Training manual

ICAR SPONSORED SHORT COURSE ON

BYCATCH REDUCTION IN FISHERIES: RECENT ADVANCES

17-26 January, 2022

Indian Council of Agricultural Research - CENTRAL INSTITUTE OF FISHERIES TECHNOLOGY

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ICAR-Central Institute of Fisheries Technology
CIFT Junction, Matsyapuri P O
Kochi – 682029, India
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FOREWORD

The global fish production reached the all-time high in 2020, estimated at 178.5 million tonnes, with the capture fishery from marine and inland waters, contributing 96.4 million tonnes. With this highest recorded production, the world fish supply reached 20.5 kg per capita in 2020. The record growth has been due to the increase in aquaculture production, whereas the global marine fisheries production has reached a plateau during the last decade and is now hovering around 84.4 million tonnes. The total fish production in India during the year 2019-20 was 11.41 million tonnes, with a contribution of 7.77 million tonnes from the Inland sector and 2.73 million tonnes from the marine sector. The country has more than 1.5 lakh marine fishing vessels, out of which nearly 26% are mechanized, 58% motorized and 16% non-motorized. By-catch, over exploitation, climate change issues, high-energy inputs and habitat degradation among others has been the major causes for the stagnation of catches from the marine fisheries sector of India. Consequently, to the developments in the fishing sector, the priority of research in fishing technology now is towards conservation and development of fishing gears and methods, that least affect the fish stocks, habitats and ecosystem. ICAR-Central Institute of Fisheries Technology for the last six decades has been engaged in research and development of resource conservation and efficient harvesting systems for inland, aquaculture and marine sectors of the country.

The ICAR sponsored short course on “Bycatch Reduction in Fisheries: Recent Advances” is an attempt towards disseminating the technologies and methodologies developed by the institute to teachers, researchers, subject matter specialists and extension personnel engaged in fisheries. The compilation of chapters in this book, which caters to the theme of the short course, will be an excellent basic reference material for the participants.

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PREFACE

Bycatch is the portion of the total catch that is incidental in fishing operations. Global estimates suggest that approximately 10% of catch is being discarded in the marine capture fisheries. The by-catch generated depends on factors like fishing type, seasonal and geographical variations and biological characterisations of the target species. Bycatch generated in most of the fisheries constitute large quantity of juveniles which cause serious lacunae in stock estimation. The short course taken up on" Bycatch Reduction in fisheries: Recent advances at ICAR-Central Institute of Fisheries technology enframes aspects such as status of the fisheries resources, fish harvesting methods and policy issues with a view to attain responsible fishing. This manual is a compilation of view of many experts from their respective fields with an aim to highlight the issues and some of the steps to address them. The document will facilitate researchers and policy makers to advance in their views on different issue and strategies for mitigation.

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Sl. No.	Contents	Page

Overview on bycatch from harvesting systems

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The term bycatch refers to the non-targeted species retained, sold or discarded for any reason (Alverson et al., 1994). Target catch is the species that is primarily sought after in the fishery and incidental catches is the retained catch of non-targeted species and the discarded catch is that portion of the catch that is returned to the sea due to economic, legal or personal considerations. Global bycatch by the world's marine fishing fleets was estimated at 28.7 million t in 1994, of which 27.0 million t (range: 17.9-39.5 million t) were discarded annually and shrimp trawling alone accounted for 9.5 million t (35%) of discards annually (Alverson et al., 1994). In 1998, FAO estimated a global discard level of 20 million t (FAO, 1999a). Average annual global discards, has been re-estimated to be 7.3 million t, based on a weighted discard rate of 8%, during 1992-2001 period (Kelleher, 2004). Davies et al. (2009) redefined bycatch as the catch that is either unused or unmanaged and re-estimated it at 38.5 million tonnes, forming 40.4% of global marine catches. The recent global estimates of bycatch are 9.1 million tonnes, with highest contribution from bottom trawls of about 4.2 million tonnes, with tropical shrimp trawl fisheries contributing the most.

The first study on the fisheries bycatch along the Indian waters was by George *et al.*, (1981) who had reported that bycatch formed about 55% of the total trawl landings at Shakthikulangara and 56% at Cochin fishing harbours of Kerala. Sukumaran *et al.*, (1982) had reported that shrimps contribute only 13% of average annual trawl catches from Malpe and Mangalore in Karnataka state (India) during 1980-82 and the trawl by-catch was as high as 85% during this period. The total bycatch generated along the east coast of India by shrimp fisheries was reported by Gordon, (1991) to vary between 99–130 thousand tonnes annually. The bycatch generated by the shrimp trawlers along Vishakhapatnam coast was reported by Rao, (1988). The estimate of the total bycatch was 40,410 tonnes of which 32,420 t was discarded and the rest 8,258 t was landed. Sujatha, (1995) reported 288 species belonging to 68 families and constituting about 11% of the total trawl landings off Vizhakapatnam. Total of 87 species constituted the low value bycatch generated by commercial trawlers operating from the Veraval coast (Pravin and Manohardoss, 1996a). Pillai, (1998) described the bycatch generated along the Indian coast and the total bycatch was found to be highest along the Gujarat coast and around 40% of the bycatch comprised of juveniles. The bycatch generated by the shrimp trawlers along the upper east coast of India was reviewed by Dixitulu, (2003). The constituents of the trawl bycatch along south east coast was reported as 38.1% of the total catch by Jagadis *et al.*, (2003). Sciaenids (15.6%), engraulids (12.8%) and ribbonfishes (8.9%) formed the major species in the trawl bycatch along Veraval coast, as reported by Zynudheen *et al.*, (2004). Kelleher (2004) had estimated total bycatch discards in Indian fisheries at 58000 t, which formed about2% of the total landings. The trawl bycatch generated along Mangalore was reported by Zacharia *et al.*, (2005) as 56,083t in 2001 and 52,380t in 2002. Kumar and Deepthi, (2006) had reviewed the bycatch problem in the Indian context and different steps available for bycatch mitigation were discussed. The economic loss due to juvenile fishing along the Indian coast was estimated at US$ 19,445 million/year by Najmudeen and Sathiadhas, (2008). The bycatch generated by shrimp trawling along the central Kerala coast was reported by Boopendranath et al., (2008). Total of 283 species were reported as trawl bycatch component off central Kerala by Gibinkumar, (2008). Mohamed et al. (2009) have shown that the percentage of juveniles exploited by trawl ranges from 20 to 60% in case of seer fishes and groupers and as 12% in case of squids. Pramod (2010) estimated the bycatch discards from mechanised trawlers operating in Indian EEZ at 1.2million tonnes. The same study estimated 56.3% of the total catch of shrimp trawlers as bycatch. Recent estimate by Dinesh babu et al. (2013), showed that landing of low value bycatch (LVB) in trawl fisheries, increased from 14% in 2008 to 25% in 2011. A recent study carried out among the multi-day trawlers operated operating along Visakhapatnam coast showed that juveniles of 20 species formed 12,757.16 t and 286.86 million numbers per year and their contribution to the total landings of these species in trawl by-catch were 55.30% by weight and 57.03% by numbers (Ghosh et al., 2021). Abdul Azeez et al., (2021) estimated that bycatch constituted about 53.36% of the total catch from mid water trawlers operating along Gujarat coast.

The reduction in bycatch discards globally, in recent years could be attributed to (i) increased use of bycatch reduction technologies, (ii) anti-discard regulations and improved enforcement of regulatory measures, and (iii) increased bycatch utilization for human consumption or as animal feed, due to improved processing technologies and expanding market opportunities. Also, equally important as the issue of bycatch is the un-quantified impacts of different fishing systems on the ecosystem, with active fishing gears like trawls causing the most damage.
FAO has brought out International guidelines on bycatch management and reduction of discards, in view of its importance in responsible fisheries (FAO, 2011). Life under water (14th Goal) among the Sustainable Development Goal (SDG) has different targets for sustainable use of fisheries resources.

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Bycatch issues in Ring seine sector

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Introduction

Bycatch and discards are one of the major problems faced in the fishing industry globally. Bycatch is defined as that portion of catch other than targeted species caught while fishing which are either retained or discarded. Discarding is the practice of returning an unwanted portion of the catch back to the sea during fishing operations (Alverson et al., 1994). Fish are discarded for various reasons at sea, representing a waste of fishery resources and potential food (Clucas, 1997). Bycatch is recognized as unavoidable in fisheries but the quantity varies according to the gear operated (Riedel and DeAlteris, 1995; Clucas, 1998; Pillai, 1998; Ortiz et al., 2000; Hall et al., 2000; Gibin, 2008). Bycatch and discards pose a threat to biodiversity and long term sustainability of fishery resources. About 30% of the world's marine fishery resources is over exploited, 60% fully exploited and only 10% moderately exploited (DAHDF, 2014). Overexploitation of bycatch and target species in marine capture fisheries is the most widespread and driver of change and loss of global marine biodiversity (Gilman, 2011).

In Indian scenario, it is estimated that about 56.3% of the total catch of shrimp trawlers is bycatch (Pramod, 2010). In India bycatch is considered as a major threat and has been reported by several authors (Boopendranath, 2003; Sivasubramanyam, 1990; Gorden, 1990; Menon, 1996; Rao, 1998; Madhu et al., 2017).

Surrounding nets

Surrounding nets are roughly rectangular walls of netting rigged with floats and sinkers which after detection of the presence of fish are cast to encircle the fish school. Surrounding nets are generally operated in the surface area. Purse seines are the predominant type of surrounding nets (Meenakumari et. al., 2009). Purse seine fishing is one of the most aggressive, efficient and advanced fishing methods. It is aimed mainly at catching dense, mobile schools of pelagic fish and includes all the elements of searching, hunting and capture. The schools of fishes are surrounded and impounded by means of large surrounding net.

Beach seines have been used through the ages almost all over the world. According to Brandt (2005), seine nets (sagene) were used early Greeks in third millennium BC. Later Romans employed a large gear which they called 'sagena', and as they occupied very large areas of Europe this net was introduced by them to many countries. In France, the gear is known as 'seine' or 'senne' and, in the British Isles, as 'seine net' the gear is now known all over the world. They are usually deeper than the depth of the water. The top edge is framed with a float line and lower edge with a lead line. It is set in semi-circle at some distance from the shore and then hauled ashore onto the beach using long ropes. During hauling, the beach seine filters the enclosed waters from the surface to the bottom. As soon as the wing tips come within the reach of the fishermen they bring the lead line of both wings together in order to gather the fish towards the center. The bunt part with the catch inside is the last part to be brought ashore. In purse seines, a pursing arrangement is incorporated in order to close the net at the bottom after surrounding a shoal of fish. This facilitated the operation of net in deeper waters.

A purse seine is made of long wall netting framed with float line and lead line and having purse rings hanging from the lower edge of the gear, through which a purse line made from steel wire or rope which allow the pursing of the net (Nedlec, 1982; Brandt, 1984). Thus, a bowl like space is created in which the fishes are enclosed and prevented from escaping. Modern purse seines were introduced in commercial fisheries more than a hundred years ago (Skogsberg, 1923). Description of the purse seines and their operation have been given by Ben-Yami (1994), Masthawee (1986), Sainsbury (1996), Hameed and Boopendranath (2000) and others. Advances in purse seining were supported by the introduction of high tenacity synthetic twines of high specific gravity, improvements in vessel technology and gear handling equipment's such as puretic power block, fish aggregation techniques, acoustic fish detection and remote sensing techniques (Ben-Yami, 1994 and Hameed and Boopendranath, 2000).

In some parts of the world, purse seining produces the largest single catches of pelagic fishes. Purse seine fishery for tuna is carried out over a far greater geographical area. Purse seines are also used to catch the demersal fish such as cod by modifying its design to operate close to the bottom. However, the major contributor to the purse seine fisheries of the world is the vast number of smaller vessels landing small pelagic species. A conservative estimate of percentage of the world catch caught by surrounding nets fisheries would be 25 to 30 % of the world catch. (Ben Yami, 1994).

Boat seines and shore seines are the age-old fishing methods of Kerala marine fisheries. The different regional names of boat seines, are arakollivala, ayilakouivala, choodavala, discovala, deppavala, ringvala, kudukkuvala, thanguvala, kollivala, koruvala, mathkollivala, paithuvala (Pillai et. al., 2000). According to FAO (1984) thanguvala is a lampara-type net with 150 m in length and operated from beach landing canoes (thanguvallams) of length 15 m, beam 1.4 m, and depth 0.85 m. The earlier versions of thanguvallams were made as dugout canoes. The first trials with motorization of the thanguvallam were made by the Indo-Norwegian Project in Neendakara around 1955. In September 1980, new motorization trials were started by the Kerala Fishermen's Welfare Corporation in Purakkad near Alleppey with inboard diesel engine of 9 hp, outboard diesel engine of 5 hp, and outboard kerosene engine of 7 hp. With a continuous improvement, the motorization program was a grand success and it spread throughout the entire coast of Kerala. Commercial purse-seine fishing started during the late seventies in Cochin, Kerala (Jacob et al., 1987) and the process of large-scale motorisation of country craft began in the early eighties. The eighties were an important period in the development of marine fisheries in Kerala. In the first half of the period the motorized sector grew rapidly and the adoption and popularization of ring seines in the mid-eighties was the single most significant development in the post motorisation of Kerala fisheries.

Evolution of Ring Seine Fishery

The ring seine or mini purse seine gear was first introduced by the Central Institute of Fisheries Technology as new gear for the traditional craft (Panicker et al., 1985). After the popularisation of ring seine, the koruvala and kollivala become obsolete. Nair and Chidambaram (1951) reported during the period 1895, oil sardines were caught in boat seines (paithuvala, odamvala, etc.) for day fishing. Nair and Chidambaram (1951) have conducted a detailed study about the craft and gear employed for exploiting small pelagic fishery, fishing method and fishing seasons during which they observed the seine nets (mathikollivala and ailakollivala) made of hemp with 50-60 ft in length.

Pramod (2010) states that ban on purse seining initiated in the eighties to prevent loss of livelihood for traditional fishers, and an improvised gear called "ring seine" was developed from a traditional seine gear. Ring seine operation started in Kerala with plank built canoes. The large and medium sized plank built canoes locally called as thanguvallam and dugout canoes are used for the operation of the gear. There is no difference in the pattern of operation by these two categories of canoes except in the size of the net. The plank canoes use bigger size (length and breadth) of nets depending up on its accommodation capacity. There is also considerable variation between regions in the number of craft used for a ring seine unit. The ring seiners with 30 to 32 ft LOA having 8 to 15hp or 9.9 hp Suzuki engines used for propulsion of the craft was reported by D'Cruz (1998). However, in certain cases, two engines are also used in a single unit. These are necessitated by the total load of the large gear, 20-30 crew members and bulky catch.

