Chapter 3
Responsible fishing and its strategic implementation for sustainability

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Introduction

India is situated north of the equator between 8°4' and 37°6' north latitude and 68°7' and 97°25' east longitude, is the largest peninsular country in the world bordered by Arabian Sea in the west, Indian Ocean in the south and the Bay of Bengal in the east. India has a coastline of 8118 km and 0.5 million sq. km continental shelf endowed with 2.02 million sq. km of Exclusive Economic Zone (EEZ). It has a catchable annual fisheries potential yield of 4.41 million t occupying third rank in world marine fish production (Table 1). India's territorial waters extend into the sea to a distance of 12 nautical miles from the coast baseline. The vital details on marine capture fisheries of India are given in table 1.

Table 1. Marine capture fisheries of India

		India
Lengthofcoastline(km)	:	8,118
Continentalshelf(km2)	:	5,30,000
ExclusiveEconomicZone(km2)	:	20,20,00
Annualpotentialyieldfrom EEZ(metrict)	:	4.41
Fishingvillages(No.)	:	3,432
Fishlandingcentres(No.)	:	1,535
Fishermenfamilies(No.)	:	8,74,749
Fisherpopulation(No.)	:	40,56,21
Marinefishingfleet(No.)	:	1,99,141
Mechanisedfishingvessels(No.)	:	72,749
Motorisedfishingvessels(No.)	:	73,410
Non-motorisedfishingvessels(No.)	:	52,982
Fishproduction(2016)(million t)		3.63

Source: GOI (2011a); DADF (2012); CMFRI (2012, 2013a, 2016)

The contribution to foreign exchange earnings by the fishery sector substantially increased from `46 crores in 1960 - 61 to 30,420.83 crores (US$ 4.7 Billion) in 2015-16. Seafood exports from India, during 2015-16, has been 1.05 million t (MPEDA, 2016). USA and South East Asia continued to be the major importers of Indian seafood as in the previous year. Frozen Shrimp was the major export item followed by frozen fish. (MPEDA, 2016).

Item wise exports 2015-2016 (Value in USD)
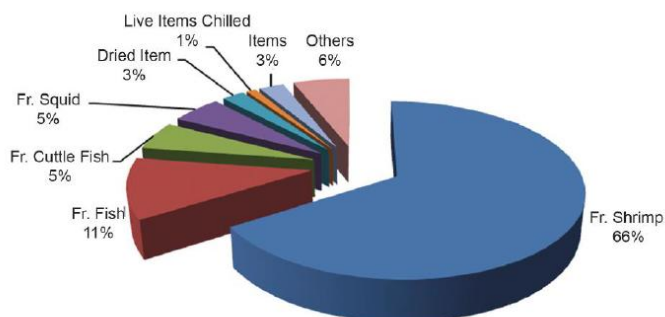
MPEDA (2016)

Fishery resource potential and production

Fish production in India has shown an increasing trend during the last six decades. Globally, India ranked second in world total fish production. The total fish production in the country increased twelve fold from 0.74 million t in 1950 to 10.07million t in 2014-2015 (FAO, 2016). India, with its highly productive fishing area has registered 3.63 million t marine fish production during 2015-16. Indian mackerel became the highest contributor with 2.49 lakh tonnes as the declining trend in Indian oil sardine landings continued.

The summary of the potential resources in the different realms and depth zones are given in Table 2 and 3

Table 2. Potential yield for different realms

Realm	Potential(t)
Pelagic	2,128,424
Demersal	2,066,763
Oceanic	216,500
Total	**4,411,687**

  Source: GOI (2011b)

Table 3. Potential yield for different depth zones

DepthZone	Potential(t)
Upto100m	3,821,508
100-200m	259,039
200-500m	114,640
Oceanic	216,500
Total	**4,411,687**

  Source: GOI (2011b)

Fish harvesting systems

Fishing gears and practices ranging from small-scale artisanal to large-scale industrial systems are used for fish capture in India. Most important among these are

trawls, purse seines, lines, gillnets and trap systems. Some of the traditional gears have also evolved into large and more efficient versions.

The mechanisation of indigenous vessels enabled the fishermen to fish in distant off-shore waters, which were previously inaccessible to them (Chidambaram, 1956). Introduction of small mechanised vessels, motorisation of country vessels, introduction of resource specific vessels and introduction of fishing fleet with state of the art equipment for fish detection and capture were the four development phases (Edwin et al 2014). Synthetic materials have been the mainstay in the production of fisheries gear since the past half century, the main synthetic fibre being used for fishing are Polyamide (PA), Polyethylene (PE), polypropylene (PP) etc.

