Fishery Technology 53 (2016) : 263 - 272

Impact of Trawling in Indian Waters - A Review

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Abstract

Trawling which is the highest contributor to the marine fishery in India has undergone sea change as a fishing technique and fishing pattern. During recent years, the reduction of catch per unit effort from existing fishing grounds led to various modifications in trawl net design and trawling operations, which has resulted in increase in fish production. Impacts of trawling in Indian waters have been monitored by various agencies during last 25 years. Although there are a good number of articles in peer reviewed journals, a huge quantity of useful information still lies in the form of reports and grey literature which is not easily available to the researchers. This paper attempts to compile information available from various research papers, reports and presentations in seminars and symposia, to serve as an updated guide for trawl impact studies. The information are categorized as (i) impact on the ecosystem, (ii) impact on fishery and (iii) impact on biodiversity. The paper also analysis recent trends in trawling like pelagic and high speed trawling in Indian waters, taking up an example from the trawl fishing off Karnataka, south west coast of India. It was seen that after the introduction of high speed pelagic trawling, some of the areas which were unsuitable for trawling, have also been brought under exploitation. The utility of log book data in resource conservation studies and the need for incorporating spatial studies in trawling impact assessment in the context of ecosystem stability and fishery sustainability are also discussed.

Keywords: Impact of trawling, trawl footprint, vulnerable marine ecosystems, biodiversity, bycatch and discards, spatial analysis

Received 21 July 2016; Revised 22 October 2016; Accepted 29 November 2016

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Introduction

The marine fisheries sector in India has witnessed a phenomenal growth during the last five decades both quantitatively and qualitatively. Indian marine fish production which was fluctuating between 2.3 to 3.3 million t in 1990-2010, reached 3.9 million t by 2012 (CMFRI, 2013). Technological interventions in the mechanised sector with enhanced endurance of fishing vessels, better fish finding and geo-positioning equipments, better communication systems, storage facilities and coverage of far off fishing grounds improved marine fish production. Contribution of mechanised sector (formed mainly of trawlers and purse seiners) has dominated during last four decades. By the end of 1990s, their contribution was around 50% which increased to 65% by 2000 and to 78% in 2012 amounting to 3.08 million t of fish production (CMFRI, 2013).

Genesis of trawl fishery along Indian coast commenced with the introduction of a few boats by the erstwhile Indo-Norwegian Project, in 1953. During the last 60 years, changes have occurred especially in the depth of operation, hours of operation per fishing trip and species composition of the landings. Many designs of two seam trawls, four seam trawls, six seam trawls, bulged belly trawls, high opening trawls and large mesh trawls were designed and developed in India. In the early sixties, the depth of operation was up to 10-20 m, which extended up to 30 m in 1967-70. During 1970-80, the depth of operation further extended to 40 m and during 1980-85 the trawlers operated up to a depth of 55 m. During this period, night trawling and multi-day trawling also were started. By 1985-1995, the depth of operation extended up to 100 m and it further went up to 150 m by 2000. Average fishing hours per trawlers shows that during last two decades it increased from 7 h in 1990 to more than 33 h by 2012 (Dineshbabu et al., 2013).

As the profits from the trawling operations increased, there has been a unhealthy competition in exploitation of marine resources, which lead to generation of huge quantity of bycatch and also negative impact on marine biota (Dineshbabu et al., 2013). The changes in fishing practices such as introduction of pelagic trawls and target specific trawl designs (Sayana et al., 2016) and introduction of high speed engines have lead to conflicts and sociological issues in marine fisheries sector. Specific research programs have been conducted at different stations to study the impact of trawling on physical structure of bottom, hydrographic parameters and impact on biota due to intensification of trawling (Bhat, 2003; Zacharia, 2004; Thomas & Kurup, 2006). Negative impacts of bottom trawling, technologies for bycatch reduction, biodiversity conservation and for minimisation of bottom impacts for Indian waters have been discussed by Meenakumari et al. (2009) and Boopendranath (2012). The present paper reviews the multi-dimensional impacts of trawling on the ecosystem, fishery and biodiversity by compiling information available from research papers, reports and proceedinhgs of seminar and symposia. Along with the review of existing literature on the trawl impacts, spatial analysis of trawl operations and mapping of fishing pressure have been carried out along Karnataka coast, in line with "trawl foot print analysis" (Black et al., 2013). The spatial trawling operation details of fishing years 2007-2009 and 2012-2014 were compared to understand the extent of change in trawling.

Materials and Methods

Available research papers as well as the project reports of various agencies and seminar and symposia papers were collected and compiled (Bhat 2003; Gowda, 2004; Zacharia, 2004). In order to understand changes due to fishing pressure on the trawl fishing ground, the spatial data of trawling collected for years 2007-2009 and 2012-2014 (August-June) were analysed in GIS platform. For the spatial analysis of trawling operations, data were collected from a commercial trawler (15.85 m L_{OA}; 350 hp; trip duration: 5-8 days) which was also used as sampling boat. Specially designed logbooks were prepared and the crew members were trained in data collection. By 2012, most of the trawlers were equipped for high speed pelagic trawling with an installed engine horsepower more than 400 hp and average trip duration extended to 13 days. Along with sampling boat data, fishing data on area of operation were also collected from log sheet records of four commercial trawlers. During 2007-2009, fishing information of the 396 days of fishing in 43 cruises were recorded from the sampling boat and for complementing the operational area data, 1,520 days of fishing information from four commercial trawlers in 165 cruises were also collected. Similarly during 2012-2014, data for 479 days of fishing in 52 cruises made by the sampling trawler and 1,568 days data from four commercial trawlers for 392 cruises were collected. Fishing operations base map was prepared using the data collected from the sampling boat. To make the fishing area map as comprehensive as possible, data collected from log sheet of commercial boats were populated in the database, with the additional data points if any, which was not figured in the sampling boat operational data. ArcGIS software was used (Black et al. 2013) for mapping of spatial distribution of fishing and for calculation of fishing area. ROV recordings from "*R. V. Rathnakar*" operated by the Geological Survey of India, Mangalore were utilized, in order to study the bottom features of trawling grounds.

