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Effect of trawling and its by-catch on marine ichthyofauna off south west coast of India

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Abstract
Bycatch is recognized as unavoidable in any kind of fishing but the quantity varies according to the gear operated. The changing perspective of bycatch itself offers the greatest challenge, as yesterday's by-catch becomes today's target catch. However, this study to ascertain the ichthyofaunal biodiversity loss due to trawling was conducted between August, 2010 to May, 2012 recorded a total 131 species of finfish and shellfish belonging to 62 families and 18 orders. Family Carangidae contributed 10.69 per cent of total number of species followed by Engraulidae (6.11%), Leiognathidae (6.11%), Synodontidae (3.82%), Tetraodontidae (3.82%), Nemipteridae (3.05%), Sciaenidae (3.05%) and Scombridae (3.05%) to the total number of fish species whereas, other families contributed less than 3 percent and a total of 52 commercial species were reported in by-catch in the year 2010-11 whereas, it reduced to 41 species during the year 2011-12 with increased species number of low value fishes. This trend showed that significant increase of low value fish species with decrease in commercial fish species in by-catch. The average bycatch contribution was 33.54% (2010-11) and 45.68% (2011-12) during the study period. The results of Shannon-Weiner index (H') showed variability in different capacity engines. This study also indicated that the Mangalore coast is one of the major fishing harbours having rich biodiversity. Hence, it is recommended to reduce the fishing pressure especially by trawling to conserve the resources and biodiversity of the marine fauna.

Keywords: Trawling, bycatch, biodiversity, south-west coast

Introduction
Trawling, an important commercially used capture method in the world can causedamage to the continental shelves and consequently the physical destruction of marine ecosystems (Jennings and Kaiser, 1998) [27]. Trawls are operated from surface to bottom intending to target specific groups of organisms but being the most destructive non-selective gear catches everything that come across its towing path (Hameed and Boopendranath, 2000) [12]. The number of trawlers operating in Indian waters was estimated at 35,228 with 71.4% are operated in the west coast and rest on the east coast (Anon., 2010) [1] which contributed to the maximum to the share of the marine landings of the south-west coast (CMFRI, 2017) [5].
Karnataka has a coastline of 300 km with 96 fish landing centres among which Mangalore in Dakshina Kannada, Malpe in Udupi and Karwar in Uttara Kannada are the major landing centres. Mangalore being the largest marine fish landing centerwith a wide continental shelf contributes about 40% of the total marine landings of the state (Kurup *et al*., 1987) [16]. Bottom trawling in Mangalore was introduced in 1961 with an objective to exploit the fishing grounds and to target high valued prawns, squids, cuttlefishes, threadfin breams, ribbon fishes, etc. (Dineshbabu *et al*., 2012) [8].
Since, the bottom shrimp trawlers catch everything that comes on its way; the fishermen consider non-target resources as bycatch and discard them back into the sea. These are called as accidental catch or incidental catch (Clucas, 1997) [4]. Bycatch as defined by Davies *et al.* (2009) [6] are the unused and unmanaged catch of the marine ecosystem and is a major component of the negative impact of fishing on the marine resources.
Since, the increasing demand for fish consumption paved the way for more and more exploitation of resources leading to higher rate of discards associated with bottom trawling started damaging the resources, there is dire need of regular assessment of bycatch to understand the extent of indiscriminate fishing causing the loss of resources (including juveniles of commercially important fishes). Therefore, the present study on analysis of bycatch off the coast of Mangalore was undertaken to analyze the trend in the bycatch and miscellaneous fish landings of trawlers as an indicator of biodiversity.

Materials and Methods

The present investigation was carried out along the coast of Mangalore (Lat. 12˚50′54″N; Long. 74˚50′11″E) and the sampling stations were so selected to represent variability in fishing grounds, species diversity and fishing methods. Multiday trawlers were selected for collection of bycatch data once in a month during the period from August, 2010 to May, 2012 by employing the stratified random sampling design developed by CMFRI and the monthly estimates of catch and species composition were made based on the data collected from the landing centre (Srinath *et al*., 2005) [23].