Now, the entire mechanised fisheries sector uses only synthetic fibers for net making. Twisted netting yarns and braided netting yarns of different sizes are available in the country. Polyamide (PA) monofilament is being extensively used as an import substitute for tuna and shark longlines. The development of combination wire rope for deep-sea fishing is a recent innovation which has now been commercialised. CIFT has standardised specifications for the use of PP multifilament netting yarn with lower specific gravity and better tenacity than nylon.

There are about 1, 99,141 fishing vessels in the sector, of which nearly 72,749 are mechanised vessels (36.5%), 73,410 are motorised (36.9%) and the rest 52,982 non-motorised (26.6%) (Table.4).

Table 4. Fishing vessels in India

State/UnionTerritory	MechanisedVessels	MotorisedVessels	Non MotorisedVessels	TotalMarine FishingVessels
WestBengal	14,282	0	3,066	17,348
Odisha	2,248	3,922	4,656	10,826
Andhra Pradesh	3,167	10,737	17,837	31,741
TamilNadu	10,692	24,942	10,436	46,070
Puducherry	369	1,562	662	2,593
Kerala	4,722	11,175	5,884	21,781
Karnataka	3,643	7,518	2,862	14,023
Goa	1,142	1,297	227	2,666
Maharashtra	13,016	1,563	2,783	17,362
Gujarat	18,278	8,238	1,884	28,400
Daman&Diu	1,000	359	321	1,680
Andaman & Nicobar	61	1491	1637	3189
LakshadweepIsland	129	606	727	1462
Total	72749	73,410	52,982	1,99,141

Source: DADF (2012)

Advances in satellite-based technologies such as global positioning system (GPS) have positively influenced the precision in fishing, and Global Maritime Distress Safety System (GMDSS) based rescue system have facilitated safety of fishermen. Satellite remote sensing application in Indian fisheries helped to make maps of Potential Fishing Zones (PFZ), which in turn helped the fishermen to reduce search time and significantly increase catch per unit effort (Solanki et al., 2003).

The increase in fish production over the years has been the result of increased vessel number and capabilities, availability of large and more efficient gear systems, developments in electronic, navigational and acoustic detection equipment which increased the area of operation of the mechanised fishing fleet.

The FAO Code of Conduct for Responsible Fisheries

The Code of Conduct for Responsible Fisheries (CCRF) sets out the principles and international standards of behaviour for responsible practices to ensure long term sustainability of living aquatic resources, with due respect for the ecosystem, biodiversity and environment. It covers conservation; management and development of fisheries; capture, processing and trade of fish and fishery products; aquaculture; fisheries research; and integration of fisheries into coastal area management. The key principles of the Code include (i) management of stocks using the best available science; (ii) application of the "precautionary principle," using conservative management approaches when the effects of fishing practices are uncertain; (iii) avoiding overfishing and preventing or eliminating excess fishing capacity; (iv) minimisation of bycatch and discards; (v) prohibition of destructive fishing methods; (v) restoration of depleted fish stocks; (vi) implementation of appropriate national laws, management plans, and means of enforcement; (vii) monitoring the effects of fishing on the ecosystem; (viii) working cooperatively with other states to coordinate management policies and enforcement actions; (ix) recognizing the importance of artisanal and small-scale fisheries, and the value of traditional management practices.

Article 8 of CCRF: Fishing operations

Article 8 in the Code of Conduct of Responsible Fisheries is elaborated in *FAO Technical Guidelines for Responsible Fisheries 1: Fishing Operations* (FAO, 1996a). Article 8 contains 11 Sections and 52 sub-sections dealing with the Code of Conduct for Responsible Fishing Operations. The Article 8 include Sections (8.1) Duties of all states, (8.2) Flag State duties, (8.3) Port State duties, (8.4) Fishing operations, (8.5) Fishing gear selectivity, (8.6) Energy optimization, (8.7) Protection of aquatic environment, (8.8) Protection of the atmosphere, 8.9) Harbours and landing places for fishing vessels, (8.10) Abandonment of structures and other materials, and (8.11) Artificial reefs and fish aggregation devices.