Bottom trawling imparts both short-term and long-term impacts to the marine ecosystem in terms of physical and biological damages. In India, the studies on the impact of trawling on hydrographic parameters and bottom fauna were carried out since the introduction of trawling (Table 1). Bottom trawling inflicts impact on environmental parameters, sediment geochemistry, epifauna, infauna, macrobenthos and meiobenthos. An increase in turbidity, decrease in dissolved oxygen, reduction in sediment, organic matter were found to effect the ecology of the trawling grounds. Variations in sediment texture, disparity in sediment water column fluxes of nutrients and changes in chlorophyll content are the different physicochemical impacts identified by various workers. Epifaunal seafloor habitats destructions on seagrasses, seamounts and coral reefs were observed in various critical ecosystem in south east coast of India. This in turn were found to impact the survival of a variety of marine organisms and sessile fauna like sponges, hydroids, anthozoans, bryozoans, gorgonians and polychaete which depend on these habitats on food and shelter. An increase in abundance of opportunistic species and a reduction in faunal diversity are the impacts on infauna. This may lead to change in the trophic fabric of ecosystem and dietary shifts.

Complete elimination of bycatch and discards in trawl fishery is an unrealistic goal. The efficient use

Table 1. Literature on the impact of trawling on the hydrographic parameters, sediments and biota of fishing ground

	Impact categories	Authors & year
Hydrographical parameters		
1	Significant increase in turbidity noticed after trawling	Zacharia, 2004; Bhat, 2003; Gowda, 2004
2	Decrease in the dissolved oxygen in bottom waters and increase in nitrite-nitrogen, inorganic phosphate and chlorophyll pigments.	Bhat, 2003; Gowda, 2004; Thomas et al., 2004
3	Increase in turbidity and long lasting sediment clouds in the water column.	Thomas et al., 2004; Thomas & Kurup, 2006,
Sediment characteristics		
4	Clay fraction of the sediment texture altered into more sandy and silty after trawling in the muddy bottom of 0-40 m depth	Thomas & Kurup, 2006
2	A reduction was observed in clay proportion of the sediment after trawling.	Zacharia et al., 2005
3.	Reduction in organic matter was noticed due to the scraping sediment surface by otter boards and nets	Thomas & Kurup, 2005; Raman, 2006
4	The study on the sediment characteristics in different depths carried out in the trawling grounds by experimental trawling showed that trawling reduced the organic content at varied depth.	Bhagirathan et al., 2009
Benthic biota		
	Epifauna:	
5	The damage inflicted to epifauna was evident from the enormous amount of dead shells obtained in trawled areas comparing to un-trawled areas.	Bhat, 2003 Raman, 2006 Kurup et al., 2004
6	The dislocated fauna mainly comprised of the benthic fauna with the non-edible crab forming the dominant group followed by echinoderms, stomatopods, molluscs, sponges and sea pens in South East coast of India	Jagadis et al., 2003
7	Intense trawling after monsoon trawl ban found to decrease the epifauna and infauna in the trawling grounds off Veraval, Gujarat. The major groups that sufferd depletion were gastropods, polychaetes, corals etc.	Bhagirathan et al. 2008; 2014.
8	Increase in the abundance and biomass and subsequent decrease in diversity indices of macrobenthos is noted as an immediate effect of trawling	Zacharia, 2004; Kurup, 2004
9	Bivalves, gastropods, polychaetes, foraminiferans and scaphopods generally showed an increase after trawling while some of the gastropods like *Cerithium* spp., *Cavolina* spp., and *Strombus* spp. decreased after trawling	Zacharia, 2004
10	The increase in number of polychaetes has been attributed to the survival of opportunistic species in response to bottom trawling Meiobenthos	Gowda, 2004; Kurup, 2004
11	There was a significant increase in the density of nematodes and foraminiferans, while that of harpacticoids, polychaetes, kinorhynchs and molluscs decreased.	Zacharia, 2004
12	The increase in number of nematodes after trawling has been attributed to the dominance of opportunistic species in response to bottom trawling	Gowda, 2004

of discards as a potential source of food is suggested as a measure to cope up with the reality. In tropical countries, in addition to the targeted catch in trawling, the bycatch are also having commercial value as food for human, animals and other uses. Driven by increased human population, shortage of fish supplies from conventional sources and notably by the growth of aquaculture, more and more bycatch are being brought to the shore as low value bycatch (LVB). This trend has led to substantial reduction of discards from the trawl fishery. The studies conducted in 2005 showed that the discards from Indian fishery was above 20% of the catch. The discards from Indian trawl fishery was closely monitored by ICAR-Central Marine Fisheries Research Institute (CMFRI) and the study showed that there was a steady reduction of discards from trawlers, which reduced to 12% in 2008 and then to 6% in 2011. The LVB was found to contribute an additional revenue of Rs. 693 million for the trawl operators in eight major trawl landing centres in India, during 2011. This economic benefit and encouragement from fish meal operators are leading to increased landings of LVB (Dineshbabu et al., 2013). Even though it improves the economy of the fisheries sector, the trend is perceived to have a profound influence on the ecosystem and also in sustainability of fishery since most of the fishes brought for fishmeal are juveniles of commercial fishes. Considerable damage to the ecosystem due to intensive trawling is being reported from various trawl impact studies around Indian coast. Intensive trawling with trawls having small codend mesh size using high power engines is escalating the damages to ecosystem and endangering the sustainability of the fishery. The quantification of trawl bycatch and discards have been a topic of concern for Indian fisheries scientists and many studies have been carried out to quantify the bycatch. Some of the studies on estimation and quantification of bycatch in trawl fisheries from various geographic areas around Indian seas are given in the Table 2.