Presently in Kerala the ring seine belt extends from Muthalampozhi in Thiruvananthapuram district to Talapady in Kasaragod (Edwin and Das, 2015). Each region has its own peculiarities in construction and operation of the gear. After the success of the ring seine fishery it spread to the other parts of the country including Andaman and Nicobar Islands and contribute 8.8 to 18.3 % of the total marine production of the country with 2.01 to 6.63 lakhs tonnes (Sivadas et al., 2015). In the state of Kerala ring seine contributed major share to capture fisheries (50.11%). Out of this, it contributes 92 % of sardine, 41.8% of mackerel, 82.8% of white baits, 13.3 % of carangids (CMFRI, 2013).

Structure of Ring Seine Net

Although there is great variation in the details of ring seines, not only in different fisheries but in each individual fishery, nevertheless there has evolved a certain basic design. The structure of the ring seine has many features of the purse seine and of the lampara. All three are kept on the surface of the water by a similar float line strung with floats, and are hung vertically in the water by a heavily weighted lead line. The ring seine, like the purse seine, has purse rings along its lower edge. Some of the chief structural differences between the ring seine and the purse seine are that the purse seine is made of comparatively heavy tarred webbing, is practically uniform throughout its entire length, and is practically square on the ends; while the ring seine, like the lampara, is made of light webbing, is gathered on the ends, and is made in three parts: a central bunt of thick webbing and two end portions or wings. The relative lengths of bunt and wings vary greatly.

The introduction of ring seine, offered an efficient alternative gear for operation from the boat seine craft thanguvallam in the artisanal sector. Along with CIFT's introduction and popularisation of ring seines in Cochin and Kasaragod areas, other developments were initiated by fishermen (Rajan, 1993) contributing to easy acceptance of ring seines. According to Shyam et al. (2012), modification of the traditional boat seine vessels to make it more efficient resulted a most popular seining method for the pelagics along Kerala coast.

Typical cotton thanguvala of the early sixties described by Kuriyan et al. (1962) had a length of 42m and a depth of 5.2m. The mini- purse seine introduced by CIFT with an overall length of 250m and a depth of 15m at the wing end and 33m at the bunt. It is seen that the number of ring seine units as per estimates of 1992 was 2229 and the number further rose to 2875 by 2005 (GoK, 2005) as against the 300 recommended by the Central Institute of Fisheries Technology (Panicker et al., 1985). A number of variations have occurred in the design of the gear due to innovations by the traditional fishermen (Edwin and Hridayanathan, 1996; Vijayan et al., 2000). The impact of transition from the traditional boat seine, thanguvala or koruvala operated from thanguvallam (traditional boat seine craft) to the present-day ring seine has been studied by Achari (1993).

Many authors have studied the structural variations of ring seines of Kerala. According to the census conducted by SIFFS the ring seines are classified according to the type of craft, mesh size and size of gear (SIFFS, 1992). Rajan, (1993) classifies ring seines based on the number of crafts used for operation. The design and operational aspects of the ring seines prevalent in the Alleppey- Cochin coast was described by Edwin and Hridayanathan (1996). Rajan (1993) describes the salient features of the ring seine unit along Kerala coast. The size of gear as reported by Edwin and Hridayanathan (1996) showed that average length of a thanguvala of Alleppey region was 630m and depth 100m with a mesh 18-20mm. The thanguvala reported by D'Cruz (1998) showed that the thanguvala had further grown in dimensions and due to the large size of the nets, trolleys are used for transportation of the gear. The studies by Kurup and Radhika (2003) showed that the ring seines of Kerala had a length of 800-1700m with bunt mesh size of 16mm. Large ring seines up to 900m length and 90m depths were reported by Krishna et al. (2004) from Thrissur District and such gear could not be lifted manually. Edwin et al. (2010) reported ring seines with a mesh size of 20 mm with a length and depth of 600-1000 m and 83-100 m respectively and having a weight of 1500 to 2500 kg is targeted to catch the pelagic shoaling fishes like the sardines and mackerel in Ernakulam district. Edwin and Das (2015) describe the regional and structural variation of ring seine fishing systems of Kerala in detail.

Ring Seine Fishing Vessels

The introduction of ring seine offered an efficient alternative gear for operation from the boat seine craft thanguvallam in the artisanal sector. With CIFT's introduction and popularisation of ring seines in Cochin, other improvisation were initiated by fishermen in Kasaragod areas (Rajan, 1993) contributing to easy acceptance of ring seines. The ring seiners of Kerala are classified mainly in to two classes; outboard engine propelled motorized and the inboard engine driven mechanized ring seiners. The motorized ring seine fishery depict regional, operational and structural differences. Among mechanized ring seine units, regional differences are limited and are similar in all districts.

Motorized Ring Seiners: Three types of motorized ring seine are commonly operated in Kerala. Large motorized ring seine vessels made of wood or FRP with an assisting skiff vessel are commonly observed in Thiruvananthapuram to Kozhikode districts. The fishing vessels used for operation are of 7.6-14.6 m and propelled with 25 and/or 40 hp outboard engine. Two types of fishing gear are used in such units i) 200- 500 m in length and 40-60 m in depth with mesh size of 10-14mm and ii) 350-650 m in length and 50-70 m in depth with mesh size of 16-22mm. Large motorized units have one additional carrier vessel for transporting the catch to the landing center.

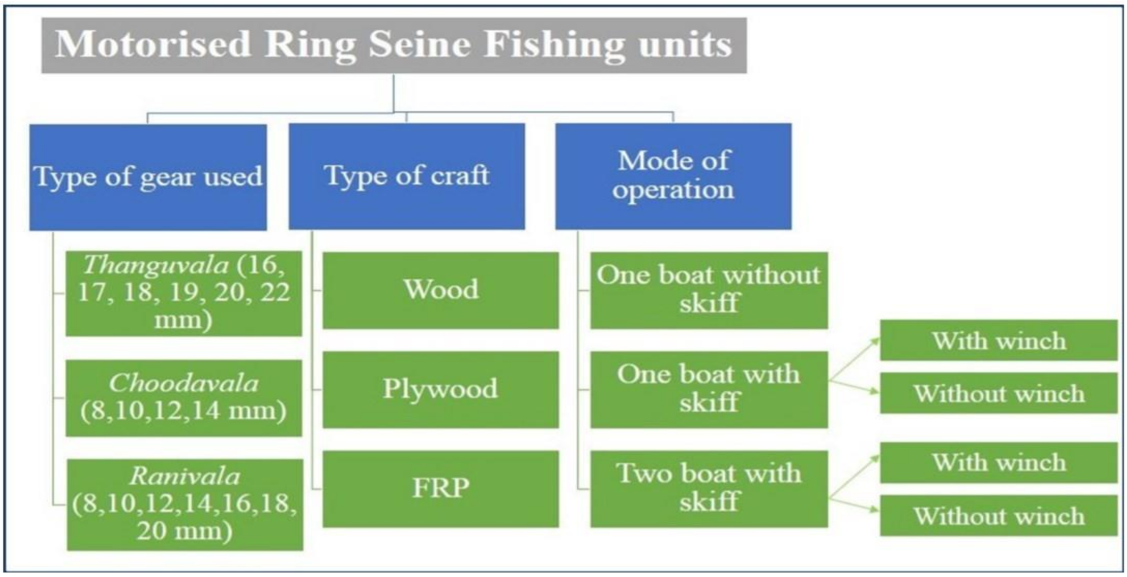

Fig.1. Classification of Motorised ring seiners of Kerala

One boat operation with a small FRP boat in near shore waters is widely prevalent in the districts of Alappuzha, Ernakulam and Kozhikode. In Alappuzha this type of fishing is locally known as sundarivala and in Kozhikode as ossamvala. The ring seine unit comprises of a 6.1-7.6 m wood /FRP fishing vessel propelled by one or two 9.9 hp outboard engines using a fishing gear of 130 -210 m in length and 35-45 m in depth with a mesh size of 8-10 mm.

The third type of motorized ring seine fishing unit is the ranivala, which is a common practice in the northern part of Kozhikode district, Kannur and Kasargod. Ranivala unit consists of three to six numbers of motorized craft, one large craft with fishing gear (ring seine) and known as valavallam of 9.8 – 11.6 m LOA fitted with 25 hp or two 9.9 hp or a combination of 25 hp and 9.9 hp OBM engines for propulsion.

Mechanised Ring Seiners: The number of mechanised ring seiners are less, compared to the motorised units. The common construction materials for mechanised ring seiners are steel, wood and FRP. The wooden ring seiner are restricted to an LOA of 70 m and the newly constructed inboard ring seiner are either steel or FRP construction. In northern districts like Kasaragod, Kannur and northern side of Calicut region mechanised ring seiners are of FRP construction. In southern region of Kerala coast steel and FRP ring seiners are in operation. In central Kerala steel ring seine units dominated and the number of skiff (carrier) vessels associated with a mechanised ring seine fishing unit also varied with region. In Kozhikode and Malappuram districts ring seiners with three to four carrier vessels are a common sight.

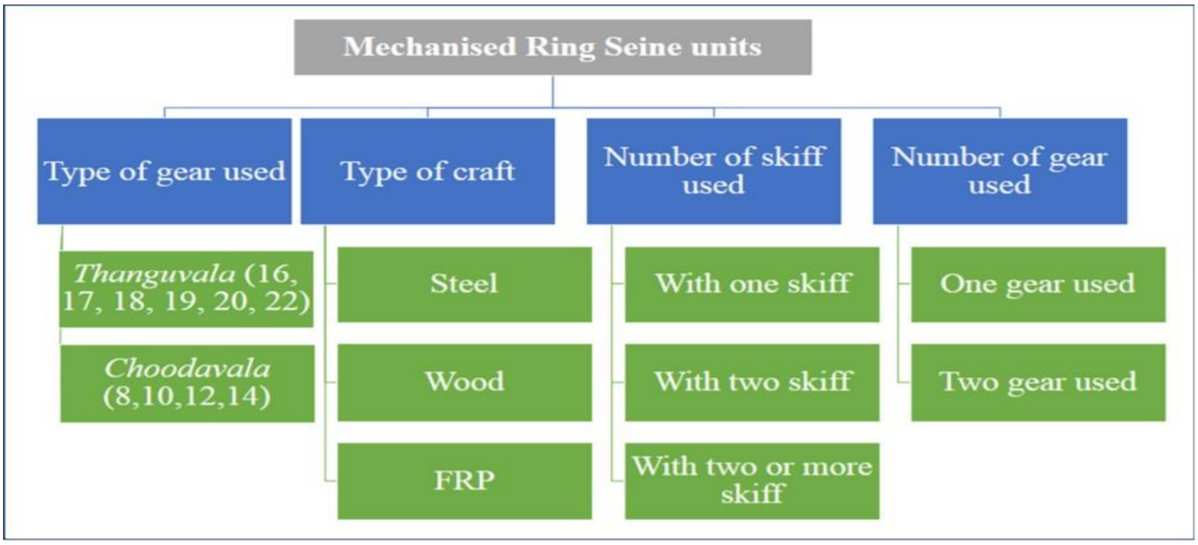

Fig. 2. Classification of the Mechanised Ring seine units

Bycatch occurrence in ring seines

Ring seines are usually defined as mobile gears intended to catch pelagic fishes are showing a changing pattern in its species diversity. Ninety percent of the ring seine catch comprises of targeted species like sardine, mackerel, anchovies and tunas along with 10% of non-targeted species like Thryssa spp, lesser sardine, carangids and seer fish in Andhra Pradesh region (Rajeswari et al., 2013). Bycatch studies in ring seines are scarce.

According to the study conducted by ICAR-CIFT it is shown that Large meshed ring seine (LMRS) targeted catch was 112379kg and bycatch constituted 8677kg. Small meshed ring seine (SMRS) the targeted catch was146520kg and bycatch accounted 50222kg. A total of 56 bycatch species were identified from ring seines. The targeted groups were sardine, mackerel, anchovies and prawns and the non-targeted groups were mullets, ambassids, half beaks, pomfrets, sciaenids, carangids, catfishes, silver bellies and miscellaneous (mixed group) of fishes.

The major pelagic resources constituted in bycatch were *Escualosa thoracata, Nematalosa nasus, Opisthopterus tardoore, Anadontostoma chacunda, Thryssa dussumieri, Thryssa hamiltonii, Thryssa mystax, Thryssa vitrirostris, Thryssa purava, Megalaspis cordyla, Caranx hippos, Caranx ignobilis, Alepes djedaba, Alepes klenii, Parastromateus niger, Scomberoides commersonianus, Sphyraena obstusata, Polynemus plebeius, Lepturacanthus savala, Scomberomorus guttatus, Valamugil cunnesius, Valamugil seheli, Mugil cephalus, Exocoetus volitans, Hyporhamphus limbatus*.

The major demersal resources constituted in bycatch were *Gerres poieti, Gerres filamentosus, Pampus argenteus, Pampus chinensis, Lactarius lactarius, Scatophagus argus, Secutor* *ruconius, Secutor insidiator, Leiognathus splendens, Leiognathus brevirostris, Siganus canaliculatus, Trypouchen vagina, Acanthurus pyroferus, Sillago sihama, Epinephelus ongus, Epinephelus diacanthus, Johnius belangerii, Johnius glaucus, Kathala axillaris, Ambassis gymnocephalus, Cynoglossus macrostomus, Cynoglossus bilineatus, Cynoglossus arel, Arius caelatus, Arius arius, Arius dussumsieri, Arius maculates, Lagocephalus inermis, Ostracion cubicus, Pisodonophis cancrivorus.*

In LMRS, bycatch constituted 7.7% of the total catch. There were 29 species belonging to 22 genera, 16 families and 5 orders. The major families constituting the bycatch in LMRS were Clupeidae, Engraulidae, Carangidae, Stromateidae, Sphyraenidae, Leiognathidae, Trichiuridae, Gobiidae, Acanthuridae, Sillaginidae, Serranidae, Sciaenidae, Scombridae, Exocoetidae, Hemiramphidae and Tetraodontidae. In SMRS, bycatch constituted 34.2 % of the total catch. There were 45species belonging to 26 genera, 19 families and 6 orders. The major families constituting the bycatch were Clupeidae, Engraulidae, Carangidae, Gerreidae, Stromateidae, Lactariidae, Sphyraenidae, Leiognathidae, Trichiuridae, Gobiidae, Sillaginidae, Sciaenidae, Ambassidae, Cynoglossidae, Ariidae, Mugilidae, Hemiramphidae , Tetraodontidae and Ostraciidae.

