase in the landings. Among the three groups, *Hilsa* shad forms a subsistence gillnet fishery, and the recruitment success of this anadromous fish is strongly driven by the hydrographic parameters in the sea as well as in the rivers, and spawning success in the rivers²⁵. Considering catch as a surrogate of abundance, this climate-driven fishery reflects that the strength of the stocks and higher abundance results in higher catches. The penaeid prawn fishery, on the

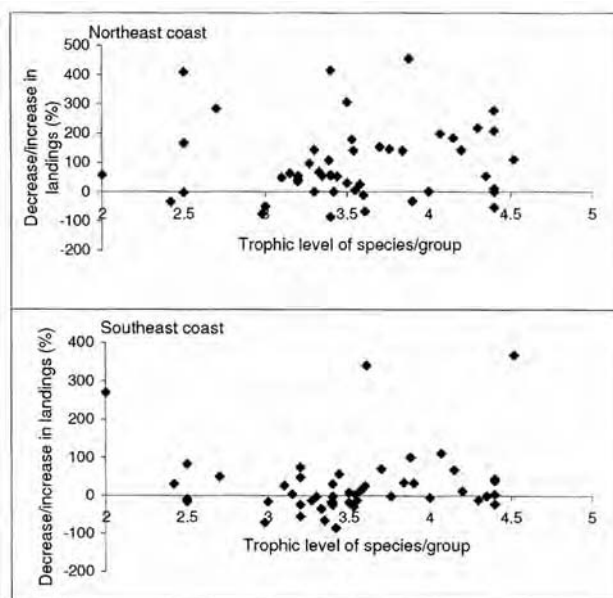


Fig. 6—Plot of mean trophic level (TL) vs difference in annual average landings (%) of respective species/group during 2000-06 as compared to 1990-99

contrary, is market-driven. The high unit price for penaeid prawns induces a target bottom trawl fishery, and increasing catch may not reflect increasing stock biomass. In such cases, the catch is related to fishing effort. The fleet mechanised craft consists of mostly bottom trawlers, which increased by about 40% during 1998-2005 along the NE coast. The catch may increase with increasing effort up to certain level, but further increase in effort may result in overexploitation and decrease in abundance and catch. The third component, the non-penaeid prawns are low-value bycatch in the trawl fishery for prawns. Hence, the landings of non-penaeid prawns has also increased due to increase in trawl effort. Thus, the three major groups, viz., *Hilsa* shad, penaeid prawns and non-penaeid prawns that contributed to decrease in the TrL along the NE coast are driven by climatic, trawl fishery and market, and trawl fishery factors, respectively.

The situation is different along the SE coast. Catch differences between 1990-99 and 2000-06 were not as conspicuous as along the NE coast. Increases of larger magnitude in the landings occurred before 1990 similar to the one that is happening now along the NE coast²⁶. Suggested that increase in sea surface temperature and chlorophyll *a* concentration induced increase of oil sardine populations along the Indian coast since the 1990s. Between 1980-89 and 1990-99, the landings from climate-driven small pelagic

fisheries such as the oil sardine, lesser sardines, other clupeids and Indian mackerel increased by 85, 879 *t*; and from the market-driven target fisheries for penaeid prawns by 16, 488 *t*. All these species/groups are of low TL, thus effecting FDFW.

By considering the climate-driven fisheries such as the small pelagics especially the clupeids on one hand, and the combined market-driven and bycatch on the other, we conclude that the FDFW is not due to fishing alone, but has a major share from the climate-driven fisheries. Had the climate been not suitable for the low-TL small pelagic fisheries, the mean TrL would not have reduced to the extent as it was witnessed along the NE coast during 2000-06, and along the SE coast during 1980-89.

Conclusions

The following conclusions are arrived at based on the present analysis: (i) The species mix, especially that of the small pelagics is different between the NE and SE coasts. (ii) Oil sardine and Indian mackerel catches along the SE, and hilsa shad catch along the NE coast showed an increasing trend after 1990 due to climate-driven changes. (iii) Unlike the NE coast, the fish catch along the SE coast did not show an increasing trend in the last 15 years. (iv) Fishing Down Marine Food Web is driven by climatic and fisheries factors. (iv) The climate-driven, low trophic level, low value clupeids, and the fishery-driven, low TL, but high value penaeid prawns play major roles in determining the quantity and value of the catch. (v) Due to proliferation of the climate-driven small pelagics, which are characterized by fast growth, small body size, quick generation turnover and large interannual variabilities, predictions on the future trend in the FDFW may not be realistic.

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