Boopendranath (2007; 2012) and Pravin et al. (2011) have reviewed the different of Bycatch Reduction Devices (BRD) worldwide. There are different designs of BRDs and also operation based bycatch reduction strategies. In tropical fishery scenario, where various species at different phases of their life cycle co-exists, mesh size regulation and similar design based restrictions have a lot of practical difficulties. It is suggested that the design based BRDs in association with area closures and temporal closures of trawling will be the best option for the bycatch reduction in tropical waters. Report of the Expert consultation on International guidelines for bycatch management and reduction of discards (FAO, 2010) suggested that closure of nursery/spawning grounds or areas of special biological significance can reduce bycatch and such measures help in the creation of marine protected areas, marine parks and zones reserved for traditional fishing activities, for sustaining the biodiversity and for improving marine fisheries.

There have been serious concerns over the impacts of discards on the marine ecosystem. In recent studies in India, the discarded bycatch as well as bycatch landed for fish meal preparation were found to constitute more than 50% of undersized commercial species. If such a trend continues, exploitation of juveniles can put these species or population at risk of depletion. Ecosystems impacts, which occur, due to discarding of the species of high trophic importance may affect the ecosystem structure and integrity. Various workers attempted to assess the loss of biodiversity and capture of juveniles as trawl bycatch. (Table 3).

The modifications in trawl nets and trawling operations has taken place at a fast pace since 2000 and during this period steel trawlers replaced traditional wooden trawlers in large numbers. Low profitability in trawling operations as a result of low catch per unit and increase in fuel expenses have led to unhealthy competition in trawl fishery which was reflected in increasing installed engine power, diversified trawl designs, high storage capacity and increasing trip duration. These modification happened at a fast pace without any scientific rationale, management regulations and without any ecosystem considerations. In order to understand impact of such innovations in trawl fishery, data during 2007-2009 and 2012-2014 periods were analyzed. Ever since regular spatial data collections on trawl fishing operations started from 2007, a time series database on daily fishing operations have been maintained at CMFRI. The fishing operation details of 2007-2009 was analysed in GIS platform and compared with fishing operational details of 2012-2014. The period selected for the study reflects the fast evolving modifications happening in trawl fishing in South west coast of India. Multi-day trawlers operated is 10 m to 150 m depth and the total area covered off Malabar and Konkan coast during 2009-2012 was estimated at 40,666 sq km

Table 2. Literature on estimation and quantification of bycatch and discards from trawl fisheries of India

1.	Survey of bycatch in Indian marine fisheries, 79 percent of total landings in the shrimp trawl fishery consisted of non-shrimp catch	George et al., 1981
2.	Estimation the bycatch levels in India as part of Bay of Bengal Programme of FAO.	Gordon, 1991
3.	Impact of bottom trawling on exploited resources along the southern region of Karnataka, Kerala and Tamil Nadu during 1985-90.	Menon, 1996
4.	Estimation of bycatch landings along Cochin, Visakhapatnam and in Saurashtra region (Gujarat).	Pillai, 1998
5.	Impact of coastal bottom trawling on demersal fishes and macro benthos along the west coast	Menon et al. 2000
6.	The characterization and quantification of bycatch and discards along Kerala coast	Kurup et al., 2003; 2004
7.	The characterization and quantification of bycatch and discards along Karnataka coast.	Zacharia, 2004 Dineshbabu et al. 2010
8.	Utilization of bycatch and its impact on fishery along the Coromandel Coast Estimated bycatch from shrimp trawl in India	Lobo et al. 2010 Bhathal, 2005
9.	Estimation of trawl bycatch was 22.5 lakh tonnes, thus the bycatch represented 56.3 percent of the estimated total marine catch.	Chandrapal, 2005
10.	Analysis of reasons of increased bycatch landing in Karnataka	Dineshbabu, et al., 2011
11.	Spatio-temporal assessment of fishing grounds of bycatch and discards off Karnataka	Dineshbabu et al., 2012
12.	Estimation of bycatch and discards of North Kerala	Manojkumar & Pavithran 2012.
13.	Application of GIS in trawl bycatch reduction	Dineshbabu et al. 2012.
14.	Appraisal of trawl fisheries of India with special reference to bycatch and discards	Dineshbabu, 2013; Dineshbabu et al. 2014.

(Fig. 1). During this period the sampling boat, as well as four commercial boats avoided some of the area within the operational boundary and GIS based mapping of operation showed that only 75% of the area (approximately 30,221 sq km) were trawled. The rest of the area was reported as unsuitable for trawling by all the trawler operators. Unsuitable features of the sea bottom with reef and rock prevent trawling in about 10,455 sq. km area within the fishing ground polygon (Fig. 2). The comparative study of fishing operations from these trawlers during 2012-2014 showed that the fishing area is extended within the fishing area polygon and about 90% of the area within fishing area polygon has been brought under use, by using pelagic and high speed off bottom trawl operations (Fig. 3). The amount of juvenile bycatch brought in by the trawlers also increased due to this innovations in trawling operations (Dineshbabu et al., 2014).