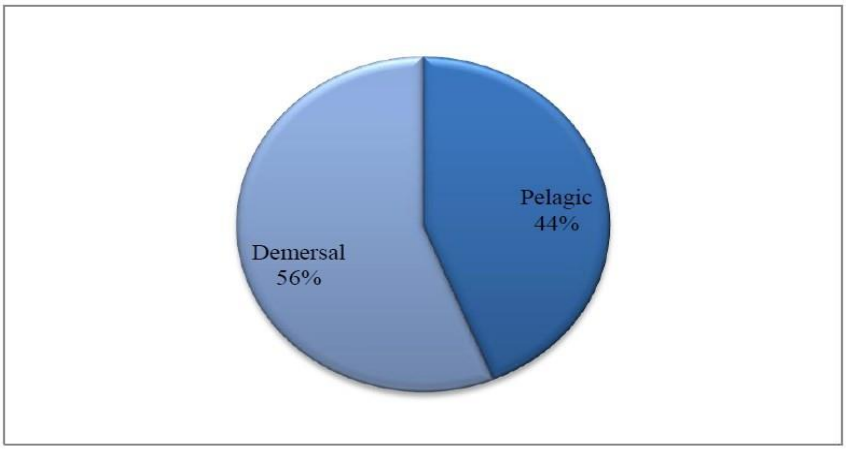

Fig.3. Percentage of demersal and pelagic groups in bycatches of ring seines

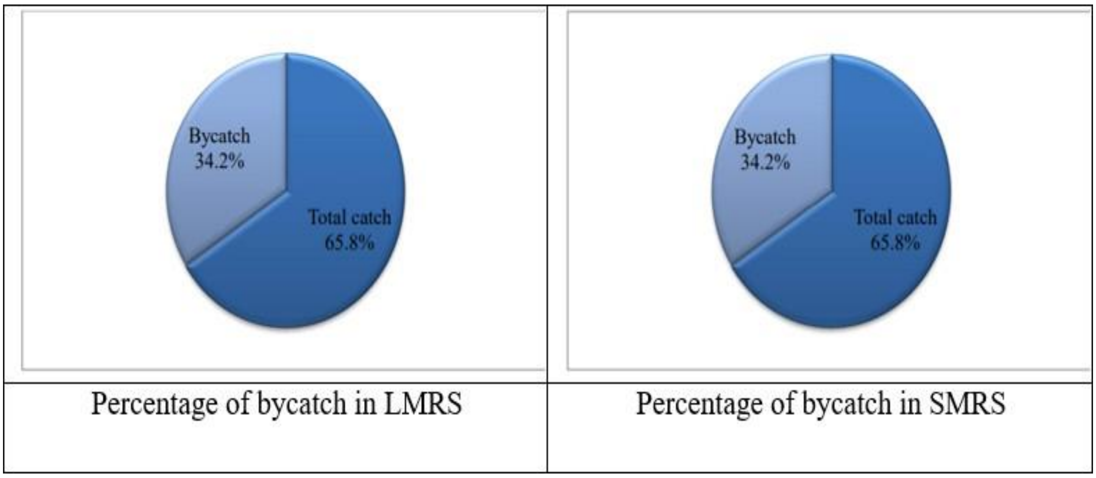

Fig.4. comparison of percentage catch between LMRS and SMRS

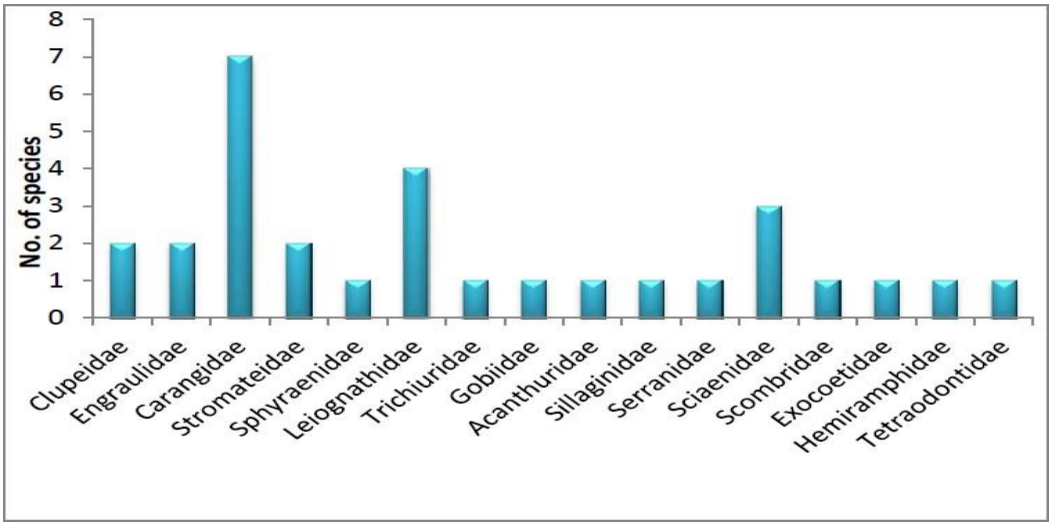

Fig. 5. Number of species in each family in LMRS

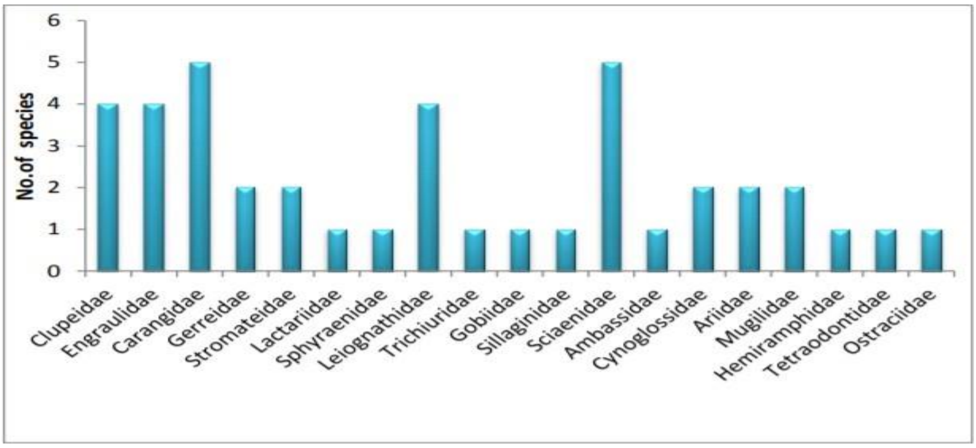

Fig. 6. Number of species in each family in SMRS

Name of Gear	vernacular name	Minimum mesh size (mm)	Type of mesh	Maximum Dimension (hung length and hung depth)
Seine net*				
Sardine/Mackerel seine nets	Chalavala	22	Diamond	600 m X 60 m
Anchovy seine nets	Netholivala	10	Diamond	250 m X 50 m

Table 1. Regulation of size and mesh size of Ring seines

Juveniles fish in ringseine comprises of oil sardine (30%) and mackerel (15%) of the total catch along the Kerala coast. (Najmudeen and Sathiadhas, 2008) Juveniles in choodavala was in the range of 20-33% (Edwin et al., 2010). Large scale occurrence of Juveniles (less than 140 mm) (in numbers landed) in ring seine landings was as high as 90%. (CMFRI, 2013) of Cochin.

A short-term study in 2016 was conducted by ICAR-CIFT on the juvenile incidence in the small mesh ring seine fishery of Chellanam which showed that Sardinella longiceps (oil sardine) was the most dominant species landed. Total juvenile landings from the study were 6.70 t of which oil sardine juveniles formed 76.11% (Gomathi, 2016). According to CMFRI (2017), during the period 2013-2015, the juvenile fish catches of oil sardines in Kerala had an estimated loss of 48 crores.

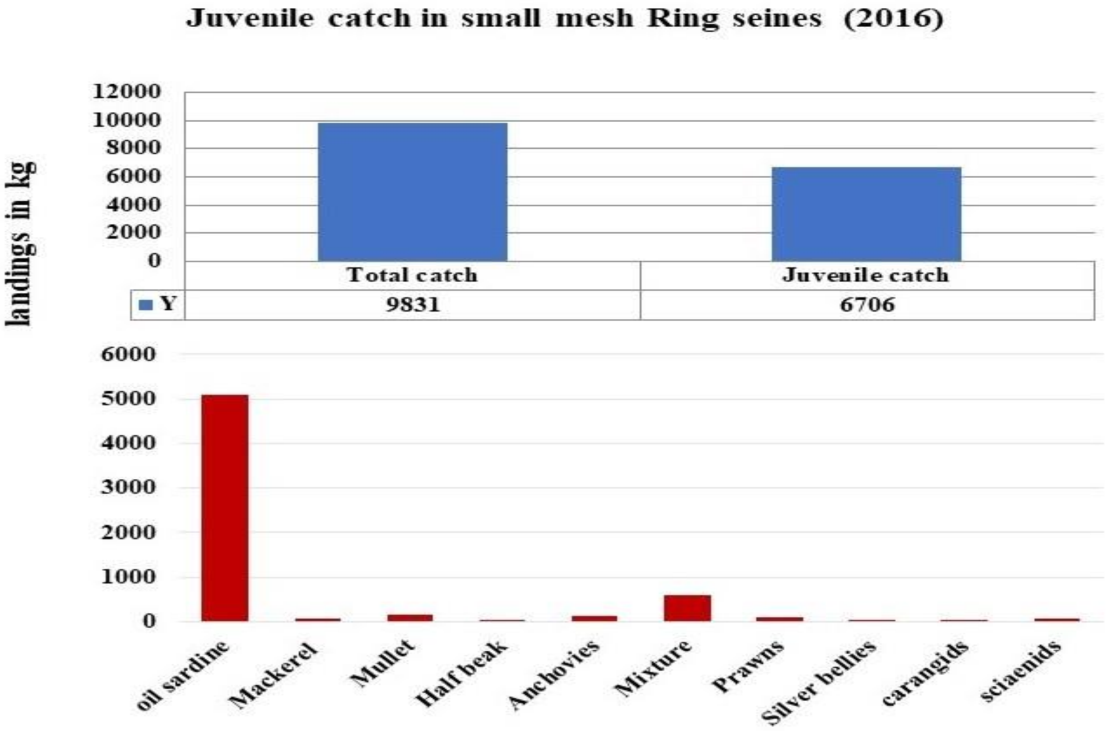

Fig.7. Juvenile landings by individual species: a case study by ICAR-CIFT

Suggested Management measures:

- Mesh size regultion-22mm oil sardine and mackerel (Kurup et al., 2009)
- Anchovy ring seines-12mm (Kurup et al., 2009)
- Identification spawning and nursery ground and imposing seasonal ban on the ring seine units in the identified areas.
- Regulation of size and mesh size of Ring seines

Marine mammal bycatch

Dolphins interaction with fishing gears have been recorded for centuries, however their reported frequency has increased in the recent years. The exact reasons are still unclear (Bearzi, 2002), nevertheless, this might come as a consequence of human population growth and the increasing demand of fish protein for human consumption, which naturally lead to increased fishing and to the gradual depletion of fish stocks across the world's oceans (Pauly et al., 2002). Dolphin interactions can be useful for in seining where the presence of dolphins is used as an indication to detect fish shoal. Most of the reports describe unfavourable effects, i.e. gear damage and catch loss due to cetacean depredation and scattering of fish shoal (Wise et al., 2001).

Incidental catch of finless porpoise, *Neophocaena phocaenoides* are reported from Off Mangalore and Gulf of Mannar regions (Jayaprakash et al., 1995). Dolphins 'caught' in large numbers by a ring seine operating at Cochin Fisheries Harbour, is also reported (Prajith et al., 2014). Silas et al. (1984) reported that 1% of the total landings by fishing gear at Cochin were dolphins. Joseph et al. (2021) reported 15% fishers reported incidental bycatch of cetaceans in seines and gillnets. Cetacean bycatch reported by seines mainly occurred in shallower waters (Joseph et al., 2021).

Compared to the high sea purse seiner, ring seines are lightly constructed purse seines with polyamide multifilament twines. Cetaceans can easily tear the webbing and escape from the gear, even it is accidently entered in the gear. It leads to the partial or total loss of catch and huge economic loss to fishers. Incidentally captured cetaceans in the bunt portion were release alive to avoid further damage to gear and catch. Due to the above mentioned reason, fishers avoid fishing particularly in the areas with severe encounter of cetaceans and rarely fishers harm the animals with spear, stones, crackers etc. to move away from the fishing ground.

Measures:

- Bycatch can be minimised by improvement in the net design appropriate for schools of target fishes, mesh size optimisation, use of aprons and operational procedures.
- Use of dolphin wall net (DWN) on the outer side of the purse seine to reduce the bite of the net by marine mammals has been reported by Prajith et al. (2014).
- Use of acoustic pingers and alarms have also been observed to reduce marine mammal interaction in gears.

Conclusion

There are not many reports of incidental bycatch landings like dolphins and turtles in purse seines operating in Indian waters. Bycatch reduction is not only a technical issue of harvesting technology and biology, but also a human issue involving behavior and decision-making by producers and consumers. Bycatch reduction also occurs within the context of different industrial and regulatory structures of fisheries, which in turn can impact the choice of basic regulatory approach – private solutions, direct regulation, incentive- (market-) based, and hybrid – and then choice of policy instruments. Initial trials of acoustic pingers have been carried out along Kerala coast by ICAR-CIFT and the results are encouraging.

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Fishing Regulations in India

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Introduction

Fisheries play an important role in the global provision of food, directly accounting for at least 15% of the animal protein consumed by humans and indirectly supporting food production by aquaculture and livestock industries. Plateauing of catches from mid 1990s, economic and growth overfishing at several centres, and intersectoral conflicts in the coastal belt have highlighted the need for regulation of fishing capacity, adoption of responsible fishing practices and caution in marine capture fisheries development. Overfishing and fishing down effect is evident in Indian fisheries. Ongoing declines in production of the world's fisheries may have serious ecological and socioeconomic consequences. As a result, a number of international efforts have sought to improve management and prevent overexploitation, while helping to maintain biodiversity and a sustainable food supply.

Fishery laws and regulations enforced by a set of rules to conserve fishes in public waters. Laws support conservation measures and check the injurious methods of fishing. In prehistoric India, people were conscious about conserving natural fishery resource. According to FAO (2009), fisheries management is the integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives. Fisheries production and yield are constrained by a number of factors which can be classified as biological, ecological, environmental, technological, social, cultural, and economic considerations.