Article 8 of the Code of Conduct for Responsible Fisheries which covers Fishing Operations and Article 12 on Fisheries Research have a number of provisions which are of direct relevance to the fishing gear research, design, development and operations. Section 8.4 on Fishing operations, says that states should ensure that fishing is conducted with due regard to the safety of human life relating to the organisation of marine traffic, protection of marine environment and prevention or loss of fishing gear. It also seeks to prohibit destructive fishing practices such as dynamiting and poisoning, it also explains the need to minimise loss of fishing gear and ghost fishing effects of lost and abandoned fishing gear through development of technologies, materials and operational methods; and emphasises the need for environmental impact assessment prior to the introduction of new fishing gear and practices to an area.

Section 8.5 on Fishing gear selectivity focuses on the development and wide spread adoption of fishing gear and methods which would minimise waste, discards, catch

of non-target species. The article on Fisheries Research, also seeks to ensure investigations on selectivity of fishing gear, the environmental impact of fishing on target species and behaviour of target and non-target species in relation to fishing gears. (Boopendranath, 2010).

Section 8.6 deals with appropriate standards and guidelines which would lead to the more efficient use of energy in harvesting and post harvesting activities within the fisheries sector and Section 8.7 deals with the pollution and disposal of waste generated during the vessel operation

Section 8.11 seeks to promote the development and use of artificial reef and fish aggregation devices. Responsible fishing technologies have been reviewed by Boopendranath (2009) and Boopendranath and Pravin (2009).

CIFT's initiatives in Responsible fishing

Fishing vessel design

Fishing craft mechanization in India progressed through four stages, beginning with motorization of some of the existing designs of traditional crafts, followed by introduction of mechanised craft, introduction of more specialized crafts, broadening to a full-fledged fishing fleet. ICAR-CIFT in collaboration with FAO naval architects introduced several standard designs of fishing crafts for different types of fishing operations. Twelve standard designs of wooden fishing boats in the size range of 7.67 to 15.24 m were developed and introduced by ICAR-CIFT, which gave a major fillip to the mechanization programme of Indian fisheries. It has been estimated that over 80% of the mechanized wooden fishing crafts in the Indian fishing fleet conformed to the popular ICAR-CIFT designs or its later adaptations. Designs of boats for fishing in rivers and reservoirs, pole and line fishing vessel, trawler-cum-carrier vessel, steel trawler-cum purse seiner, gillnetter were also developed by ICAR-CIFT. Design of a steel fishing trawler (15.5 m) with energy saving features has also been introduced by the Institute.

Solar powered FRP boat for inland waters

Institute has recently developed a solar powered FRP boat which can be operated in reservoirs, small rivers, and aquaculture ponds and can also be used for recreational fishing activities. The boat is capable of running for 2.5 to 3.0 hours after full charge and attains a speed of nearly 4.0 knots in calm waters. Considering the 240 days of fishing in a year the fuel saved compared to an equivalent diesel powered boat is about Rs. 48,000. The boat has wider space, a canopy for protection from rain and sun, low rolling characteristics during fishing, and also has provision of navigational lights to facilitate fishing in the night.

Fuel efficient multi-purpose fishing vessel

ICAR-CIFT has been instrumental in introducing designs of commercial, research and multipurpose vessels as per requirements of Governments and other organizations. Latest in these initiatives has been the introduction of fuel efficient multi-purpose fishing vessel FV Sagar Harita. The vessel built under the project "Green Fishing Systems for the Tropical Seas" (GFSTS) funded by National Agricultural Science Fund (ICAR-NASF) was officially launched on 18 April, 2016. The hull of this vessel is made of marine grade steel and the cabin and wheelhouse is made of FRP to reduce weight and to improve the carrying capacity and speed. The main engine power is 400 hp which is about 20% lower

than vessels of comparable size. The fishing gear handling equipment such as split trawl winch, long line setter and hauler, and gillnet hauler designed at ICAR-CIFT with hydraulic power were installed onboard. RSW tanks ($0\ ^0C$ to $-1\ ^0C$) of 2 tonne capacity have been provided for fish preservation onboard. A 600 watt solar power panel has been installed for emergency lighting and navigational aids to promote the utilization of renewable energy resource and conserve the diesel consumption. Acoustic fish detection and trawl monitoring system with underwater sensors have also been installed onboard.