The ROV recording of bottom features, taken during 2013 from the Geological Survey of India Vessel *"R.V. Rathnakar"* (Fig. 3), shows the rough nature of the bottom with rocks and reef like structures, which is not conducive to bottom trawling and hence may serve as a natural marine protected area within the fishing ground. The comparative study of the operational maps of 2007-2009 and 2012-2014 showed substantial encroachment of trawlers in a naturally protected marine ecosystem by means of pelagic trawling with high power engines. Probably these kind of natural protected area within the trawling ecosystem of Indian waters may be one of the reasons for high resilience of the ecosystem. There should be in-depth studies on the catch coming from pelagic trawling to understand the impact of the innovations on the fishery.

Spatial studies of fishing operations help us to take a precautionary approach to avoid collapse of

Table 3. Literature on impact of bycatch and discards from Indian trawl fisheries on biodiversity and fishery sustainability

Impacts		Authors & year
1	Maximum discards along Karnataka coast in 1980s were represented by stomatopods.	Menon, 1996
2	Along the southern region of Karnataka, Kerala and Tamil Nadu (south India) the discarded by-catch included many low-valued ground fishes (20 genera), crustaceans (26 genera), gastropods (23 genera), bivalves (15 genera), polychaetes, anemones; sponges, echioderms (10 genera), gorgonids, ascidians, echiurids, jelly fishes *etc*, besides the unmarketable juveniles of fishes, prawns, crabs and cephalopods.	Menon, 1996
3	228 fin fish species belonging to 68 families had been identified as a constituent of finfish bycatch landed by small trawlers operating off Vishakapatanam (East coast of India).	Sujatha, 1995
4	87 species belonging to 42 families constituted 82.7% of the low value by-catch landed by mechanised trawlers operating off Veraval (Northt west coast of India). Sciaenids were the major group contributing 15.6 per cent followed by engraulids (12.84%), ribbon fishes (8.9%), penaeid and non penaeid prawns (8.2%), squids and cuttle fishes (7.7%), polymemids (4.9%), white fish (4.2%), nemipterids (3.9%), leiognathids (3.3%), carangids (2.8%), flat fish (2.7%) and others (7.7%). Balance 17.3 per cent is constituted by shells, jelly fish, squilla, crabs, sea snakes and unidentified groups.	Pravin & Manohardoss, 1996 Zynudheen et al., 2004
5	Discards from bottom trawlers of Kerala coast (South west coast of India) were represented mainly by epifaunal species and juveniles of commercially valuable species and the discards were represented by 103 species of finfishes, 65 gastropods, 12 bivalves, 8 shrimps, 2 stomatopods, 12 crabs, 5 cephalopods, 3 echinoderms and 4 jellyfishes	Kurup et al., 2003
7	The discarded bycatch of trawl fishery of Karnataka (South India) consisted of 53 species of fishes (23 always discarded), 12 crustaceans (6 always discarded), 27 molluscs (22 always discarded) and 7 other invertebrates (always discarded).	Zacharia *et al*., 2006
8	Study on biodiversity of trawl bycatch off Kerala coast (South India) recorded 534 species associated with the trawl bycatch, which included 10 species each of Porifera and Cnidaria, 3 species of Annelida, one species each of Bryozoa and Sipunculida, 135 species of Mollusca, 72 species of Arthropoda, 18 species of Echinodermata, 279 species of Pisces and 5 species of Reptilia.	Bijukumar, 2008
9	Bycatch composition of trawl landings of Kerala coast (South India) overall 217 species of fishes were recorded in the trawl bycatch, classified under 21 orders, 88 families and 155 genera, representing predominantly by demersal (79 species) and reef-associated forms (78 species).	Bijukumar & Deepthi, 2009
10	As per the observations on bycatch by single day trawlers off Karnataka (South India) a total 35 species of finfishes, 20 species of crustaceans, 20 species of gastropods, 3 species of cephalopods, 2 species of stomatopods, 3 species of echinoderms, 2 species of coelenterates and one sea snake consisted the bycatch from single day trawlers.	Dineshbabu et al., 2010
11	In multiday trawlers the bycatch was constituted gastropods, echinoderms, gorgonids and sea snakes. Out of the 202 species identified, 45 species were of commercial value to the fishery of Karnataka (South India)	Dineshbabu et al. 2010
12	281 species were identified from the trawl bycatch, off southwest coast of India. The bycatch included 191 species of fishes, 11 species of shrimps, 3 species of lobsters, 13 species of crabs, 11 species of cephalopods, 44 species of molluscan shells, 2 species of echinoderms, 2 species of jelly fishes, 2 species of stomatopods and one species each of sea snake and sea turtle.	Gibinkumar et al., 2012
13	Resource damage due to landed low value bycatch along Indian coast was analysed. Following species, represented mostly by juveniles, were identified from major trawl landing centres of IndiaWest coast:Veraval: 41 species of fish, 13 species of crustaceans and 3 species of molluscs; Mumbai: 51 species of fish, 20 species of crustaceans and 11species of molluscs; Karwar: 57 species of fish, 10 species of crustaceans and 10 species of molluscs; Mangalore: 95 species of finfishes, 27 species of crustaceans and 20 species of molluscs.Calicut: 116 species of finfishes, 19 species of crustaceans and 24 species of molluscs; Kochi: 25 species of finfishes, 16 species of crustaceans and 15 species of molluscans East Coast Chennai: 102 species of finfishes, 64 species of crustaceans, 26 species of molluscs; Vishakhapatnam: 65 species of finfishes, 20 species of crustaceans and 6 species molluscs.	Dineshbabu et al. 2014
14	Juvenile bycatch from trawl fishery found to affect the catch of stock of *Nemipterus randalli* stock, The economic impact of the juvenile exploitation was projected.	Dineshbabu & Radhakrishnan, 2009
15	Juvenile bycatch of *Scomberomorus commerson* from trawl fishery found to affect the fishery of seerfishes from gillnet.	Dineshbabu et al., 2012