Further, a questionnaire was also prepared to collect the data and due care was taken while preparing the questionnaire to include all relevant questions such as species composition of commercial catch, bycatch, total quantity landed, etc., to be answered by the respondent to fulfill the objectives laid down in the study. Total quantity of individual fish landed as bycatch and their per cent composition was calculated by using the formula

$$\text{Projected weight of individual species} = \frac{\text{Weight of individual finfish in the sample}}{\text{Total weight of the sample}} \times \text{Projected weight of finfish of respective year}$$

Each fish species in trawl catch was identified up to species level following standard FAO identification sheets (Fischer and Bianchi, 1984) [10]; Fish Base (http://fishbase.org); ITIS (Integrated Taxonomic Information System) standard report (http://www.itis.gov) and WoRMS (World Register of Marine Species (http://marinespecies.org) (Appeltans *et al.*, 2011) [2]. The ichthyofaunal biodiversity was estimated by Shannon-Weiner diversity indices (Shannon and Wiener, 1963) [28] and Simpson diversity index (Simpson, 1949) [29].

Results and Discussion

Commercial fishing by Single Day Trawlers (SDTs) generally start from the month of October. During the period of 2010-11 the landings by single day trawlers was 2087.84 t out of which 1406.32 t (67%) was landed as commercial catch and the rest 681.52 t (33%) was trash fish catch or the bycatch whereas the landings for the year 2011-12 was 2236.03 t where 1284.65 t (57.5%) were categorised as commercial catch and sent to the market while the rest 951.38 t (42.5%) of fish were sent to the processing and reduction industry for fish meal and fish oil production (Fig.1).

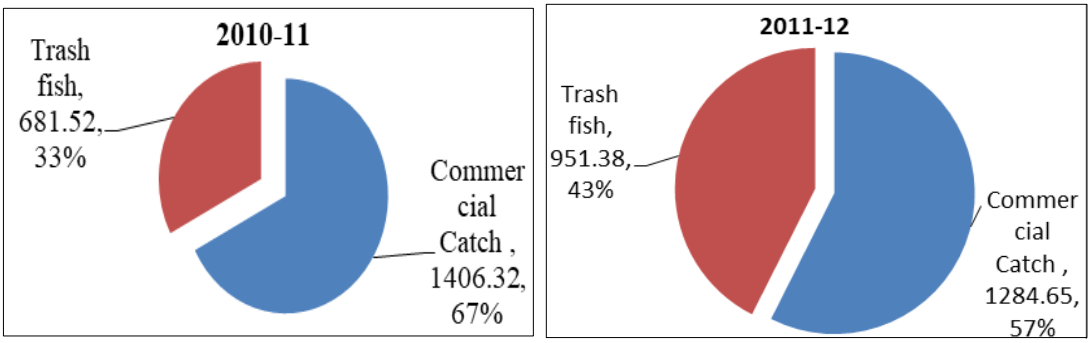

Fig 1: Landings of Commercial Fishes and Trash Fishes by SDTs during 2010-12

Seasonal trends in landings of bycatch by single day trawlers recorded that commercial fish landings increased during pre monsoon months and highest was recorded during the month of May, 2011 whereas the trash fish landing recorded was highest during the month of March 2012 (171.54 t) (Fig.2).