Regulation on mesh size of nets, limiting the size of fish limiting the total catch, restriction in modes of fishing, restrictions on time of fishing, licensing and leasing of fishery rights, declaration of sanctuaries, prohibition of anicuts and fixed engines are some common approaches towards management of Fisheries.

International Agreements

Four international agreements emerging out of the endorsement of the Code of Conduct for Responsible Fisheries are relevant in this context for incorporation under the relevant laws/legislation proposed in this regard

i. Agreement for implementation of the provisions of the United Nation Convention on the Law of the Sea of 10 December 1982 relating to the conservation and management of straddling Fish Stock and Highly Migratory fish Stock.
ii. Agreement to promote compliance with International Conservation and Management Measure by Fishing Vessels on the High Seas.
iii. International plan of action to prevent, deter and eliminate, illegal, unreported and unregulated fishing.

iv. International plan of Action for Management of Fishing Capacity, Conservation and Management of Shark, Reducing incidental catch of Sea birds in long line Fishing.

Fisheries Management in the Indian context

Under the Constitution of India, fisheries within the territorial waters, which extend upto a distance of twelve nautical miles from shore, is a state subject and the primary responsibility of its development rests with the state government. The central government is responsible for all fishing activity that takes place beyond this limit- the deep sea or EEZ (exclusive economic zone) that extends up to a distance of 200 nautical miles. The state government has command over the fisheries, which are in the territorial waters of 12 miles, over communities that are dependent on the fisheries in the area and the marine resources in the area.

Indian Fisheries Act, 1897

The need of fisheries legislation was emphasised as long back as in 1873 when the attention of government was drawn to the destruction of fishery resource in the dam and reservoirs. The government then enacted the Indian Fisheries Act which came into being in 1897 and is considered as the mother act of fisheries in India. The act highlighted the conservation aspect and banned use of explosive and poisoning of water which destroy the fish. It enables the provisional government (state) to frame rules in selected waters for protection of fish. After independence the various developmental programmes took place with the creation of the large number of reservoirs, stagnant and running water spreads offering scope for increase in inland production. New techniques were introduced for hatchery production of major fish seeds. The vast change and rapid industrialization created pollution problems affecting the fish life which necessitated the revision of the 1897 Act and for formulating new legislations. The Indian Fisheries Act, 1897 is meant to regulate riverine fisheries and fisheries in inshore waters, to prohibit the use of poisons and dynamite in fishing, and to protect fish resources in selected waters through regulation of, among other things, the erection and use of fixed engines (the reference is to nets, cages, traps, etc.), the construction of weirs, the use of nets of certain types and dimensions, etc.

The Merchant Shipping Act, 1958

An Act to foster the development and ensure the efficient maintenance of an Indian mercantile shipping in a manner best suited to serve the national interests and for that purpose to establish a National Shipping Board to provide for the registration of Indian ships and generally to amend and consolidate the law relating to merchant shipping. The Act was amended in 1983 to provide for registration and control of Indian fishing boats. The Act enables defining a fishing vessel and prescribes registration procedure besides provision for data collection. It applies to fishing boats of 20 m and above, while specifying that the Central government will have the power to declare that boats of less than 20 m shall be required to be registered under The Merchant Shipping Act, 1958.

Indian Wildlife (Protection) Act, 1972

It is under this act that marine protected areas/ sanctuaries are declared. Certain marine species are protected under this Act by listing them in Schedule I of the Act, which prohibited hunting and trading of these species.

The Marine Product Export Development Authority Act, 1972

The MPEDA was established in 1972 under an Act of the Parliament, namely the MPDEA Act, 1972 (Act 13 of 1972), under the Ministry of Commerce, Government of India, when it was felt and declared that it is expedient in the public interest that the union should take under its control the marine products industry for its development.

Code of Conduct for Responsible Fisheries

The code which was unanimously adopted on 31 October 1995 by the FAO Conference provides the required framework for national and international efforts to ensure sustainable exploitation of aquatic living resources in harmony with the environment. In fisheries management, the Code advocates conservation and management measures based on the best scientific evidence available. The Code advocates that countries should have clear and well-organized fishing policies in order to manage their fisheries. It is important that fishing industries at all levels operate within a clear fisheries management and legal framework so that everyone involved in fisheries has a clear understanding of the rules to be followed. The Code also advocate optimum fishing fleet and gear to ensure sustainability and precautionary approach as the guiding principle for fishery management. The regulations should facilitate resolution of conflict among fisheries and also suggest policy measures to facilitate sustainable use of coastal resources and energy in fishing (FAO, 1995).

Steps initiated by India to Implement Responsible Fisheries and Aquaculture

A national level committee was set up in the Department of Animal Husbandry, Dairying and Fisheries for implementation of FAO Code. The Code has been translated into all the regional languages, programmes have been designed to create awareness among the fishermen and fish farmers, recommended to categorize fishing vessels below 20m OAL in the terrestrial waters and deeper zone. A national level committee has revalidated to evaluate existing fisheries potential in the Indian EEZ for future planning and exploitation. Monsoon fishing ban has been imposed in Indian coast for resource conservation and the reduction in the fishing pressure to stimulate rejuvenation of fish stock. The broad objectives of the policies are fisheries in responsible manner and ensure socio-economic security.

The Territorial Waters, Continental Shelf, EEZ and other Maritime Zones Act, 1976

This act recognizes the sovereign rights to conservation and management of living resources in the Indian EEZ, in addition to their exploration and exploitation. Section 15 (c) further gives powers to the Central Government to make rules, *inter alia*, for conservation and management of the living resources of the EEZ, and Section 15 (e), for the protection of the marine environment

The EEZ is a sea zone prescribed by the UN Convention on the Law of the Sea over which a state has special rights over the exploitation and use of marine resources, including energy production from water and wind. The territorial sea extends to 200 nautical miles on the seas around India through enactment of territorial waters, continental shelf, EEZ and other maritime act, 1976. India has acquired exclusive right to exploit the living and non-living resources of this area comprising 2.02 million km^2 and Ministry of Agriculture enacted the Maritime Zones of India (Regulation of Fishing by Foreign Vessel) Act, 1981 to regulate the fishing by foreign vessels in the EEZ of India. Introduction of legislation for wholly Indian owned deep-sea fishing vessels (more than 20 m OAL) operation in EEZ is essential to optimize the catch and share the catch data with research organizations for further analysis to evolve further programmes. Ministry of Agriculture should prepare model legislation and circulate to the state Government and others concerned seeking their comments before its finalization for enactment.

The Indian Maritime Zones Act deals with the prohibition of fishing in maritime zones of India by foreign vessels, grant of licences, prohibition of fishing by Indian citizens using foreign vessels, and cancellation or suspension of licenses or permit. It also deals with foreign vessels entering maritime zones of India without license or permit to stow gear and the power for seizure and contravention. The act permits fishing for scientific research, investigation etc.

According to the maritime zones of India Rules, 1982, every owner of a foreign vessel or any other person described in section 4, who intends to use such vessel for fishing within any maritime zone of India, shall make an application in Form A to the Central Government.

Marine fishing regulations in the coastal states of India

In the marine sector, the fast pace of development of mechanization programmes created conflicts between the traditional, mechanized and deep-sea fishing sectors and such instance were frequently noticed in the coastal waters of many parts of country during the seventies. A committee, appointed by Government of India in 1977 (Majumdar Committee) to study their problems, recommended that the state governments should be advised to enact necessary legislation to enable them to regulate fishing in their respective territorial water as per the constitutional provision. A model bill was prepared and circulated by the Ministry of Agriculture in 1979 based on the recommendation of the above advising the state and union territories to enact suitable marine-fishing regulations.

The Indian Marine Fishing Regulation (IMFR) Act 1980 was the first comprehensive national legislation designed to regulate marine and coastal fishing activities along the Indian coast. IMFRA (1980) was enacted to protect the interests of different sections of people using traditional fishing crafts, to conserve fish, to regulate fishing on a scientific basis and to maintain law and order in the sea. The central government also directed all coastal states to formulate similar acts to regulate mechanised fishing activities along their coastal waters. Today, most of the coastal states have enacted legislations to regulate mechanised fishing.

The regulations concerning Indian Marine Fisheries are:

i. The Indian Fisheries Act, No. IV of 1987, Government of India
ii. The Indian Fisheries Act as adopted and applied by the state of Saurastra, 1897
iii. The Mysore Game and Fish preservation Act 2 of 1901, Government of Mysore

iv. The Game and Fish preservation Regulation Act 12 of 1914, Government of Travancore (1914) (Modified 1921)
v. Cochin Fisheries Act 3 of 1917 (Modified 1921), Government of Cochin
vi. Andaman and Nicobar Island Fisheries Regulation 1 of 1938
vii. The United Province Fisheries Act 45 of 1948
viii. Government of Travancore-Cochin Fisheries Act 34 of 1950
ix. Maharashtra Fisheries Act 1960 (Modified 1962), Government of Maharashtra
x. The Indian Fisheries (Pondicherry Amendment) Act, 18 of 1965
xi. The Indian wild life Act 1972. 21b-The Territorial Waters, Continental Shelf, EEZ and other maritime zone Act, 1972
xii. The Marine Product Export Development Authority Act, 1972
xiii. Maritime zone of India (Regulation of fishing by foreign vessels) Act, 1981
xiv. The Kerala marine fishing regulation Act and Rules, 1980 (Act 10 of 1981)
xv. The Goa Marine Fishing Regulation Act, 1980
xvi. The Maharashtra Marine fishing Regulation Act, 1981, Government of Maharashtra
xvii. The Orissa Marine fishing Regulation Act, 1981, (Orissa Act 10 of 1982) and the Orissa Marine fishing Regulation Rules, 1983
xviii. The Tamil Nadu Marine fishing Regulation Rules, 1983
xix. The Karnataka Marine fishing Regulation Act, 1986
xx. The Andhra Pradesh Marine fishing Regulation Act, 1994
xxi. Lakshadweep Marine Fishing Regulation –Rules, 2000
xxii. The Gujarat Fisheries Act, 2003
xxiii. Andaman and Nicobar Marine Fishing Regulation Act, 2003

All the states regulate the marine fishing activities under these Act while the Gujarat Fisheries Act, besides regulating marine-fishing operation in territorial waters, also regulate fishing in inland waters providing standards for sale of fry and fingerlings, mariculture prohibition of fishing within a radius of 100 m downstream in the river mouth and prohibition of exotic fish introduction, etc.

The marine fishing regulation Act enacted by the states indicate that there is no uniformity in the regulations of fishing and the areas exclusively earmarked for traditional fishing operations varied from 5km from shore in Odisha and Goa, 6 km in Karnataka, 8 km in Andhra Pradesh and 10 km in the case of Gujarat and Kerala (Table 1). Hence there is a need for harmonising a regulation at least with regard to the adjoining states. The implementation of marine fishing regulations poses a greater challenge to the maritime state in the absence of suitable infrastructure and manpower for its enforcement. It is high time that the coastal states revisit the provision of these Acts with a view to incorporate suitable change/additions by amending the Acts to suit the current requirement and for their effective implementation by creating the required enforcement mechanism. The Govt. of Kerala in 2017/18 amended the KMFRA with following points in view.

Based on the model bill, all the maritime states and union territories of Andaman and Nicobar Islands and Lakshadweep Islands enacted the marine fisheries regulation Act (marine fishing regulation in the case of UTs) which mostly provides the provisions given below.

- Restricting the catching of any species of fish for such period of time
- Regulating the mesh size of the fishing vessels
- Licensing and registration of fishing vessels
- Conservation of fishery resource in ecologically sensitive areas
- Punitive action for violations of the Act/Rules.

States	Year Adopted	Area reserved for traditional craft	Area reserved for Mechanized craft (upto 12 nautical miles)
Gujarat	2003	5 nautical miles (nm)	Beyond 5 nm (9km)
Maharashtra	1981	5 fathoms (Mumbai, Raigad, Thane) 10 fathoms (Ratnagiri, Sindhudurg)	
Goa, Daman and Diu	1980	2.6 nm(5 km)	Beyond 2.6 nm (5 km)
Karnataka	1986	3.23 nm (6 km)	Vessels upto 50ft beyond 3.23 nm (6 km) Vessels above 50ft beyond 10.79 (20 km)
Kerala Southern sector (1): Kollengode to Paravoor Pozhikkara Southern sector (2): Pozhikkara to Kovilthottam Northern Sector: Kovilthottam to Manjeswaram	1980	Southern sector (1): upto 25 fathoms Southern sector (2): upto 18 fathoms Northern sector: upto 12 fathoms	Motorized fishing zone Southern sector: area upto 20 fathoms Northern sector: area upto 10 fathoms Mechanized fishing vessels less than 25 GRT Southern sector: upto 35 fathom line Northern sector: upto 20 fathom line
Tamil Nadu	1983	3 nautical miles	Beyond 3 nautical miles
Andhra Pradesh	1994	upto 8 km	*Mech. boats – beyond 8km *20 m OAL and above – beyond 12.4 nm (23 km)
Orissa	1982	2.6 nm (5 km)	* upto 15 mts – beyond 2.6 nm (5 km) *above 15 mts – beyond 5.39 nm (10 km)
West Bengal	1993	Non –mechanized: up to 9 mts – till 4.3 nm (8 km) Non -mechanized above 9 mts – upto 10.7 nm (20 km) but not below 8 km	Mechanized upto 15m – upto 50 kms but not 10.7 nm (20 kms) Mechanized above 15m – beyond 26. 99 (50 kms)

Table.1 Marine Fishing regulation act in different states of India (ICSF, 2022)

Biological Diversity Act, 2002

The objective of the Act is to protect biological diversity and sustainable use of biological resource of India. The Act also encourages conservation and has a provision to declare a fish stock threatened if it is over-exploited.

Coastal Aquaculture Authority Act, 2005

The costal aquaculture authority Act, 2005 (Act 24 of 2005) came on 23 June 2005. The main objective of the authority is to regulate aquaculture activities in coastal area to ensure sustainable development without causing damage to the coastal environment. The authority is empowered with the regulations for the construction and operation of aquaculture farms in coastal areas, inspection of farms for ascertaining their environmental impact, registration of aquaculture farms, removal or demolition of coastal aquaculture farms which cause pollution, etc. Aquaculture Authority established this law, which gives some provisions to prevent construction of shrimp farm in mangrove areas, sensitive area and in agriculture land. Compulsory Environment impact assessment (EIA) for large farms, effluent treatment plant, use of chemical and drugs and licensing and mandatory application of code of conduct.