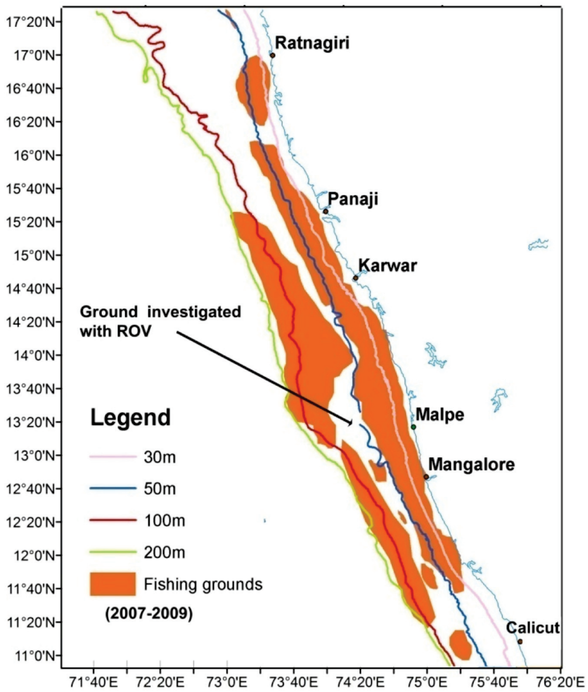

Fig. 1. Mapping of fishing ground using the operational data collected from commercial trawlers during 2007-2009. Arrow indicate the area studied for bottom characteristics using ROV

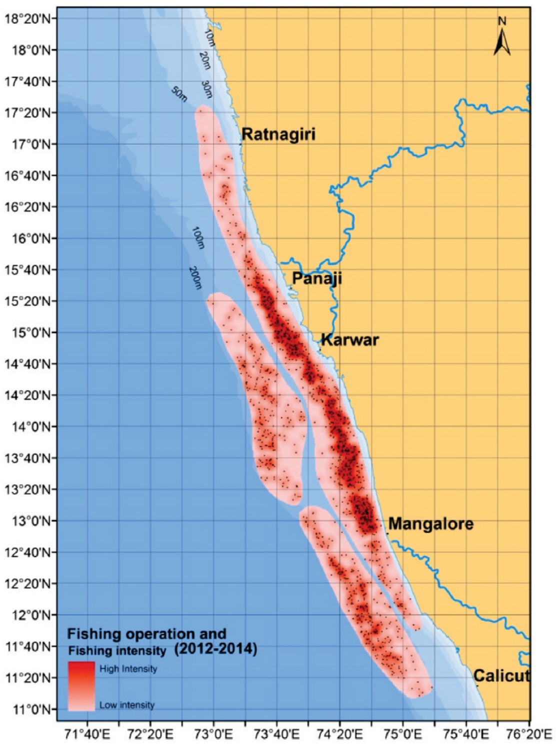

Fig. 2. Mapping of intensity of fishing in the fishing grounds off Karnataka using the operational data collected from commercial trawlers during 2012-2014

fishery by avoiding natural marine protected areas within the fishing grounds. "Trawl footprint" is the measurement and mapping of geographical areas which are being fished by trawling (Black et al., 2013). In the countries, where the trawl fishery is well managed, the database from log sheet submitted were taken as the basis of the mapping. Trawl foot print map will help in identifying the fishing pressure exerted in different fishing grounds and facilitate fisheries management and ecosystem conservation (Baird et al., 2011). Such studies also provide database to carry out biomass assessment of the resources available in swept area method (Black et al., 2013).

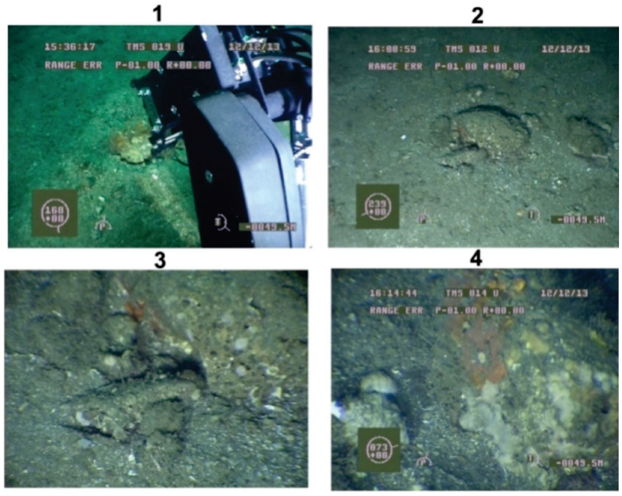

Fig. 3. The ROV recording of the bottom characteristics of the areas found avoided by trawlers during 2007-2009, in the study area

In India, the log sheet maintenance is not a mandatory requirement and hence mapping of fishing ground was not possible. Off late, fishermen who are concerned about the sustainability of the fishery, are sharing the fishing data which is producing very useful outputs. Globally trawl footprint studies are being used to identify the vulnerable marine ecosystems which will help to focus the fishing impact studies based on the critical nature of the fishing ground and such tools give a strong basis for participatory decision making on effort reduction in terms of months and seasons with stress on specific resources very effectively.