'Target catch' is the species or species assemblage primarily sought in a fishery, 'incidental catch' is the retained catch of non-targeted species and 'discarded catch' is that portion of catch returned to the sea because of economic, legal or personal considerations (Alverson et al., 1994). Bycatch includes both discarded and incidental catch. In addition to the non-targeted finfishes and invertebrates, bycatch also involve threatened and protected species like sea turtles.

Responsible Fishing Gear

ICAR-CIFT has been in the forefront of developing technologies for responsible fishing and fisheries conservation.

Eco-friendly trawls

Demersal trawls are generally non-selective and a large number of non-target species and juveniles are landed during trawling, in addition to its impact on benthic communities. Resource specific trawls for semi-pelagic resources have comparatively low impact on the benthic biota. CIFT Semi-pelagic Trawl System (CIFT-SPTS) otherwise known as the off bottom trawl system has been developed as an alternative to shrimp trawling in the small-scale mechanized trawler sector, after extensive field-testing. The system consists of an 18 m four panel semi-pelagic trawl with double bridles, front weights and vertically cambered high aspect ratio otter boards of 85 kg each. It is capable of attaining catch rates beyond 200 kg h^{-1} in moderately productive grounds and selectively harvest fast swimming demersal and semi-pelagic fin fishes and cephalopods, which are mostly beyond the reach of conventional bottom trawls, currently used in commercial trawl fisheries in India.
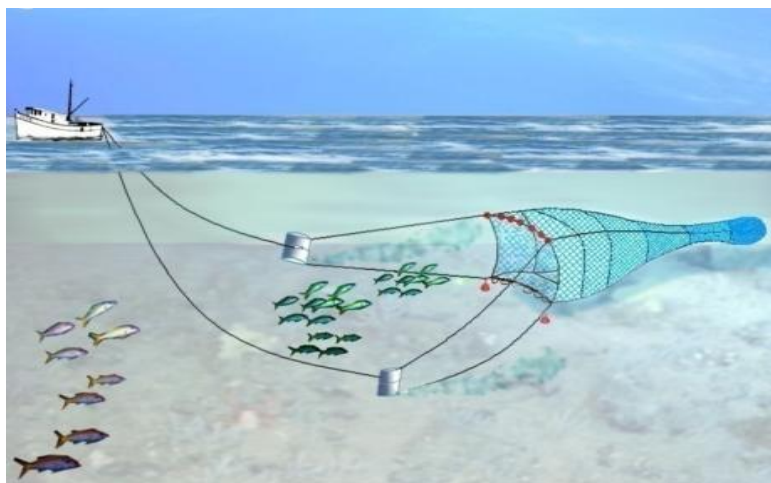
Eco-friendly off bottom trawl system

Selectivity of fishing gears

Information on fishing gear selectivity is important in biological investigations, fish stock assessment, fisheries management and for fishing gear design and development. Selectivity characteristics such as mean selection length, selection range, selection factor and selection curve of square mesh and diamond mesh with respect to demersal catch components have been determined through covered codend experiments.

Bycatch Reduction Technologies

Among the different types of fishing, shrimp trawling accounts for the highest rate of bycatch, of which a significant portion is constituted by juveniles that are generally discarded. Further, higher the quantum of bycatch the less will be the economic benefit accruing from the fishing operation. Bycatch is unavoidable in any fishing operation and only its quantities vary according to the type of the gear and its operation. Therefore, one of the important areas of research of the institute has been the development of bycatch reduction technologies. Devices developed to exclude the endangered species like turtle, and to reduce the non-targeted species in shrimp trawling are collectively known as Bycatch Reduction Devices (BRDs). These devices have been developed taking into consideration variation in the size, and differential behaviour pattern of shrimp and other animals inside the net. BRDs can be broadly classified into three categories based on the type of materials used for their construction, viz., Soft BRDs, Hard BRDs, and Combination BRDs. Soft BRDs make use of soft materials like netting and rope frames for separating and excluding bycatch. Hard BRDs are those, which use hard or semi-flexible grids and structures for separating and excluding bycatch. Combination BRDs use more than one BRD, usually hard BRD in combination with soft BRD, integrated to a single system. Oval rigid grid BRD, Fish eye BRD, Big eye BRD, Sieve net BRD which have given bycatch exclusion rates of 11-63% with an accompanying shrimp loss of 1-8%, have been recommended for shrimp trawls, for bycatch reduction and protection of juveniles. Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) is a Smart Gear award winning design (WWF) developed by CIFT for protecting juveniles and for pre-sorting of the catch (Boopendranath et al., 2008; WWF, 2009).