Other Legislations directly relevant to Marine Fisheries

The Coast Guard Act, 1978 provides for the constitution and regulation of an Armed Force of the Union for ensuring the security of the maritime zones of India with a view to the protection of maritime and other national interests in such zones. Among other things, it provides for safety and protection of islands and offshore structures; protection and preservation of maritime environment and endangered species; prevention and control of pollution in the maritime zones; assistance to fishermen in distress at sea; safeguarding life and property at sea; preventing poaching in Indian waters; assisting in ocean research-related activities; enforcing maritime law; and carrying out other duties as and when assigned by the Government of India, without duplication of efforts.

The Indian Ports Act, 1908 confers the power of administering major ports to the Central Government and lays down rules for safety of shipping and conservation of ports. The Major Port Trusts Act, 1963 specifies that the administration, control and management of major ports lie with the respective Port Trusts.

Section 26A of the Indian Wildlife (Protection) Act, 1972 recognizes the need to protect the occupational interests of fishermen, while declaring a sanctuary in territorial waters. It also specifies that the right of innocent passage of any vessel or boat through the territorial waters shall not be affected in this process.

The Environment Protection Act, 1986 authorizes the Central Government to protect and improve environmental quality, control and reduce pollution from all sources, and prohibit or restrict the setting and/or operation of any industrial facility on environmental grounds. Notably, for the first time, it makes provisions for citizen suits in the lower courts, allowing a citizen to prosecute a polluter by filing a complaint with a Judicial Magistrate Court. Subsequent notifications under the Environment Protection Act, 1986 have also made it mandatory to conduct environmental impact assessments (EIAS) for specified developmental activities and have made public hearings mandatory for all developmental activities that require environmental clearance from the MOEF.

The Majumdar Committee (1976)

The committee was appointed to study the situation regarding conflicts between traditional and modern workers. It proposed the Marine Fishing Regulation Bill, and suggested a seasonal ban on trawlers. The committee suggested the bill should be passed by the Parliament. The Government shifted the responsibility to the state and for state it became a problem because whenever there was a ban it was challenged on the grounds that they were fishing beyond 22 kilometres.

Coastal Zone Management Policies

In addition to these measures in the fisheries sector, the government also planned a series of interventions through the declaration of its Coastal zone management policies. Recognising the economic values of tropical coastal zone biodiversity, the UN Convention on the Law of the Sea (UNCLOS) advised member states to "adopt laws and regulations to prevent, reduce and control pollution of the marine environment including rivers, estuaries and other structures, considering internally agreed rules, standards and procedures. Inspired by this international obligation, the Ministry of Environment and Forests (MoEF) issued a notification in 1991 to regulate economic activities along the Indian coastal zone. The basic objective of the CRZ notification 1991 was to demarcate the coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters, which are influenced by tidal action as Coastal Zone Regulation Zone mainly to protect coastal communities, conserve coastal resources and maintain a balance between development and environmental protection. The Central Government asked Coastal States and Union Territory Administrations to identify the CRZ areas within their respective territories and prepare Coastal Zone Management Plans for the development of these areas. The state shall be responsible for monitoring and enforcement of the provisions of this notification within their respective jurisdictions.

New Deep Sea Fishing Policy (1991)

In March 1991, the Indian government announced NDSP as part of the economic reforms programme. The policy involved three schemes - leasing out of foreign fishing vessels to operate in the Indian EEZ, engaging foreign fishing vessels for test fishing and forming joint ventures between foreign companies and Indian companies on 49:51 equity basis in deep sea fishing, processing and marketing. Government of India started giving licenses to joint venture, lease and test fishing vessels. This was opposed by millions of fishers.

Murari committee (1995)

The committee studied the proposal of the NDSP and the opposition that was made to it. The parliament members from all the political parties were members of the Committee. It came up with 21 recommendations, some of them being:

- No renewal, extension or new licenses be issued in future to joint venture/ charter/ lease/ test fishing vessels.
- The present licenses be cancelled as per going through the legal procedures,

- Upgrade the skill of the fishing community to equip them with exploiting the deep sea resources,
- Stop pollutions,
- Supply of fuel at subsidised rate,
- Fishing regulations in the entire EEZ,
- A separate ministry to deal with the entire fisheries,
- Monsoon trawl ban.
- The area already being exploited or which may be exploited in the medium term by fishermen operating traditional craft or mechanized vessels below 20m size should not be permitted for exploitation by any vessels above 20m length except currently operated Indian vessels which may operate in the current areas for only three years.

The Central Cabinet, GOI, had accepted all the recommendations in the committee on 28th of September 1997. The Minister of Food Processing Industry nominated a small committee from the National Fisheries Action Committee against Foreign Fishing Vessels to oversee the implementation of Murari Committee recommendations. The committee met several times and worked together with the Food Processing Ministry and transferred the Deep Sea Fishing from the Ministry of Food Processing to the Ministry of Animal Husbandry. Since then, the Ministry of Animal Husbandry never called the committee who was indeed responsible for the transfer. Now the Ministry of Animal Husbandry is not implementing the Murari Committee recommendations, but has started giving new licenses and importing fish like Bombay ducks, sardines and mackerels.

National Environment Policy 2004

The National Environment Policy (NEP, 2004) is intended to be a guide to action: in regulatory reform, programmes and projects for environmental conservation; and review and enactment of legislation, by agencies of the central, state, and local governments. It also seeks to stimulate partnerships of different stakeholders, i.e. public agencies, local communities, the investment community, and international development partners, in harnessing their respective resources and strengths for environmental management. On the whole, it is expected to do better than fiscal neutrality, and likely raise substantial resources from outside the fiscal regime to realize its objectives. The principal objectives of NEP 2004 are Conservation of Critical Environmental Resources; Intra-generational Equity; Livelihood Security for the Poor; Inter-generational Equity; Integration of Environmental Concerns in Economic and Social Development; Efficiency in Environmental Resource Use; Environmental Governance and Enhancement of Resources for Environmental Conservation.

The Marine Fishing Policy, 2004

The Marine Fishing Policy seeks to bring the traditional and coastal fishermen in to the focus together with stakeholders in the deep-sea sector so as to achieve harmonized development of marine fishery both in the territorial and extra territorial waters of our country.

The policy objectives are: (1) to augment marine fish production of the country up to the sustainable level in a responsible manner so as to boost export of sea food from the country and also to increase per capita fish protein intake of the masses, (2) to ensure socio-economic security of the artisan fishermen whose livelihood solely depends on this vocation. (3) to ensure sustainable development of marine fisheries with due concern for ecological integrity and bio–diversity.

Coastal Aquaculture Authority Act, 2005

The costal aquaculture authority Act, 2005 (Act 24 of 2005) came on 23 June 2005. Main objective - To regulate aquaculture activities in coastal area to ensure sustainable development without causing damage to the coastal environment.

The authority is empowered with the regulations for the construction and operation of aquaculture farms in coastal areas, inspection of farms, ascertaining their environmental impact, registration of aquaculture farms, removal or demolition of coastal aquaculture farms which cause pollution, etc.

Coastal Regulation Zone Notification, 2011

The Ministry of Environment and Forests had issued the Coastal Regulation Zone (CRZ) Notification on 19.2.1991 under the Environment (Protection) Act, 1986, with the aim to provide comprehensive measures for the protection and conservation of our coastal environment.

Main objectives:

- To ensure livelihood security to the fishing communities and other local communities living in the coastal areas;
- To conserve and protect coastal stretches and;
- To promote development in a sustainable manner based on scientific principles, taking into account the dangers of natural hazards in the coastal areas and sea level rise due to global warming.

Blue Revolution - Neel Kranti Mission (2014)

The Government of India in December, 2014 had launched 'Blue Revolution' Mission with a central outlay of Rs. 3000 crores. The Scheme aimed with a focus of an integrated approach for the development and management of fisheries covering both the marine and inland fisheries to ensure a sustained annual growth rate of 6% to 8% in fish production. It was also aimed to increase fish production and productivity by utilizing the fisheries resources judiciously, and also doubling income of fishers and fish farmers in these five years. The scheme adopted the strategy of encouraging private investment, entrepreneurship development and better leveraging of institutional finance. Skill development and capacity building in fisheries and allied activities and creation of post-harvest and cold chain infrastructure facilities are the channels of achieving the targets. The scheme was implemented from 2015-16 to 2019-20. The salient features of BR scheme and achievements made are given below:

- To tap the total fish potential of India on both inland as well as in the marine sector and to triple the production by the year 2020.
- Transforming the fisheries sector into a modern industry through the utilization of new technologies and processes.

- Doubling the income of the fishers through increased productivity and improving the post-harvest marketing infrastructure including e-commerce, technologies, and global best innovators.
- To ensure the active participation of the fishers and the fish farmers in income enhancement.
- Developing the nutritional and food security of the nation.

Salient Features of the Blue Revolution Scheme:

- Providing suitable linkages and convergence with the 'Sagarmala Project' of the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNAREGA), Ministry of Shipping, National Rural Livelihoods Mission (NRLM), Rashtriya Krishi Vikas Yojana (RKVY), etc.
- The Blue Revolution scheme concentrates mainly on enhancing the production and productivity of aquaculture and fisheries both from the inland and marine sources.
- Promoting and encouraging the economically backward sections like the Scheduled Castes, Scheduled Tribes, Women, and their co-operatives to take up fishing.
- The Blue Revolution Scheme encouraged entrepreneurship development, private investment and better leveraging of institutional finance.

National Policy on Marine Fisheries, 2017

The overarching goal of the National Policy on Marine Fisheries, 2017 (NPMF, 2017) is to ensure the health and ecological integrity of the marine living resources of India's Exclusive Economic Zone (EEZ) through sustainable harvests for the benefit of present and future generations of the nation. The overall strategy of the NPMF, 2017 is based on seven pillars, namely sustainable development, socio-economic upliftment of fishers, principle of subsidiarity, partnership, inter-generational equity, gender justice and precautionary approach.

Areas dealt with,

- Marine Fisheries Sector of India – A Profile
- Fisheries Management
- Monitoring, Control and Surveillance
- Fisheries Data and Research
- Mariculture
- Island Fisheries
- Post-harvest and Processing
- Trade
- Marine Environment and Pollution
- Climate Change (Adaptation and new initiatives)
- Fisher Welfare, Social Security Nets and Institutional Credits
- Gender Equity
- Additional/Alternate Livelihoods
- Blue Growth Initiative
- International Agreements/Arrangements

- Regional Cooperation
- Governance and Institutional Aspects

National Fishery Policy, 2020

The National Fisheries Policy 2020 would offer a strategized way forward to develop, harness, manage and regulate capture and culture fisheries in a responsible and sustainable manner. The Policy will ensure a productive integration with other economic sectors, such as agriculture, coastal area development and eco-tourism, to meet the goals of the 'Blue Economy'. Whilecenter-state and inter-state cooperation, socio-economic up-liftmen and economic prosperity of fishers and fish farmers' especially traditional and small-scale fisheries are at the core of the Policy. The Policy mirrors national aspirations and the developmental goals set before the nation.

- Center will encourage and empower traditional and small-scale fisher and fisher groups for undertaking resource specific deep sea fishing.
- Untapped potential of high value resources like tuna, tuna-like species, myctophids and oceanic squids should be tapped in a sustainable manner with a precautionary approach in line with the global standards regarding wild fish harvests.
- Deep-sea Fisheries resources are to be exploited by an optimum fleet size of modern fishing vessels capable of undertaking extended voyages, infusion of modern technology and capacity building.

Pradhan Mantri Matsya Sampada Yojana (PMMSY)

The Pradhan Mantri Matsya Sampada Yojana (PMMSY) is a flagship scheme for focused and sustainable development of fisheries sector in the country with an estimated investment of Rs. 20,050 crores for its implementation during a period of 5 years from FY 2020-21 to FY 2024-25 in all States/Union Territories, as a part of Aatma Nirbhar Bharat Package. The investment of Rs. 20,050 crores under PMMSY is the highest ever in the fisheries sector. Out of this, an investment of about Rs 12340 crores is proposed for beneficiary-oriented activities in Marine, Inland fisheries and Aquaculture and about Rs 7710 crores investment for Fisheries Infrastructure.

PMMSY aims at enhancing fish production by an additional 70 lakh tonne by 2024-25, increasing fisheries export earnings to Rs.1,00,000 crore by 2024-25, doubling of incomes of fishers and fish farmers, reducing post-harvest losses from 20-25% to about 10% and generation of additional 55 lakhs direct and indirect gainful employment opportunities in fisheries sector and allied activities.

Informal management systems

The most effective way to solve the problem is to allocate rights to stakeholders. Traditional fishing communities should be given the right to fishing. Management of fisheries should be entirely in the hand of the communities, with governments serving only as technical advisors, if needed by the communities. People who press for nationalisation of fisheries subscribe to the Tragedy of the Commons argument to defend their stand. However, it is important to realise that Hardin Actually meant the tragedy of the collective- when there is no specified set of users or use rules that govern the management of the resource, where entry is free and open to all, without any accountability. Community managed systems on the other hand, have a defined set of users and have in place intricate rules, norms and sanctions that govern use, entry and conflict resolution. There are already many informal community management schemes that are in place in many parts of India.

Conclusion

The strategies or development programmes to face various difficult situations ultimately for the general welfare of multiple stakeholders in fisheries sector should bear a participatory co-management approach. Since the sector thrives significantly on the natural ecosystem is very dynamic and hence policies and strategies requires flexibility. Alterations and evolutions of policies depend upon the developments in the national and international scenario. In terms of production and marketing, uncertainty is comparatively high in marine fisheries production. Hence continuous monitoring of production, supply and demand is a pre-requisite for evolving appropriate policy decisions.