Acknowledgements

The authors are thankful to Dr. A. Gopalakrishnan, Director, ICAR-Central Marine Fisheries Research Institute, Kochi, Dr. G. Maheswarudu, Head Crustacean

Fisheries Division, CMFRI, Kochi and Dr. Prathibha Rohit, Scientist-In-Charge, CMFRI, Mangalore for their constant encouragement, support and valuable suggestions. Authors thankfully acknowledge the help of Shri. A.C. Dinesh, Geological Survey of India, Marine wing, Mangalore for responding to the request for exploring the bottom characteristics off Mangalore coast. The co-operation and help provided by the fishing community of Mangalore especially the owner and crew members of trawler group "Harikripa" and fishing operation data provided by "Sri Vinayaka" group of boat operators from Mangalore fisheries harbour are acknowledged with gratitude. The technical assistance provided by Shri. B. Sridhara, Smt. Uma S. Bhat, Shri. G. Nataraj and Shri. Y. Muniyappa of Mangalore Research Centre of CMFRI is also thankfully acknowledged.

References

Anon (2002) Annual Report 2001-2002. Central Marine Fisheries Research Institute (CMFRI), Cochin. pp 96-99

Anon (2006) Impact of coastal bottom trawling on target and non- target resources along the south west coast of India. Technical and extension series, January-February-March 2006. Mar. Fish. Infor. Serv.187:7-13

Baird, S.J., Wood, B.A. and Bagley, N.W. (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989–90 to 2004–05. New Zealand Aquatic Environment and Biodiversity Report No. 73. 144p

Bhagirathan, U., Meenakumari, B., Jayalakshmy, K.V. and Vagela, D.T. (2009) Impact of bottom trawling on sediment characteristics-a study along inshore waters off Veraval coast, India. Environ. Monit. Assess. 160(1-4): 355-69

Bhagirathan, U., Meenakumari, B., Panda, S. K., Madhu, V. R., Vaghela, D.T. and Jethva, J.K. (2014) Impact of bottom trawling on the epifauna off Veraval coast, India. Indian Geo-Mar. Sci. 43(2): 297-312

Bhat, U. G. (2003) Impact of trawling on the benthic assemblage in the coastal waters off Karwar. Report submitted to Ocean Science and Technology Cell on Marine Benthos (Ministry of Ocean Development), 120 p

Bhat, U.G. and Shetty, D.C. (2005) Impact of Trawling on the Benthic Assemblage of Coastal waters of Karwar. In: The Seventh Indian Fisheries Forum, 8-12 November, 2005, Bangalore, India. 165p

Bhathal, B. (2005) Historical reconstruction of Indian marine fisheries catches, 1950–2000, as a basis for testing the Marine Tropic Index. Fisheries Centre Research Reports 13(5). Fisheries Centre, University of British Columbia

Bijukumar, A. (2008) Biodiversity of trawl bycatch in Kerala coast, south India. In: Glimpses of Aquatic Biodiversity (Natarajan, P., Jayachandran, K. V., Kannaiyan, S., Ambat, B. and Augustine, A., Eds) Rajiv Gandhi Chair Spec. Publ. *7*, Cochin University of Science and Technology, Kochi. pp 236-243

Bijukumar, A. and Deepthi, G. R. (2009) Mean trophic index of fish fauna associated with trawl bycatch of Kerala, southwest coast of India. J. Mar. Biol. Ass. India. 51(2): 145-157

Black, J., Wood, R., Berthelsen, T. and Tilney, R. (2013) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2009–2010 In: New Zealand Aquatic Environment and Biodiversity Report No. 110

Boopendranath, M. R. (2007) Possibilities of bycatch reduction from trawlers in India. In: Indian Fisheries-A Progressive Outlook (Vijayan, K. K., Jayasankar, P. and Vijayagopal, P., Eds) Central Marine Fisheries Research Institute, Cochin, pp 12-29

Boopendranath, M. R. (2012) Biodiversity conservation technologies in fisheries. J. Aquat. Biol. Fish.1(1):14-26

Chandrapal, G. D. (2005) Status of trash fish utilization and fish feed Requirements in aquaculture – India. "Regional workshop on Low value and Trash fish in the Asia - Pacific region". Hanoi, Viet Nam, 7-9 June 2005. pp 241-247

CMFRI (2013) Annual Report 2012-13. Central Marine Fisheries Research Institute, Kochi, 204 p

Dineshbabu A.P., Muthaiah,c., Geetha Sasikumar, Prathibha Rohit and Uma, S.Bhat (2012) Impact of non-selective gears on king seer, *Scomberomorus commerson* fishery in Karnataka. Indian J. Geo-Mar. Sci.41(3): 265-271

Dineshbabu, A. P. (2011) Unprecedented trash fish landing at Mangalore fisheries harbour. Mar. Fish. Inf. Ser. T& E. Ser. 207. 29-30

Dineshbabu, A. P. and Radhakrishnan, E. V. (2009) Trawl Fishery of juvenile fishes along Mangalore-Malpe coast of Karnataka and its impact on fish Stock. Asian Fish. Sci., 22(2): 491-500

Dineshbabu, A. P., Radhakrishnan, E. V., Thomas, S., Maheswarudu, G., Manojkumar, P. P., Kizhakudan, S. J., Pillai, L. S., Chakraborty, R., Jose, J., Sarada, P. T., Sawant, P. B., Philipose, K. K., Deshmukh, V. D., Jayasankar, J., Ghosh, S., Koya, M., Purushottama, G. B. and Dash, G. (2013) An appraisal of trawl fisheries of India with special reference on the changing trends in bycatch utilization. J. Mar. Biol. Ass. India. 55 (2): 69-78