Square mesh codend

CIFT has for long been advocating the use of square meshes for trawl codend as a conservation measure. As the meshes in the square mesh codends remain open under tension during trawling, water flow will not be restricted and filtration will be efficient and resultant drag will be comparatively less which minimizes fuel consumption. As the mesh lumen remains open, it is easy for small fishes and juveniles to escape through the meshes which reduces the quantum of bycatch enabling the conservation of aquatic resources. In addition to these benefits, the quantity of net required for fabricating square mesh codend is less than the requirement for diamond mesh codend of the same dimensions, resulting in lower fabrication costs. As per CIFT recommendations, Gujarat Marine Fishing Regulation Act (GMFR Act-2003) has prescribed the use of 40 mm square mesh codends in the trawl nets. The use of square meshes have been successfully demonstrated by CIFT in the Sindhudurg District of Maharashtra under a UNDP – GEF project. Most recently the Govt. of Kerala has adopted 35 mm square mesh cod end for fish trawl and

25 mm cod end for shrimp trawl through amendment of the Kerala Marine Fisheries Regulation Act.

Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD)

Trawl fishermen in India and other tropical fisheries depend on both finfish catches and shrimp catches to keep the commercial operations economically viable. CIFT has developed a unique solution for this issue by developing Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD), which retains mature shrimp in the bottom portion of the net while allowing juvenile shrimp to swim out through the mesh unharmed. The device also retains mature finfish in the upper codend of the device, while allowing small sized fish of low commercial value and juveniles of commercial species to be safely excluded. JFE-SSD has bycatch exclusion rate of 43% with a shrimp retention of 96-97%. The sorting of the shrimp and the finfish between the lower and upper parts of the net enhances profitability because it reduces sorting time on the deck which increases the useful fishing time of the trawler fishermen, and it prevents shrimp from becoming crushed under the weight of fish and bycatch hauled on deck which increases the shrimp's market value.

Turtle Excluder Device (TED)

Sea turtles are endangered species. Incidental catches of turtles have been reported in the trawl landings of India particularly from West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and southern parts of Kerala. CIFT has developed an indigenous design of the turtle excluder device which is appropriate for the Indian conditions. CIFT-TED is a single grid hard TED with top opening of 1000x800 mm grid size for use by small and medium mechanized trawlers operating in Indian waters. In the TED developed by CIFT, great care has been taken to ensure 100% escapement of the turtles while exclusion of fish and shrimp is at the minimum possible level. MPEDA, Kochi has adopted the technology and distributed about 2900 CIFT-TEDs to trawler fishermen and operators in states affected by sea turtle mortality, *viz*., West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and Kerala. Demonstration cum training on fabrication, installation, operation and maintenance of CIFT-TED were conducted at several centres in West Bengal, Orissa, Andhra Pradesh and Kerala, in collaboration with MPEDA, Department of Fisheries, Department of Wildlife and NGOs.

Bycatch reduction in gillnets, purse seines, hooks and lines, and traps

Bycatch in drift gill nets may include marine mammals, sea turtles and sea birds, in addition to non-targeted fish species. Optimisation of gill net mesh size and hanging coefficient according to the target species and size group and judicious deployment of gill net in terms of fishing ground, fishing depth and season in order to minimise the gear interaction with the non-targeted species are important bycatch mitigation measures for gill net fisheries. One approach to minimise ghost fishing by lost gill nets, is to use biodegradable natural fibre twines or time release elements to connect the netting to floats (Hameed and Boopendranath, 2000).

Bycatch incidence in purse seine is said to be mostly due to accidental pursing of juvenile shoals. Selection of mesh size for the purse seine appropriate for the target species, proper choice of fishing area, depth and season could also lead to better

selectivity of purse seines. Special escape panels known as Medina panels, which are sections of fine mesh that prevent dolphins from becoming entangled in the gear, and back down manoeuvre have been deployed to prevent capture of dolphins in purse seines (Ben-Yami, 1994). Optimized hook design and size and selection of bait type and bait size appropriate for the target species and size class, proper choice of fishing ground, depth and time of fishing are approaches for mitigation of bycatch issues in hook and line fisheries and minimise gear interaction with other species. Optimised trap design according to the target species and provision of escape windows for juveniles and non-target species in the design side and appropriate choice of bait type, fishing area, fishing depth, fishing time also help to minimise juvenile catch in traps.