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Trawling: types and methods

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Introduction

Bottom or demersal trawling continues to be one of the most important fishing methods of the world.In Indiamore than 35,230 trawlers of various sizes ranging from 9 to 24 m LOA with engine power ranging from 45 to 450 hp @ 2000 rpm are in operation. Trawl is a bag net towed through water to filter out fishes, the mouth of which is kept open horizontally by means of a beam or otter boards and vertically by means of floats, kite and sinkers. Horizontal mouth opening is also affected by dragging the net from two boats known as bull trawling or pair trawling. The main principle of trawling is the movement of the net under water filtering the water through the mesh in the netting, without either permitting the fish to escape or gilling them. Trawl net is fabricated using polyethylene netting after cutting and shaping the panels as per the design

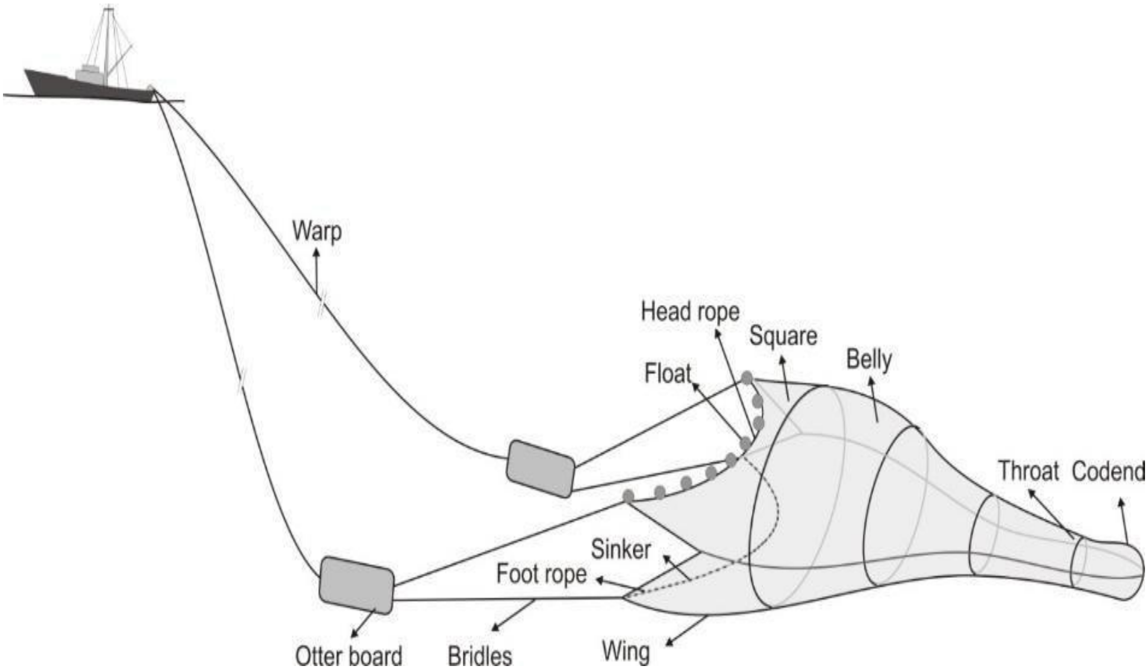

Fig.1. A demersal trawl in operation

In India, trawling was first attempted during exploratory surveys conducted from S.T. Premier off Bombay coast in 1902. Several designs of demersal trawls have been introduced in Indian fisheries in subsequent years.

The most important issue in this sector is the excess capacity in terms of number of trawlers. The size of the trawlers has also increased over the years. Since the in introduction of Chinese engines in the Indian waters, the horse power of the vessel has also increased tremendously and as a result of these changes there is a tough competition out at sea within and between the sectors, which is leading to overexploitation of the resources.

Classification of trawls

Trawls are classified based on the device used for mouth opening, number of panels used for fabrication, depth of operation and based on target species.

1. Beam trawl

Beam trawl was the forerunner of all trawl gears. In beam trawls, mouth of the net is kept open using a rigid and curved metal frame with a shoe at the bottom known as beam. This is the simplest method of bottom trawling practiced mainly in the North Sea for flatfish and shrimps. Since the shoe penetrates the seabed and the marks remains for a long period, beam trawling adversely affects bottom ecosystem. Due to the plowing effect, resistance is high resulting in more fuel consumption than otter trawling. Moreover, a large net requires a large beam which is very difficult to safely handle onboard a fishing boat.

2. Otter trawl

In otter trawls, the most popular method of trawling, the mouth opening of the net is achieved by the attachment of two otter boards, through bridles, on each side of the net. The towing warps are attached to these boards at an angle, so that while towing the water force acting on them tends to diverge them resulting in the opening of the net mouth.

3. Pair trawls

In pair trawling or bull trawling the net is towed by two boats cruising on a pre-arranged parallel course and speed. The distance between the two boats is also maintained constant, so that the diverging warps keep the mouth of the net open. Main advantage of this method is that a much larger net can be used, as two boats are engaged. As the vessels are operated from a distance from each other scaring effect due to vessel noise is also minimal. Pair trawling is banned in many countries as it generates huge quantity of bycatch.

Trawl types based on number of panels:

Two seam nets have only two major part i.e., upper and lower panels and these two are seamed together laterally to form the two seams. The upper part invariably includes the overhang or square. Cross section of the net is elliptical in shape and since the vertical opening is comparatively less, these nets were mainly operated for shrimps. Presently all the trawls are two seem.

Four seam nets are having upper, lower and two side panels with or without overhang. Cross section of the net is rectangular in shape and hence the vertical opening of the trawl may be influenced by the width of the side panels.

Six seam nets have six panels and cross section of the net generally acquires oval shape. The six and eight seam nets are designed to have more vertical opening and hence suitable for catching fishes.

Design of trawls

The efficiency of a trawl mainly depends on the symmetry of construction of the body and mouth configuration. A trawl is designed in such a way that (i) it offers minimum resistance during tow (ii) total drag matches available towing force of the trawler, (iii) it achieves maximum mouth opening, and (iv) offers least hindrance to the movement of fish within the net towards the codend. While designing a new gear, different factors have to be taken into consideration such as strength and elasticity of webbing, resistance to the water flow, weight and bulk, speed of operation, cost of materials and conditions of fishing ground. A selective, environment friendly and energy efficient trawl system is generally the aim in design process. Important design considerations in the design of trawl gear involve biological and behavioural characteristics of the target species; fishing conditions in the trawling ground where the system is to be used; and characteristics of the fishing vessel from which the gear is to be operated. Length of the trawl is measured along the lastridges (side lines) from wing (jib) end to tip of codend and it varies from 1.1 to 1.5 times the head rope length. Right size of a trawl for a particular vessel can be selected according to the total twine surface area or by comparison with a trawl of the same type used by a vessel in the same horse power. Design drawing of the trawl net is prepared to provide all information relating to the size, shape, material and construction using recognized nomenclature and symbols, prior to the fabrication of the net.

Trawling operation

Demersal trawls can be operated from a few meters to more than around 1000 meters in the sea. The demersal trawl is designed and rigged to have bottom contact during fishing and is, depending on the bottom substrate equipped with different kinds of ground rope rigging. This is for the purpose of shielding lower leading margin of the trawl from ground damage whilst maintaining ground contact and easy move on the bottom. The trawlers must have sufficient towing force for towing the gear and require a winch or mechanical hauling system. However, in some small-scale operations hauling is done manually. The methods adopted for demersal trawling are beam trawling, side trawling, stern trawling, double rig trawling, bull trawling and multi-rig trawling. Stern otter trawling is the most popular method in India.

1. Beam trawling:

On arrival at the fishing ground, the beam trawls are hoisted on the booms which are then swung out. The operation is undertaken while the fishing vessel sails on a straight course. When hauling, the net is heaved in until it is at the boom tips. The cod end is taken by the line attached to the cod end strap and the catch is emptied out directly.

2. Otter trawling:

The Vigneron-Dahl system was introduced during 1920s where the otter boards were attached to the wings by means of sweep lines and bridles. This helped in increasing the effective swept area and thus increased the catch due to the herding effect of sweep lines and otter boards. In larger trawls, in addition to the weight on the foot rope, iron bobbins or rubber discs are attached depending upon the nature of fishing ground. The towing warps are provided with markers at distinct intervals for facilitating the release warp, in small-scale operations. In large scale operations it is hydraulically or electrically controlled with metering arrangements. The length of warp released in bottom trawling depends on the depth of the fishing ground and nature of sea bottom. The ratio of depth of fishing ground and the warp released is known as scope ratio or in other words, it is the warp-length ratio. The length of warp to be released is generally (i)

5-6 times the depth in shallow waters below 50 m, (ii) 4-5 times the depth in off shore waters of 50-100 m, (iii) 3- 4 times the depth in deep waters of 100-200 m and (v) 2-3 times the depth in deep sea of 200 m and more The speed at which the trawl is towed over the bottom range from about 2 to 2.5 knots for slow swimming species to 3- 4½ knots for fast swimming fish. Towing a particular trawl too slowly may cause the otter boards to close together, providing insufficient spreading power to the net which tends to sag on to the bottom. Towing too fast may result in the net lifting off the bottom and floating which may lead to fouling of gear. Winches are used to pay out and haul the warps. The winches have two drums, one for each of the two warps; an additional drum is provided for operation of try net in shrimp trawling. In larger trawlers, single drum split winches are used for each of the warps. Hauling speeds could vary from 30 to 60 m.min-1. Stern ramps are provided in larger stern trawlers, which facilitate the shooting and hauling up of the large trawl gear with less manpower. In large trawlers net drums are used to haul up, pay out and store the sweeps, bridles and net with its rigging. The factors such as (i) availability of fish (by using echo-sounders, fishery charts and fishery forecasts), (ii) depth and nature of sea bottom of the fishing ground, (iii) current and wind speeds are to be taken into consideration before the commencement of fishing operation. On reaching the ground the warps are attached to the net and the codend is closed properly. The codend is the first part to be released, followed by the main body of the net. The vessel steams forward slowly releasing the net and the otter boards. The winch is stopped after releasing few meters of the warp to ensure the proper spreading of the bridles and otter boards. The gear is then lowered to the desired fishing depth by releasing sufficient length of warp. The net is dragged for a duration of about 1 to 4 hours, depending on the concentration of catch. The net is hauled by heaving in the trawl warps evenly on to the winch drums, until the otter boards reach the gallows. Sweeps and bridles are then hauled up followed by the main body of the net and finally the codend. In small trawlers, the sweeps and the net are shot and hauled in manually and sweeps may remain connected to the otter boards. In large trawlers, a Kelley‘s eye, independent wire and back-strop is used for facilitating the hauling of the sweep lines and net on to the net drum after the otter boards have reached the gallows.

Conservation Strategies

Large mesh trawls: In these trawls, the front trawl sections are made using large mesh panels which results in reduction of trawl resistance. The reduced drag permits greater trawling speed and operation of a large trawl with the available installed engine power. Trawls with a mesh size up to 5 m is now under operation in Kerala. Such trawl uses only 3 large floats for lifting the head line.

Rope trawl: In rope trawl, the front trawl sections are replaced by ropes, which as in the case of large mesh demersal trawl, results in reduction of trawl resistance with the same advantages as in large mesh trawls. Finfishes are retained due to the herding effect of the ropes.

High opening trawls: High opening demersal trawls are designed to harvest off bottom fishes, which are beyond the reach of conventional demersal trawls, along with bottom resources. It has been reported that the large mesh high opening trawls offer 18% lesser resistance compared to conventional bottom trawls which in turn results in utilization of lesser horse power.

High Speed Demersal Trawls: Commercial exploitation of active fishes with low population density fishery resources requires high speed trawling. High speed demersal trawls (HSDTs) have been developed with light material, large meshes, smooth tapering along the belly facilitating even distribution of stress along the framing and strengthening ropes facilitating smooth filtration and herding.

Bulged belly trawl: In the bulged belly design, wide side panels are provided to increase the vertical opening, and at the same time tapering of the belly is streamlined so as to improve herding and filtration efficiency. The improved bulged belly trawl fitted with tapering jibs consistently landed better shrimp catches. Technological Strategies Increasing awareness on responsible fishing methods has resulted in studies to improve the selectivity of the trawls. Size selectivity in bottom trawls can be achieved by controlling the mesh size and shape. Species selectivity can be achieved using separator panels and grids by making use of the behavioural differences in species in the fishing area.

Separator trawls: It is designed to separate shrimp from fishes based on the difference in their swimming behaviour. Insertion of a horizontal panel in the separator trawl, separates the fish and shrimp catch, leading them to separate codends. The selection process of this device is based on the fact that shrimps which are usually distributed close to the bottom move to the lower codend while the high swimming species usually end up in the upper codend. Separator trawls reduce the sorting time, as the catch is landed in a pre-sorted condition.

Short body shrimp trawl: CIFT has developed and successfully field tested a 27 m shrimp trawl with relatively short body and large horizontal spread suitable for selective retention of shrimp. The width and length of the trawl funnel has been reduced by increasing the tapering ratio and the vertical opening of the mouth has been reduced to eliminate bycatch. Because of the larger horizontal spread of the mouth the effective sweep area is more, which is the most vital requirement for a shrimp trawl. Trials carried out along the coastal waters off Cochin with a prototype of short body shrimp trawl reveals considerable reduction in the catch fish due to the behavioral difference of the targeted species.

Cut-away top belly shrimp trawl: A shrimp trawl without top belly has been developed and field test at CIFT. Results reveal that considerable reduction in the quantity of bycatch landed. The net was able to cover more area within the stipulated speed and time due to reduced drag.

Semi-pelagic trawls: 27m four panel CIFT-SPTS in combination with high aspect ratio Suberkrub otterboards weighing 85kg each with front weights is designed to catch fishes, which are up to 4 m above the ground, with minimum impact to the sea bottom.

Krill trawl: Krill (*Euphausia superba*) is a small crustacean found in the Antarctic waters of the Southern Ocean. Large trawls with small mesh inner lining is operated in Antarctic waters for krill fishing.

Mesopelagic trawls: Mesopelagics are small fishes in the size range of 3 to 30 cm inhabiting the disphotic oxygen minimum zone in world oceans in the depth range of 200 to 1000 m. Large trawls are used in Oman and South Africa for commercially harvesting mesopelagics mainly for making fishmeal and fish oil.

Environmental impact of bottom trawling

Bottom otter trawls interact physically with the bottom sediment, which might result in removal or damage of sedentary living organisms (including seaweed or coral) and in the case of uneven bottom surface displacement of stones or other larger objects. On flat sandy/muddy bottom the sediments might be whirled up into the water masses and suspended. The short and long-term impact on the bottom environment is still poorly documented. The major negative impact of bottom trawling is the capture and discarding of huge quantity of juveniles of fishes and other aquatic organisms.

Conclusion

Trawls are non-selective fishing gears creating plowing effect on the sea bottom leading to the destruction of benthic ecosystem. In trawl design and improvement, the aim should be to produce a trawl system which can selectively and efficiently catch the target fish, eliminating juveniles and other aquatic organisms with minimum environmental impacts. Since trawling is an energy intensive fishing method, development of low drag trawl systems to save energy and cost of operation is imperative. Resource specific trawls like semi-pelagic trawls should be popularized to minimize the impact on ecosystem. Excess capacity in terms of number of trawlers, size, engine power and trawl efficiency are major issues which needs to be addressed to make the trawling economical and sustainable.