Dineshbabu, A. P., Thomas, S. and Radhakrishnan, E. V. (2009) Geo-temporal distribution and resource abundance mapping of juvenile and adult threadfin bream, *Nemipterus mesoprion* in trawling grounds off Karnataka coast. Book of abstracts; International Symposium on "Marine ecosystems, challenges and opportunities, 9-12 February. Marine Biological Association of India, Cochin, pp112-113

Dineshbabu, A. P., Thomas, S. and Radhakrishnan, E. V. (2010). Bycatch from trawlers with special reference to its impact on commercial fishery, off Mangalore. In: Coastal fishery resources of India - Conservation and sustainable utilisation. (Meenakumari, B., Boopendranath, M.R., Edwin, L., Sankar, T.V., Gopal, N. and Ninan, G., Eds) Central Institute of Fisheries Technology, Kochi, pp 327-334

Dineshbabu, A. P., Thomas, S. and Radhakrishnan, E. V. (2012) Spatio-temporal analysis and impact assessment of trawl bycatch of Karnataka to suggest operation based fishery management options. Indian J. Fish. 59(2): 27-38

Dineshbabu, A.P. (2013) Trawl fishery of Eastern Arabian Sea, Asia Pacific Fisheries Commission and FAO for the regional guidance for the management of tropical trawl fisheries in the Asian region during 30th September- 4th October 2013, at Phuket, Thailand http://www.apfic.org/attachments/article/92/APFIC%20(Dinesh,%20India).pdf.

Dineshbabu,A.P., Thomas, S., Radhakrishnan, E. V., B. Sridhara, Y. Muniyappa, S. Kemparaju and Nataraja, G. D. (2011) Mapping of fishery resources in trawling grounds along the Malabar-Konkan coast. Mar. Fish. Inf. Ser. T&E. Ser. 210: 1-12

FAO (2010) Catch concepts: Diagrammatic Presentation, FAO Yearbook: Fishery and aquaculture statistics 2008. FAO, Rome: 96p

FAO(2004) The state of world fisheries and aquaculture. FAO, Rome. 153 p

George, M. J., Suseelan, C. and Balan, K.(1981) By-catch of shrimp fisheries in India. Mar. Fish. Inf. Serv. T. E. Ser. 28: 3-13

Gibinkumar, T.R., Sabu, S., Pravin, P. and Boopendranath, M.R. (2012) Bycatch Characterization of Shrimp Trawl Landings off Southwest Coast of India. Fish. Technol. 49: 132-140

Gordon, A. (1991) The bycatch from Indian shrimp trawlers in the Bay of Bengal: the potential for its improved utilization. Bay of Bengal Programme, Natural Resources Institute, Overseas Development Administration, Madras, India. BOBP/WP/68, 32 p

Gowda, G. (2004) Impact of bottom trawling on benthic communities. Final Report submitted to Ocean Science and Technology Cell on Marine Benthos (Ministry of Ocean Development). 62 p

Krishnan, A.A., Durgekar, R.N., Zacharia, P.U. and Krishnakumar, P.K (2005) Effects of experimental bottom trawling on the benthic macrofauna off Mangalore coast, Karnataka India. In: The Seventh Indian Fisheries Forum, 8-l2 November, 2005, India. Abstracts, 165 p

Kumar B.A. and Deepthi G. R. (2006) Trawling and bycatch: implications on marine ecosystem. Current Science. 90(7): 922-931

Kurup, B. M., Premlal, P., Thomas, J.V. and Anand, V. (2003) Bottom trawl discards along Kerala coast: A case study. J. Mar. Biol. Assoc. India 45: 99-107

Kurup, B.M. (2004) Immediate effect of trawling on sea bottom and its living communities along Kerala coast. CMFRI- Winter School on Ecosystem based management of Marine Fisheries, 174-179

Kurup, B.M. and Thomas, J.V. (2005) Bottom trawl landings Vs. Discards along Kerala coast a situation analysis. Fish. Chimes. 25(1): 70-76

Kurup, B.M., Premlal, P., Thomas, J .V. and Anand, V. (2004) Status of epifaunal component in the bottom trawl discards along Kerala coast (South India). Fish. Technol. 41(2): 101-108

Kurup, K. N., Nair, G. K. K., Annam, V. P., Kant, A., Beena, M. R. and Khambadkar, L. (1987)An appraisal of the marine fisheries of Karnataka and Goa. CMFRI Sp. Publ., 36: 1-104

Kurup. B.M, Premlal, P., Thomas. J.V. and Anand. V. (2004) Status of Epifaunal Component in the Bottom Trawl Discards Along Kerala Coast (South India). Fish. Technol. 41(2): 101-108

Lobo A.S., Balmford, A., Arthur, R. and Manica, A. (2010) Commercializing Bycatch Can Push a Fishery Beyond Economic Extinction. Conservation Letters 3: 277-285

Luther, G. and Sastry, Y. A. (1993) Occurrence of spawners, juveniles, young fish in relation to the fishery seasons of some major fishery resources of India, Mar. Fish. Inf. Ser. T& E. Ser. 122 Central Marine Fisheries Research Institute, Cochin

Manojkumar, P.P and Pavithran, P.P. (2012). Bycatch and discards in commercial trawl fisheries of Malabar region.http://eprints.cmfri.org.in/9780/1. pp 61-64

Meenakumari, B., Bhagirathan, U. and Pravin, P. (2009) Impact of bottom trawling on benthic communities: a review. Fish. Technol. 45(1): 1-22

Menon, N. G., Nammalwar, P., Zachariah, P. U. and Jagadis, I. (2000) Investigations on the impact of coastal bottom trawling on demersal fishes and macrobenthos. Central Marine Fisheries Research Institute, Annual Report 1999–2000, Cochin. pp 55-57