Green Fishing Concept

The green fishing concept encompasses energy conservation in fishing and minimising environmental impact of fishing gears in all fisheries.

Energy conservation in fishing

Motorised and mechanised fishing operations are dependent on fossil fuels, which are non-renewable and limited. Fossil fuels produces increased levels of carbon dioxide in atmosphere contributing to green house effect and other pollutants which are detrimental to the environment and human health. Green house effect leads to irreversible climatic and oceanographic changes. Moreover spiraling oil prices may severely affect the economic viability of fishing as a means of food production. World capture fisheries consumes about 50 billion litres of fuel annually (1.2% of the global fuel consumption) releasing an estimated 134 million tonnes of CO_2 into the atmosphere at an average rate of 1.7 tonnes of CO_2 per tonne of live-weight landed product (Tyedmers et al.,2005). Annual fuel consumption by the mechanized and motorized fishing fleet of India has been estimated at 1220 million litres which formed about 1% of the total fossil fuel consumption in India in 2000 (122 billion litres) releasing an estimated 3.17 million tonnes of CO_2 into the atmosphere at an average rate of 1.13 tonnes of CO_2 per tonne of live-weight of marine fish landed (Boopendranath, 2009).

Studies on GHG emmission from fishing vessel conducted in CIFT has shown that the fuel consumption is the major factor contributing to GWP in both single day and multi day trawler operations and hence offers scope for impact reduction through operational fuel savings. The GWP was incrementally higher for multi-day trawler operation corresponding to increase in size of trawlers. Global warming potential ranged from 2165 to 4328 kg CO_2 Eq. in wooden trawlers and from 2824 to 6648 kg CO_2 Eq. in steel trawlers depending on the size. The GWP was higher in very large trawler due to inorganic emission to air especially carbon dioxide. The GWP had a negative value for renewable resources i.e., wood for construction, wooden otter board, marine plywood and cotton. Among the materials used for construction of a 40 m trawl net GWP was maximum for iron sinker (64.6%) followed by high density polyethylene (HDPE) webbing (17.0%), polypropylene (PP) rope (10.3%), HDPE float (5.0%) and lead sinker (3.1%).

Various approaches to energy conservation in fish harvesting such as (i) fishing gear and methods; (ii) vessel technology; (iii) engines; (iv) reduction gear, propeller and nozzle; (v) sail-assisted propulsion; (vi) adoption of advanced technology; (v)

conservation, management and enhancement of resources, have been discussed by May et al. (1981), Gulbrandson (1986), Wileman (1984), Aegisson and Endal (1993), Boopendranath (1996), Wilson (1999, Boopendranath (2009). Other methods of energy conservation can be through use of Fish Aggregating Devices (FAD) the Institute has developed and standardized low-cost designs of floating FADs and benthic Artificial Reef (AF) modules, based on experiments off Andhra Pradesh coast, in order to make the fishing operations energy efficient and cost-effective, for the benefit of traditional fishermen operating fishing gears such as gill nets and lines. Potential fishing zone (PFZ) advisory is important service, since fishermen can use less time and fuel in searching for areas of fish abunadance. PFZ advisory mainly rely on Chlorophyll and sea surface temperature retrieved from satellite. Fishing Technology Division, ICAR-CIFT has been working on this aspect for 8 years. The main objectives are to provide *in-situ* database on chlorophyll, coloured dissolved organic matter, detritus and nutrients along with other physical parameters of coastal waters of Kochi, validate the *in-situ* measured Chlorophyll, coloured dissolved organic matter and detritus with satellite data and development of regional algorithms based on these *in-situ* and satellite data to improve PFZ advisory.

Minimising environmental impact of fishing gears

Dragged gears as trawls, particularly when they are heavily rigged, could cause severe damage to benthic fauna and flora, which occupy the bottom substratum and contribute to the productivity of the region. Direct and indirect impacts of bottom trawling on marine environment and benthic communities are well known (Hall, 1999; Kaiser and de Groot, 2000; Barnes and Thomas, 2005; Meenakumari et al., 2009 and others).

Conclusion

The implementation of responsible fishing methods starts with the research on design, development and operation of fishing vessel and fishing gear. A country like India has already a wide range of technology for bycatch reduction, minimising environmental impact and energy conservation based on FAO- CCRF. Creating awareness among stakeholders with suitable incentives will result in faster adoption of such technologies. Policy initiatives and amendment of existing legislation will facilitate sustainable fishing in India.

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