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Bycatch issues in the inland capture fisheries of India

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Introduction

Total world inland capture fish production was 11.63mmt in 2016 and China was the leading nation followed by India with 1.46 mmt. Inland waters include freshwater and brackish water bodies in the form of rivers, reservoirs, lakes, backwaters, mangroves, estuaries, tanks, ponds, paddy fields, wetlands, etc. India has vast inland resources in the form of rivers and canals, 1,97,024 km; reservoirs,3.15 million ha; ponds and tanks, 2.35 million ha; oxbow lakes and derelict waters, 1.3 million ha; brackish water, 1.24 million ha and estuaries, 0.29 million ha. Inland water bodies include fresh water and brackish water areas. The river systems of the country are classified into five groups namely Ganga, Brahmaputra, Indus, Peninsular east coast river systems and west coast river systems. It comprises of 14 major rivers, 44 medium rivers and several small rivers and streams.

Fishery resources include 2546 species so far listed 73 (3.32%) belong to the cold freshwater, 544 (24.73%) to the warm fresh waters, 143 (6.50%) to the brackish waters and 1440 (65.45%) to the marine ecosystem. Lakhs of people are engaged fishing and allied activities and earn their livelihood from the inland waters in our country. Currently these water bodies are under stress due to dam construction, siltation, pollution, land reclamation, water abstraction, etc., which adversely affected the fish production and fishery collapsed in several water bodies. Ganga action plan launched in 1986 with the main objective of pollution abatement, to improve the water quality by treatment of domestic sewage and industrial chemical wastes is a glaring example. Excess capacity and destructive fishing practices are other major reasons for declining fishery resources in inland waters.

Fig. 1. Chilika Lake

Chilika lake

Since the capture fish production from the marine waters are declining inland sector is in the focus. Further aquaculture activities, especially shrimp and carp farming are taken up in a big to meet the increasing demand for fish.

Fig.2. Pulicat Lake

Pulicat lake

Among the native fauna most of the fishes are permanent dwellers and others are migrant species coming from the marine or fresh water bodies. Most of the fishes are native species and others are exotic which are accidentally or otherwise introduced into the system. Exotic species are harmful to the native fauna. Occurrence of African catfish in the inland water bodies is a good example. Immediately after the flood in Kerala fishermen had good catch of several exotic fishes like paccu, gourami and arapaima.

Fishing craft

Variety of fishing craft are in operation in the inland waters, which include a piece of log or an inflated rubber tube to motorized FRP boats, depending on the type of fishing and nature of water body. In reservoirs bamboo raft, coracles and inflated tubes are common. In larger water bodies like Pulicat lake catamarams are used for cast netting and motorized FRP canoes are used for seine netting. In Chilika lake sail is used for wind assisted navigation in wooden canoes.

Raft

Bamboo poles are tied together with help of rope keeping all the lower end of the trunk towards the stern side. These rafts are about 6-10 m in length and 1.5 to 5.0 m wide. It is operated with the help of bamboo poles or oars in the sluggish rivers, floodplain lakes and in some reservoirs.

The life span of this raft is about 1 to 2 years. Wooden raft and banana rafts are also made in some areas.

Fig.3. Green mussel seeds collected from the sea is introduced into estuarine zones of rivers in Kerala for on bottom farming

Coracles

Coracles (Fig. 5 and 6) are primitive, light, bowl-shaped boats with a frame of woven grasses, reeds, bamboo or saplings covered with sheets. Coracles are mainly used in reservoirs and backwaters in the southern regions of the country. Coracles are about 2-2.5 m in diameter with the greatest diameter across the centre. The bottoms of the boats are covered with few layers of plastic gunny bags or with plastic sheets and is tarred to make it waterproof. coracles are steered and propelled using a single paddle.

Fig.4. Coracle of a migrant fishermen family from Karnataka

Canoes

Dugout canoes are mainly made from a single large log by scooping out the wood with the help of a small hand spade. The length of this boat ranges from 4 to 8 m. In shallow water bodies it is operated either by a bamboo pole or by an oar by 2 to 3 persons. Fishing gears like traps, gill nets and hook and lines are operated from this canoe. Plank built canoes are predominantly used in rivers and reservoirs. They are of different types and vary widely in size and shape depending on where they are used and the type of fishing to be carried out. These types of canoe are operated by oar and in case of shallow water bamboo poles are also used. Sometimes canoes are provided with arch-shaped roofing made of bamboo mat or polythene sheet which provide shelter to the fishermen. Coat tar, indigenous preservatives and FRP sheathing is used in canoes to extend the life. FRP canoes are also used for fishing in the inland waters. Its smooth finish and light weight enables the fishermen to maneuver easily in the river.

Fishing gears

Diversity of fishing gears are more in inland waters than in the sea. Hook and line, cast net, traps, drag nets, gill nets and seine nets are the most popular gears. Hand picking and other primitive tools like spears and arrows are still in use in some pockets. Nylon monofilaments gillnets are the most predominant fishing gear across the sector. Fish traps are usually made of natural biodegradable materials, whereas all kinds of nets are made synthetic materials. Proliferation non selective fishing gears like small mesh gillnets, seines and stationary bag nets is a major concern in most of the water bodies.

Seine nets are roughly rectangular in shape without a distinct bag and are set vertically in water; to surround the school of fish generally pelagic. Shore seine is a large net operated near the bank of a river, reservoirs or beels. The net usually has two wings and a middle landing part. The net is payed in the form of an arc from the shore using a boat and a number of fishermen pulls the net from the shore. The foot rope of the net always touches the bottom and the net is pulled towards the shore and the fishes are collected from shore. Do-Dandi of Ganga river, Bori of Gujarat and Gorubale of Karnataka and Pattuvala or Chavittu vala of Kerala. Tana jaal, Ghayala jaal, Raja-rani jaal,Gheesa jaal, Ber jaal, Chati jaal, Ghon jaal, Moshori jaal, Fesi jaal, and Pet-kasi jaal operated in the north eastern regions are some shore seine nets of the country.

Boat seines are also operated in inland water bodies. Its construction is similar to the bag net and is operated from boats. The net is released from one or two boats to form an arc. After encircling the fish, the net is hauled from the boat. Buro jaal and Koni jaal are single boat seines operated in backwaters of West Bengal. Pesi jaal is another small boat seine. operated in Assam. Patua-jaal is a boat seine operated in Chilika lake for small clupeids and beloniforms.

Stow nets are conical bag nets operated in shallow waters and estuaries where tidal current is strong. The mouth of the net is kept open against the current by means of stakes driven into the bottom. Examples are Oonnivala operated in backwaters of Kerala, Behundi jaal of Hooghly estuary Gunja jaal operated in creeks of Kutch region of Gujarat and Gidasavala operated in Krishna and Godavari delta of Andhra Pradesh.

Stow net is a bag net conical in shape similar to a trawl net. It is known by different names in different regions. The mouth of the net is fastened to the opposite river banks against the current using ropes or wire ropes. The upper edge of the net mouth is kept open with the help of bamboo poles fixed at both ends of the wing and near the mouth region of the net. The fishes are collected in the cod end as the current of water takes the fish inside the net. These nets are used only when there is sufficient flow of water. Baghjaal and Bion jaal of Assam are examples of stow nets.

Push nets are operated in shallow water bodies. It has a 'V' shaped bamboo frame to which the webbing is attached. The net is pushed through water by man wading and during operation it scraps the bottom. It is hauled at frequent intervals. Some scoop nets have a cod end to facilitate collection of catch. The net is also operated from boats. Pelni of Narmada, kamjaal and kursung jaal of Assam, Schiki of Hoogly and Kuppu valai of Tamil Nadu are some examples.

Stick held drag net is operated in Orissa, Madhya Pradesh, Andhra Pradesh and Kerala. Mesh size of the gear ranges from 10-15mm. Webbing is fixed to bamboo stick of 70cm to 90cm length at regular intervals to form a pouch. The net is dragged by two persons in shallow areas which are devoid of bottom obstruction. While hauling the net fishes are driven into the net from both sides by splashing water with one hand. A drag net thandevala with two poles on either side of the rectangular mouth are operated in backwaters of Kerala.

Scoop net or small bag nets with rectangular mouth or circular mouth with frame used to scoop fish out of water. Net is operated in beels, backwaters and other inland water bodies. Vadivala and koruvala of Kerala Bachra jaal and hatjaal of Assam are some examples Trawl fishing has been carried out on experimental basis in reservoirs and rivers. Otter trawling has been tried in Hoogly estuary, Hirakud reservoir, and in Gandhisagar reservoir. Operations of mini trawl in Kerala has been recommended as an active fishing method in reservoir for the control / capture / elimination of cat fishes, uneconomical fishes and trash fishes. It is not recommended in rivers.

Hand operated dredges (kuthi vaaral) are used in backwaters in Kerala to harvest clams. The dredge is made of slightly inwardly curved horizontal plate of about 50 cm length having about 40 spikes pointing downward at the lower edge of the plate. To this curved plate an arch shaped bamboo frame of about 30 cm height at the center is attached. A small bag net of about 50 cm length is attached to this frame. The net and the dredge are attached to a wooden pole of approximately 10 m length. The dredges are operated by two or more fishermen using two canoes.

Lift net is a sheet of net, usually square, but may sometimes be conical, is stretched either by everal rods, ropes, or a frame. The fishing principle is to keep the net submerged for an interval of time and then pull it rapidly out of water so as to catch any fish, which happen to be over it. A variety of nets, employing the above principle of fishing, are operated in inland water bodies. A lure and lift net techniques is practiced in Tamil Nadu.

Hand lift net operated along the shore in shallow waters. Four corners of the net are attached to poles tied at the center and is operated by dipping and quickly lifting the net out of water. Panjaal of Assam khora jai, kabjai and pah jaal are lift nets operated from boat or flat forms built in shallow waters of Brahmaputra. Kacha of Tamil Nadu, kurli of Punjab, Arippuvala and hoop nets of Kerala, Maharashtra and Tamil Nadu and Jamdajaal of Gujarat are examples.

Falling gear is usually a cone shaped net or other devices, which is dropped to cover aquatic animals and enclose them. Generally they are hand operated in shallow waters, but some are operated from a boat. The stick-held cast net is an example. The principle is to catch the fish by covering from above. The gear is cast over the area where the fish is available and the trapped fish are caught by hand. Cover pots, lantern net and plunge baskets are examples

Cast net is found throughout India. Cast nets are conical bag shaped net. It is the most widely used gear in the inland sector by single fisherman. Three types of cast nets are operated in inland waters viz. with closing strings, with peripheral pockets and without strings, pockets and hauling rope. Iron sinkers are fixed in the lower periphery of the net. The net is thrown in a circular fashion over the water and due to the presence of sinkers the net sinks to the bottom. It is then hauled up with the help of the hauling rope tied to the apex of the net. Fishes that come within the area covered by the gears enter the pockets while hauling. The cast nets vary in their sizes. Based on the size and different mesh size, the nets are named differently. The cast nets are mostly made of PA multifilament. Khewali jaal of Assam, chakar jaal of Gujarat and veesuvala of Kerala are some examples of cast nets.

Gill nets are long walls of webbing hung vertically in water are either set in one spot or allowed to drift with the current (Fig. 27). Gill nets are used in rivers, reservoirs, beels and other inland water bodies. Gill nets can be operated in the bottom, midwater or surface targeting desired fish. These nets are also used as encircling gear. It is highly selective and can be used judiciously by using the optimum mesh size to capture the right size of the fish. Gill nets are also named by the target fish they capture. Gochail jaal of Allahabad, thangadi of Hoshangabad, kuto jaal of Hoogly, current jaal, langi jaal and phansi jaal of Assam and ozhuku vala of Kerala are examples. The rampant use of very thin polyamide monofilament materials, discarded and lost nets in the inland water bodies could lead to ghost fishing and can also cause environmental and ecological problems. Proper selection of mesh sizes, hanging ratio, and mode and time of operation can make gill net an eco-friendly, low energy and sustainable fishing method.

Traps are passive fishing gears into which the fish can enter voluntarily in such a manner that the entrance then becomes a non-return passage of the device. Trap fishing is highly fuel efficient both in terms of returns and biomass per unit of fuel consumed. Traps can fish continuously during day and night with periodical checking and the organisms can be retrieved alive without any damage. Traps are mostly made of bamboo, Palmyra fibres, coconut tree, coconut leaves etc. Kankada khadia and Khonda screen traps in Chilka lake, Orissa Chempally koode of Kerala, Kumini of Madhya Pradesh, Sepa and Dingora of Assam are some examples of fishing traps.

Fish barriers are long leaders of converging screens erected in shallow waters to lead the fishes into the chambers fixed in the end. Net barriers are slowly replacing the bamboo barriers as these are cost affective and saves labour and lasts longer than the bamboo screens. The gear consists of leaders, gathering ground, channels and filter platforms. The leaders guide the fish into the trap. The length varies from 10 to 50 m depending on the width of the river stream or canal. Water seep through the platform, leaving the fish. These gears are very effective in capturing nearly all fish moving downstream. The fish reaching inside the barriers are captured by using lift nets. Roak used in river Yamuna in Agra during summer to catch major carps, jano khonda or disco net of Chilka lake, banamara and betamara of northeastern states are some examples.

***Hook and line fishing*:** Different lines such as hand line, pole and line, set line lone, drift line, long line, drop line, multiple baited lines, etc are also operated in inland waters. Some lines are operated without bait.

***Purse net* :** It is a semicircular purse net extensively used in catching Hilsa (Fig. 17). The net consists of an elliptical frame by tying two-split bamboo on either side or a bag shaped net attached to it. The net with its mouth opened vertically is towed along the river bottom by 1 to 2 fishers while being steered by 2 more. The frame of the net consists of two long slender arched bamboo strips about 6 to 7 m long tied together at both the ends in the form of hinges. To this frame is attached a rounded bag shaped net having a mesh of 22 to 70 mm made of PA about 3 to 3.5 m deep. The mouth is kept open by a brick, iron ball or a stone weight of 1.5 to 4.0 kg tied to the center of the lower lip. There is a feeler cord fixed to the upper portion of the net to transmit the disturbance caused by the entrance of fish. The stout haul rope is paid out to the desired depth. This haul rope passes through a ring or Y-shaped piece of wood in the upper lip and attached to the middle of the lower lip immediately above the weight. Net is operated from a boat moving with the current. When any fish enters the net it causes certain jerk which is felt by the fisherman holding the rope, which immediately close the net by pulling the rope and haul the net. Illishashangala jaal' and karal shangala jaal are very popular purse nets in the lower Brahmaputra, the former for hilsa and the latter for migratory carps. This net is also seen in West Bengal.