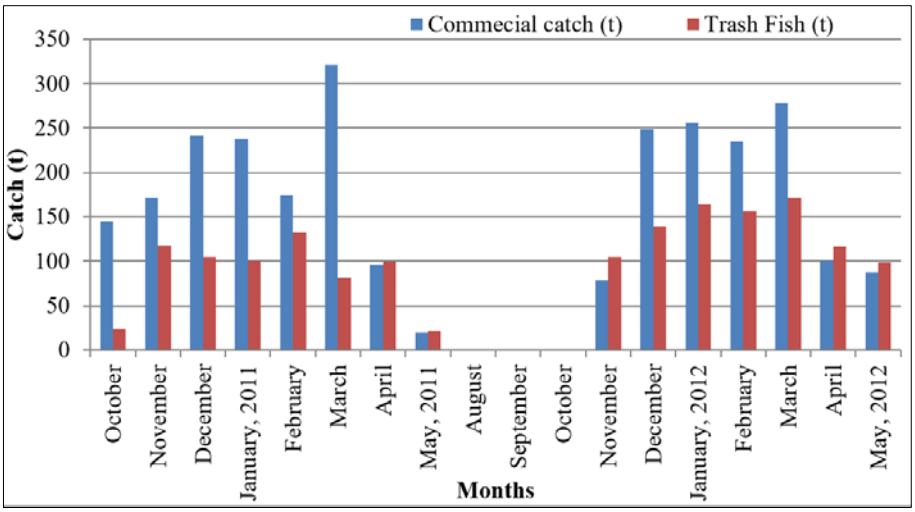

Fig 2: Monthly variation in landings of commercial fishes and trash fishes by SDTs during 2010-12

The multiday Trawlers (MDTs) started fishing immediately after fishing ban for extended periods of 8-10 days per tripin a depth of 100 meters. In the year 2010-11 the landings by the MDTs were 165853.53 t off which commercial fishes contributed 135264.21 t (82%) and trash fishes had a contribution of 30589.32 t (18%). Similarly, in the year 2011-12 the marine landings by MDTs were 163621.76 t out of which 126864.35 t (77.5%) was contributed by commercially important fishes and 36757.41 t (22.5%) were from trash fish catches. The trend in catches indicated that starting of fishing season contributed the most landings after which it started declining.