Menon, N.G. (1996) Impact of bottom trawling on exploited resources. In: Marine Biodiversity, Conservation and Management (Menon, N.G. and Pillai, C.S.S.,Eds) Central Marine Fisheries Research Institute, Cochin, pp 97-102

Mohamed K.S., Puthran, P., Sathianandan, T.V., Baiju, M.V., Sairabhanu, K. A., Lethy, K.M., Sahadevan, P., Chandrasekharan, M., Lailabeevi and Sivaprasad P.S. (2013) Report of the committee to evaluate fish wealth and impact of trawl ban along Kerala coast. Department of Fisheries, Government of Kerala. 68p

Pillai, N. G. K., Vivekanandan, E., Ganga, U and Ramachandran, C. (2009) Marine Fisheries Policy Brief-1. *CMFRI Special Publication*, 48p

Pillai, N.S. (1998) Bycatch Reduction devices in shrimp trawling. Fish. Chimes,18 (7): 45-47

Pillai, N. S., Varghese, M. D. and Mathai, T. J. (2004) Performance evaluation of different selective devices for the reduction of by-catch in shrimp trawls. In: Large Marine Ecosystems: Exploration and exploitation for Sustainable Development and Conservation of Fish Stocks. (Somvanshi, V.S. Ed) Fishery Survey of India. Mumbai, pp 569-576

Pravin, P and Manohardoss, R. C. (1996) Constituents of Low Value Trawl By-catch Caught off Veraval. Fish. Technol. 33(2): 121-123

Pravin. P., Gibinkumar, T.R., Sabu, S. and Boopendranath, M.R. (2011) Hard bycatch reduction devices for bottom trawls: A review. Fish. Technol. 48(2): 107-118

Raman, A.V. (2006) In: Impact of bottom trawling on benthic communities. Summary of the projects conducted in Kerala, Karnataka and Andra Pradesh (Background paper). Report prepared by Ocean Science and Technology Cell on Marine Benthos (Supported by the Ministry of Ocean Development). Unpublished Report. 37 p

Rao, K.S. (1988) Ecological monitoring of trawling grounds. J. Indian Fish. Assoc. 18: 239-244

Sayana, K.A., Rameshan,M.P., Madhu,V.R., Pravin,P. and Leela Edwin (2016) Appraisal of trawl design operated along Kerala coast. Fish. Technol. 53: 30-36

Sivasubramanyam, K. (1990) Biological aspects of shrimp trawl bycatch. Bay of Bengal News 40: 8-10

Sujatha, K. (1995) Finfish constituents of trawl bycatch off Visakhapatnam. Fish.Technol. 32(1): 56-60

Sukumaran, K.K., Telang, K.Y. and Thippeswamy, O. (1982) Trawl fishery of South Kanara with special reference to prawns and bycatches. Mar. Fish. Inf. Ser. T&E. Ser, 44: 8-14

Thomas, J .V. (2003) Impact of trawling on sea bottom and its living communities along the inshore waters of southwest coast of India. Ph.D. Thesis, Cochin. University of Science and Technology, Kerala, India. 307p

Thomas, J .V., Premlal, P., Sreedevi. C. and Kurup, B.M. (2004) Immediate effect of bottom trawling on the physicochemical parameters in the inshore waters (Cochin- Munambum) of Kerala. Indian J. Fish. 51(3): 277-286

Thomas, J. V. and Kurup, B. M. (2005) Impact of bottom trawling on sediment texture and organic matter along inshore waters of Kerala (South India). Fish. Technol. 42(2): l35-I40

Thomas, J. V. and Kurup, B. M. (2006) Effect of bottom trawling on ecological parameters along the inshore waters of Kerala, South India. In: Sustain Fish(Kurup, B.M. and Ravindran, K Eds), School of Industrial Fisheries, Cochin University of Science and Technology, Cochin-682 016, India, 446-461

Thomas, J.V. and Kurup, B.M. (2004) Immediate effect of bottom trawling on nutrients with special reference to nitrite and phosphate in the inshore waters off Kerala. J. Mar. Biol. Ass. India. 46(2): 198-203

Thomas, J.V., Sreedevi, C. and Kurup, B.M. (2006) Variations on the infaunal polychaetes due to bottom trawling along the inshore waters of Kerala (southwest coast of India). Indian J. Mar. Sci. 35(3): 249-256

Vivekanandan, E. and Narayanakumar, R. and Najmudeen, T. M. and Jayasankar, J. and Ramachandran, C. (2010) Marine Fisheries Policy, Brief-2; Seasonal Fishing Ban. CMFRI Special Publication, 103: 44p

Zacharia, P. U. (2004) Investigations on the effect off bottom trawling on the benthic fauna off Mangalore coast. Final Report submitted to Ocean Science and Technology Cell on Marine Benthos (Ministry of Ocean Development) 71p

Zacharia, P. U., Krishnakumar, P. K., Durgekar, R. N., Krishnan, A. A. and Muthiah, C. (2006) Assessment of bycatch and discards associated with bottom trawling along Karnataka coast, India. School of Industrial Fisheries, Cochin University of Science & Technology, Cochin, pp 434-445

Zacharia, P. U., Krishnan, A. A., Durgekar, R. N. and Krishnakumar, P. K. (2005) Immediate effect of bottom trawling on the physicochemical parameters of seawater and sediment off Mangalore coast, India. In: The Seventh Indian Fisheries Forum, Bangalore, India. Abstracts, 168 p. 8-12

Zynudheen, A. A., Ninan, G., Sen, A. and Badonia, R. (2004) Utilization of by-catch in Gujarat (India). ICLARM, NAGA, World Fish Center, 27: 20-23