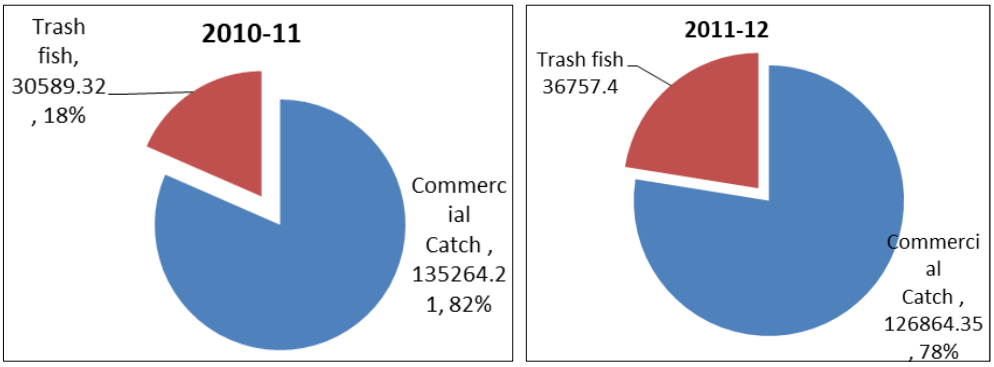

Fig 3: Landings of Commercial Fishes and Trash Fishes by MDTs during 2010-12

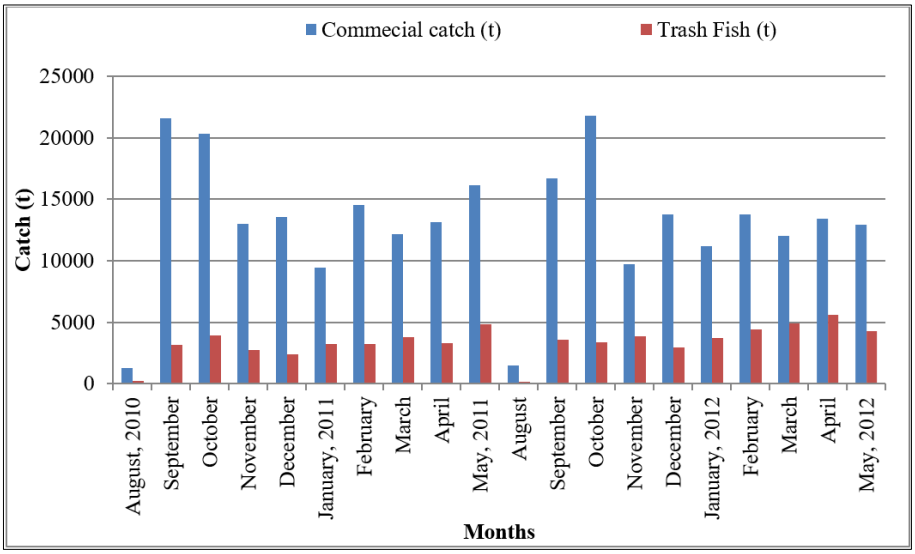

Fig 4: Monthly variation in landings of commercial fishes and trash fishes by MDTs during 2010-12

A total 131 species of finfish and shellfish belonging to 62 families and 18 orders were recorded in the bycatches during the study period out of which order Perciformes contributed 54.96% of total number of species, followed by Clupeiformes (9.92%), Tetraodontiformes (8.4%) and Scorpaeniformes (4.5%)respectively, whereas other orders contributed less than 4 percent. Similarly, Family Carangidae contributed 10.69 % of the total species followed by Engraulidae (6.11%), Leiognathidae (6.11%), Synodontidae (3.82%), Tetraodontidae (3.82%), Nemipteridae (3.05%), Sciaenidae (3.05%) and Scombridae (3.05%). (Fig. 5 and Fig. 6).

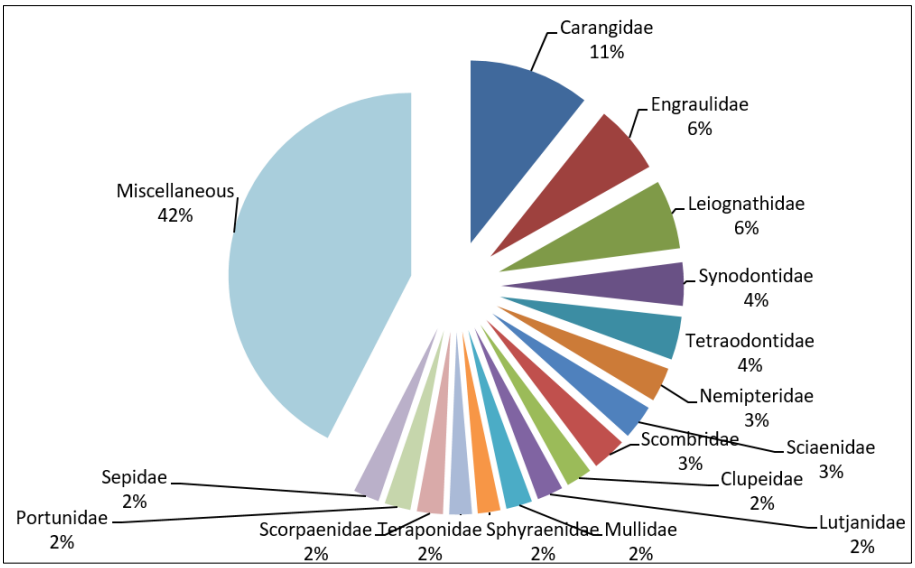

Fig 5: Per cent contribution of each family during 2010 -12

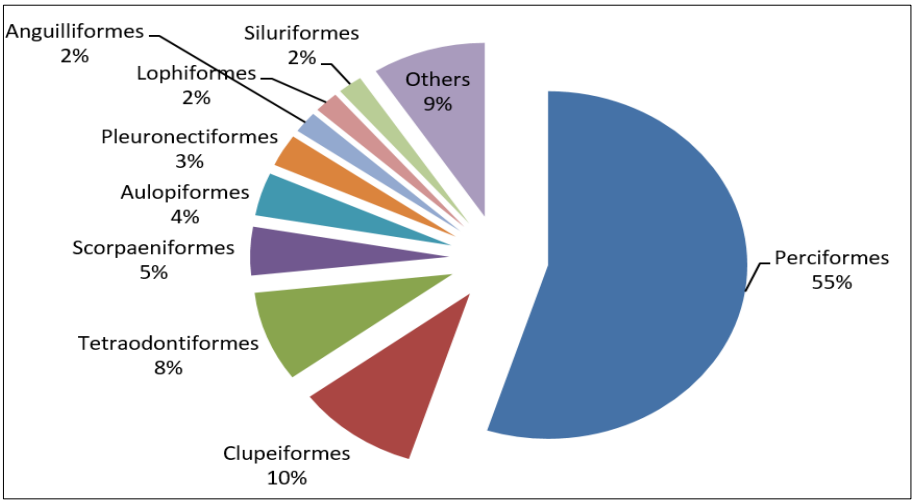

Fig 6: Percentage contribution of each Order during 2010-12

The average bycatch contribution recorded was 18.68% (2010-11) and 22.21% (2011-12). The highest bycatch percentage was observed during the months of April, 2012 (29.55%) and March, 2012 (29.08%). Lowest bycatch percentage was recorded during the months of August, 2011 (10.43%) and September, 2010 (12.72%) with a trend indicating that the bycatch landing was more in post-monsoon months than pre monsoon. (Fig 7)

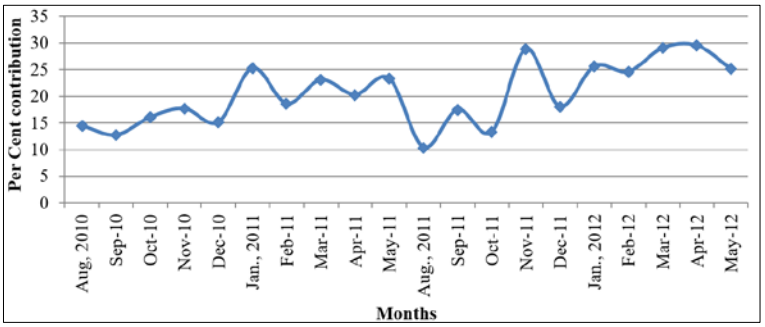

Fig 7: Percentage contribution of bycatch during the study period

The trawlers were classified into three categories based on Horse Power of engine *viz*. <140 HP, 141-300 HP and >300 HP. The maximum average catch was observed in >300 HP fishing vessels (Fig. 12) with maximum 28.64%loss of biodiversity followed by 141-300 HP and <140 HP fishing vessels. Minimum loss of biodiversity was found to be in <140 HP fishing vessels (10.97%). Simpson Index was highest (0.9889) in >300 HP multi-day trawlers compared to other two categories. K-dominance curve was obtained by plotting percentage cumulative abundance against species rank K on a logarithmic scale. The cumulative curve (K-dominance curve) or Abundance Biomass Curve (ABC) expressed as the percentage of abundance in the sample, referred to as dominance plot shows that curve in> 300 HP multi-day trawlers compared with other two categories, which lie on the lower side, extended further and rise slowly due to high abundance of species. As the percentage contribution of each species is added, the curve extends horizontally before reaching the cumulative 100%.

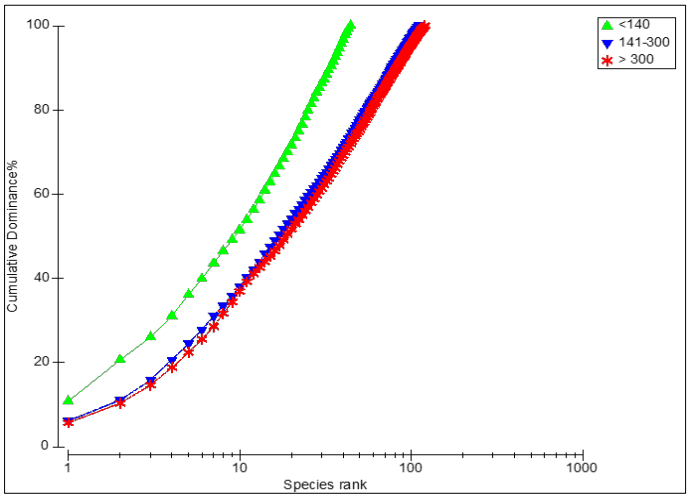

Fig 8: K-dominance curve for species biomass (Power of the engine wise)

The trash fish landings formed an average of 20.5% of the total trawl catches during the study period and contributed about 0.31 lakh t (18.7%) in the year 2010-11 and 0.37 lakh t (22.2%) in the year 2011-12. The average trash fish to target group ratio was 1: 4.07. Indian fisheries follow a trend of multi gear multi species fisheries. Where, as reported by George *et al.* (1981) [30], the shrimp trawlers produce almost 80% of the non-targeted species. Alverson *et al.* (1994) [31] concluded that shrimp trawling contributes 37.2% of the total landings worldwide with an annual contribution of 28.7 mt as bycatch out of which 27.0 mt are discarded. Menon *et al.* (2000) [17] reported that the ratio of the target and bycatch along the south-west and south-east regions of India was 1:4.6 and 1:1.26 respectively. Jayaraman (2004) [13] estimated trash fish to constitute 10-20% of total catches landed by trawlers operating along the Indian coast in 2003. Sujatha (1995) [24] identified 228 species from the discards in Vishakhapatnam which constituted 11% of the total trawl catch. Gibinkumar *et al.* (2012) [11] found 281 species in the trawl catch off south west coast of India.

Detailed catch composition of trawlers operating along the Mangalore Coast was studied to analyse the varieties and quantity of each species landed in the total catches. Among the pelagic fishes landed by trawlers the commercially important ones are oil sardines, others sardines, ribbon fish, Indian Mackerel, seer fish etc. The demersal group of fishes are represented by elasmobranchs, threadfin breams, groupers, sciaenids, lizardfishes, eels, catfishes, snappers, white fishes, pomfrets, soles, etc. Some recent studies (Bhathal, 2005) [3] have assumed that no discards exist for trawlers in India presumably due to burgeoning bycatch demand in poultry and aqua feed industries in the last two decades. Jayaraman (2004) [13] based on a study in 2003 estimated that trash fish to constitute 10-20% of total catches (2,71,000 t) landed by trawlers operating in the Indian Coast. The bycatch consisted of 53 species belonging to 27 families of finfishes. The bycatch of single day trawlers (SDTs) consisted of 35 species belonging to 20 families of finfishes as reported by Zacharia *et al.* (2006) [26]. Dineshbabu *et al.* (2012) [8] reported that the single day trawlers generally operate in the waters up to 30m depth and the entire catch was brought to shore which was separated from commercial catch and the rest of the low valued bycatch is referred as trash.

A total of 52 commercial species were reported in bycatch whereas, it reduced to 41 species during the year 2011-12 with increase in the species number of low value fishes. This trend showed that significant increase of low value fish species with decrease in commercial fish species in bycatch. Zacharia *et al.* (2006) [26] in their study on assessment of bycatch and discards associated with bottom trawling along the coast of Karnataka opined that the maximum bycatch was recorded in March followed by May in Multiday Trawlers in 2002 and the discards were highest in post monsoon months than other months. Dineshbabu *et al.*, (2010) [8] recorded the highest trash fish landings in Mangalore during December, 2007. The low valued bycatch caught earlier to the last two days were discarded due to lack of space and it was estimated that 14% of the catch was discarded during the process. Trawling operations in the nearshore waters and the use of very small mesh cod ends are considered to be the reasons for the increasing catch of juveniles. Sujatha (1995) [24] found that the low value bycatch contained 66 to 94% of juveniles in the catches of small trawlers. Sivasubramaniam (1990) [22] reported that more than 50% of the bycatch samples studied were found to be immature fish or fish that had no chance of spawning even once. He attributed the significant decline in longer living species, snappers, groupers, croackers etc., in the Asian region to the capture of juveniles.

The bycatch landings also consisted of enormous quantity of juveniles of many species. Among the commercial species, the criterion was smaller size. It was observed that on an average about 80% of the bycatch landings were consisted of juveniles of commercially important species. Sivasubramanyam (1990) [32] observed that 50% of the bycatch comprised of immature fish in trawlers from Bay of Bengal. As per the observations of Pillai (1998) [19] 40% of the catch from Indian seas consisted of juveniles. Kurup *et al.*, (2003) [16] opined that the small cod end mesh of bottom trawlers exploited juveniles and sub-adults of commercially important species in large quantities. In Karnataka, juveniles contributed 36 per cent of discards (15.9% of the total catch) in single day fishing trawlers and 78% (23.5% of the total catch) in multi-day fishing during the years 2001 and 2002 (Zacharia *et al.*, 2006) [26]. In Mangalore fishing harbour an estimated 63.7% (by numbers) of bycatch was constituted by juveniles of commercially important species during the year 2007-08 caused serious damage to the stocks of these species. Similarly, 37.4% of the total bycatch by weight was constituted by commercially important species. Whereas, in 2008-09 juveniles of commercial species formed 34% of the discards and in terms of number they formed 44% (Dineshbabu *et al.*, 2012) [8].

Generally it is understood that the bottom trawl fishing has been found to be the most destructive method of resource exploitation in structurally complex and biodiversity rich marine habitats that leads to community changes in benthos, reduction in biodiversity and biomass, reduction in size of organism (Jennings and Reynolds, 2000; Thrush and Dayton, 2002; Revil and Jennings, 2005) [14, 25, 20]. Trawlers equipped with advanced technologies in fishing and high storage capacity are intensive trawling and to catch as much as possible without any concern over the size or the species of fish or the future concerns of the fishery. This practice resulted in heavy exploitation of juveniles of commercially important fishes and ecologically important biota.

Since, Biodiversity is considered as the basis of all life on earth and is important in maintaining the health of the environment and to maintain the balance of nature against a background of physical changes (Daily *et al.*, 1997) [33]. The direct effects of marine habitat disturbance by commercial fishing have been well documented (Thrush and Dayton, 2002) [25]. Among fisheries globally, 75% of the stock have been estimated to be fished fully, depleted or overfished (FAO, 2004) [9]. In addition to the effects of exploitation, the biodiversity of many coral reef and coastal marine species is also influenced by habitat loss (Gardner *et al.*, 2003) [34]. During the study period, there was good recruitment to the fishery immediately after the ban period but the increased recruitment did not last for more than 2 to 3 months, it is clear that seasonal trawl ban in the present form, has helped long term recovery of the stock.

Trawling is one among the destructive fishing methods. Recognizing the importance of trawling to inshore and offshore fisheries, fishing companies and scientists have improved the methods of trawling not only by increasing the length of the trawler but also by increasing the winch power for improving the efficiency in trawling. But the fish diversity loss was observed due to the introduction of destructive

fishing methods (especially the high speed imported engines) and its consequent impact on profitability of the fishery along Karnataka coast. Marine fish stocks in many parts of the world have been exploited beyond recovery.

Bycatch associated with bottom trawling has become major component of impact of fisheries on marine ecosystem in almost all tropical countries. The increased demand and high economic value for shrimps and bottom dwelling fishes are considered to be the principal reason for the expansion of trawl fishing throughout Indian coast. The high investment and fluctuating returns from commercial fisheries and demand for LVB from array of fish meal plants and feed industries encourage the trawl operators to land LVB in higher quantities. Utilisation of LVB also compensates the operational cost of trawl fishery to some extent. Even though it is often argued that better utilisation of the bycatch is a solution for problem, its impact on the fish stock and traditional fisheries remains to be investigated. There is a need for regular assessment of bycatch and discards associated with bottom trawling to understand the extent of resource damage due to indiscriminate fishing. Since trawl fishery is the backbone of Indian marine fisheries, bycatch is unavoidable in multi-species scenario. Declaration of certain coastal areas as closed for trawling, usage of bigger codend meshes, and adoption of Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) in trawls and restrictions on maximum engine power would help in reducing the amount of juveniles of commercially important fishes in LVB landings as well as conservation of marine organisms along the coastal areas of India.

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