Brush parks are the most common fishing method employed in the beel (Fig.18). These parks mainly act as shelter areas. Two different types of brush parks locally known as katal / jeng and pit / chek, are erected in the beels of Assam. Katal fishing or katalmara is a method, which is extensively used in the beel fisheries of Assam. Katals are prepared by erecting tree branches in the bottom with a collection of water hyacinth, in the form of a circle. Pit / chek is a very large brush park (0.5 to 2.0 ha) erected in beels heavily infested with floating water hyacinth. Similar type of bush parks known as Phooms are seen in Loktak lake, Manipur. Fishes take shelter in this. During winter when the water level goes down, katal is surrounded using screen or net. Fishes are collected after removing the weeds

In the case of ***drive-in-nets***, the technique of this fishing method is to drive the fishes into fixed fishing gear from a distance. Sometimes gill nets are used for this purpose. The operation is done in the shallow areas. Scare lines can be made by inserting tender coconut leaves into the twists of a long coir rope or with broken pieces of bricks and thin strips of turtle shell similar to a stick held seine net. The net is fixed in the form of "U" and the fishes are driven into the net using the scare lines. In the final stage of operation of the net two ends are brought together and the confined fishes are captured. Beppevala in rivers of Kerala, gopal jaal in Allahabad, sone jaal and tik tiki khedani of Assam are examples.

Above described are major fishing gears and methods of inland waters in India and there may be some other indigenous fishing methods in certain pockets, which is likely to be insignificant in terms of catch or employment. Major issues in the sector is given below.

- Habitat degradation due various anthropogenic activities
- Siltation
- Land reclamation
- Profuse weed infestation
- Aquatic pollution
- Construction of check dams/barricades
- Destruction of mangrove forest
- Sand mining
- Water abstraction in smaller water bodies
- Invasive predators/exotic species
- Large scale prawn seed collection from natural water bodies for farming
- Destructive fishing methods
- Bycatch/discards
- Climate change

Towards Sustainable Fishery

Excess capacity and over exploitation is a major problem. Licensing of fishing craft and gear is required with periodic checking to control destructive fishing practices. Small meshed gears and use of mosquito net for fishing gear making should be banned. Gillnet with less than 90mm mesh size should not be used for hilsa fishing. Huge quantity of juveniles and post larvae are being landed in the stationary bag nets including juveniles of priced fishes like hilsa and pomfret. Such gears should be phased out or replaced with more selective gears. Buyback scheme can be introduced to purchase the licence of destructive gears. Completely ban the destructive fishing technique like blast fishing, electrical fishing and fishing using poison and chemicals. Trading of juvenile fishes need to be discouraged. Almost all gillnets are presently made of very thin nylon monofilament. Within 1-3 moths time the net get damaged and it is discarded as the fishermen usually does not mend the monofilament nets. The discarded non-biodegradable nets in the water bodies leads to ghost fishing.

CIFT has optimised mesh sizes for different gears based on the extensive field trials conducted in different water bodies and the recommendations have been communicated to the respective States for enacting. As the fisheries resources in open water bodies are common wealth, people utilising the same have the responsibly to conserve the same to prevent Tragedy of the commons proposed by British economist William Forster Lloyd. Responsible fishing practices using optimised fishing gears developed by CIFT should be adopted. It is believed that selfregulation by the fishermen and community managing the resources is better than master and slave approach for sustainable fishery

Fisheries management measures for sustainable fishery in inland waters

1. Fishing capacity regulation/ license for craft and gear
2. Prevention of destructive fishing gears and practices
3. Mesh size regulation
4. MLS for inland fishes
5. Observing closed season and closed areas
6. Discouraging use of mosquito nets/ destructive fishing gears
7. Community pond/cages for fattening live juveniles of fishes landed in fishing gear
8. Species enhancement in selected water bodies
9. Prevent habitat degradation process
10. Banning of fish seed collection from natural waters
11. Stocking and ranching
12. Restoring connection between isolated ponds and open water bodies for facilitating breeding migration
13. License for all aquaculture units to control the introduction of exotic predatory fish

Overview of gillnet operation, bycatch issues and mitigation measures

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Gillnetting

Gillnet, remains as the most popular fishing gear in the small-scale fishing sector due to its simplicity in design, construction, operation and low investment. It is a highly size selective gear and causes relatively less harm to the biota and to the environment. It is a highly energy efficiency gear (low energy gear) compared to active gears such as trawls.

Gillnet basically is a vertical wall of netting (length and height varying from 30m x 0.5m to >100 km x 50 m), rectangular in shape, kept erect in water by means of floats and sinkers. Large number of units placed in line ('fleets' of nets) are deployed in water for a certain period (soaking time) and later hauled. The net basically consists of a main netting panel (mostly made of polyamide/nylon monofilament or multifilament) of specific twine size and mesh size; selvedge, float line, lead line, floats, sinkers, buoys and buoy lines. Nets are operated as drift nets (drifting freely with one end attached to a vessel), set nets (anchored or staked to sea bed) and encircling nets (the fishes are surrounded). Once deployed in water, drift nets are generally soaked for 30 min to 6 h and set gillnets for 12 to 24 h.

Catching process

In gill net, fish is caught in one of the meshes of the net, normally by the gill region. The mesh size is selected in such a way that the fish can only partly penetrate the mesh and when it tries to pass through the mesh further forward, senses an obstruction and tries to pull back. In its struggle to free itself the twine slips back over the gill cover and prevents the fish from escaping. Thus, the fish is gilled and hence called ‘gillnet’. There are other methods of capture like wedging, when the fish is held tight by the twine of the mesh around its body; snagging, when the fish is held tight around the head; and entangling when the fish is held in the net by the teeth, opercular spines or other protruding appendages of the body without actually entering the mesh.

Design & operational parameters

The main parameters considered for designing a gillnet are: size of mesh in relation to the size of the targeted fish, diameter of the twine in relation to mesh size, hanging coefficient (looseness of the net), visibility of the net, softness of the material, buoyancy and ballast (weight) given. Netting is rigged to head rope with 0.4-0.7 hanging coefficient, generally around 0.5 which determines the looseness of the netting and thereby the shape and opening of the mesh.

Operational parameters: Nets, particularly those operated in shallow or moderate depth and nets which are not too large in size are operated manually while large nets operated in deeper waters are operated using powered net haulers. Large mechanized vessels carrying out gillnet cum longlining are very common and they are equipped with net haulers for handling the net.

Gillnets are either set on stern and hauled over side or are set and hauled over stern. Non-motorized and motorized vessels undertake single day trips while mechanized vessels operating large sized nets targeting large pelagics carry out multiday fishing ranging from a week to more than a month.

Gillnets were considered as resource specific, eco-friendly and responsible fishing gears without imparting any damage to the ecosystem. Of late, unscrupulous expansion of the gear, use of very small mesh sizes and very thin monofilament material are making gillnets a threat to the ecosystem. This selective gear too lands sizeable bycatch including endangered species. This necessitates monitoring and intervention in the design and operation of gillnets

Bycatch issues in gillnets

Bycatch occurs virtually in all fisheries. Bycatch is the unintended catch of species other than the target species, or individuals of the target species that are of undesirable size. Long-lived marine megafauna including turtles, birds, mammals, and sharks are highly susceptible to fisheries bycatch as they reside across geopolitical boundaries and oceanographic regions.

Wide spread use of large-scale gillnets, especially drift gillnets resulted in `gillnet bycatch'. Gillnet selectivity is influenced by the looseness of the net. Drift gillnets which are loosely hung (Hang. Coeff. < 0.5) and that too without head rope when drift with wind and current, tend to gill, entangle and enmesh a wide range of organisms including endangered species. Gillnet bycatch include non-target organisms such as marine turtles, marine mammals, sea birds, sharks & rays, juveniles of target species etc. Lost gillnets can also be highly disadvantageous to these organisms due to ghost fishing.

Incidental catch of marine turtles

Marine turtle interactions with fishing gears have been reported across the world since 1970s and have become an area of critical importance. Turtle interaction and capture occurs both in active and lost gillnets. Aabandoned and lost pieces of net drifting in water interfere with their feeding and nesting areas. Turtles entangling with nets often die due to drowning as entangled turtles cannot easily come to the surface for breathing.

In India too, incidental capture in gill nets and trawls has become a serious threat to sea turtle populations. Due to an increase in the number of fishing units, and size of gear, incidental bycatch has increased in recent years to the extent that it is the most significant cause of sea turtle mortality in Indian waters. In India, 76.5% of the incidental turtle capture occurs in gillnets. It is more pronounced in the east coast: Orissa, Tamil Nadu & Andhra Pradesh.

India is a signatory to the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and a party to the 1979 Bonn Convention on the Conservation of Migratory Species of Wild Animals (CMS). In September 1977, all the five species of marine turtles found in Indian waters are protected under the Indian Wildlife Protection Act 1972 which provides total legal protection to turtles from being hunted or traded. As a consequence of the implementation of regulatory measures, the threat from targeted capture and trade decreased while incidental capture of sea turtles in gear operated for other species of fish and shellfish has become more significant over the years.

Marine mammal bycatch

Mammals get entangled in active as well as lost gillnets, especially in invisible monofilament gillnets. As early as in 1994, there were reports on fishing gear and cetacean interaction. Dolphins, whales and other cetaceans used to get entangled in fishing nets especially tuna gillnets. Cetaceans mostly get entangled in gillnets when they deprade on the catch. It is estimated that 84% of global cetacean bycatch was due to gillnetting.

From Indian waters, 26 species of cetaceans have been recorded which are protected under the Indian wildlife protection act, 1972. The incidence of cetacean bycatch in tuna and seer fish gillnet fishing has been recognized since 1980s in India. Around 98% of mammal mortality is due to entanglement in gillnets.

Seabird bycatch

Gillnets have been the cause of some of the highest recorded mortalities of seabirds. Incidental catch of sea birds in drift gillnets has been widely reported from certain regions of the world viz., from Pacific, Atlantic oceans and Baltic Sea while there are no records from Indian ocean.Seabird bycatch is generally poorly documented from different regions.The introduction of monofilament netting has increased seabird bycatch rates as a result of reduced net visibility. There are no reports from India on sea bird bycatch in marine gillnets.

Juvenile catch

Though gillnet shows high size selectivity, species selectivity is rather poor. In tropical seas where multispecies fishery exists, juveniles of target and non-target species are often caught when multi-mesh gillnets are operated. In India, majority of the species caught in gillnets with 30- and 32-mm mesh size comprise of juveniles.

Shark bycatch

Coastal and deep water gillnets cause negative impacts on several species including sharks. When these nets are lost or abandoned they lead to “ghost fishing” and sharks especially sawfish species are caught.

Indian sharks are classified under IUCN categories with24% of the species in Indian waters as “Near Threatened”, 26% - “vulnerable” and 3% critically endangered”. Targeted gillnet fishing for sharks and rays exists in some areas. Large mesh bottom set gillnets -Thiranivalai or Thirukkuvalai targeting rays are operated in Kanyakumari coast of Tamil Nadu.

Coastal gill nets are still used in huge numbers in most parts of the world and are responsible for massive bycatch mortality of sharks and rays.

Reasons for gillnet bycatch

- Increased fishing effort: Due to change of material and due to mechanization/motorization there was a tremendous increase in the quantity of net deployed per operation. In the last 5-6 decades, in India, gillnets of length 180-300 m in 1960s, increased to 2 – 16 kilometres.

- Use of loosely hung drift nets: Using nets rigged with low hanging coefficient (<0.4) increased the chances of entangling non-target organisms.
- Widespread use of nylon monofilament gillnets: Use of gillnets of very thin nylon monofilament yarn viz., diameter of 0.12 to 0.20 mm lasts only for 3-4 months increased the chances of gear loss. These nets easily break and are almost invisible in water due to which entangling with non-target organisms is on a very high side.
- Use of multi-mesh and non-optimum mesh size: Selectivity is affected when multi-meshed gillnet units are operated as a single fleet of net. In tropical seas, due to multi species nature of the fishery, different size groups of species including juveniles are caught in multi-mesh gillnets.

Mitigation measures

Unlike trawl fisheries, gillnet bycatch issue received global attention rather late and hence less progress has been made on control measures. Mitigation measures include management measures and gear &operation-based technical measures.

Management measures:

- Implementation of fishing gear regulation (to control fishing capacity), mesh size regulation and minimum legal size would enable reduction in bycatch and sustainable operation of gillnets.
- Implementing minimum legal size of fish - For the first time in India, Kerala state has prescribed minimum legal size for 58 species of fish and shellfish to be landed.

Technical measures

1. Turtle bycatch control:

- Spatial and/or temporal restriction as turtles show preference to specified areas and seasons for nesting. Seasonal and area wise ‘no fishing zones. Ex; banning of gillnets within 5 km of the 3 mass nesting beaches of Olive Ridley turtle in Orissa, India for 3 months
- Reduction in gillnet profile (vertical height) causes reduction in amount of webbing in demersal gillnets which in turn reduces or eliminates the bag of slack webbing and decreases the chances of sea turtle entanglement.
- Combined effect of stiffer and shorter net reduces chances of turtle entanglement
- Attachment of visual mitigation measures like shark shaped silhouettes and light sticks and light emitting diode lamps in gillnets have shown reduction in number of turtles caught
- Making the nets more visible especially the upper portion by using thicker twine, attaching corks, colouring the net etc will help to reduce turtle interactions.
- Increasing net hanging ratio, using buoylessfloatlines and/or reducing the number of floats

- Use of easily degrading materials (e.g. thinner and weaker material) which reduces the floatation capacity of lost gillnet which in turn decreases the vertical profile of nets and allow larger organisms to break free of the gear and escape.
- Survival rate of entangled turtles can be improved by facilitating their reach to the surface to breathe during net immersion by setting the net in shallow waters, reducing the soaking time and frequent patrolling of nets deployed.

2. Mammal bycatch control

- Reducing the number and capacity of vessels and volume of net (length x height)
- Use of *acoustic pingers* and alarms causes cetaceans to avoid the sound source. It can reduce bycatch of marine mammals by 70-90%.
- Subsurface deployment of nets reduces the chances of cetacean bycatch in gillnets.
- Incorporating weak ropes and weak gillnet webbing made of biodegradable natural material help entangled mammals to escape, thereby reducing mortality and serious injury.
- *Acoustically reflective nets*- Incorporating reflective components such as barium sulphate or metal compounds into the nets. These materials causes increase in acoustic reflectivity, net’s visibility or twine stiffness.
- *Tie-downs* in bottom-set, midwater or driftnet gillnet fisheries by reducing the profile of the gillnet and by giving a vertically curved shape to the net reduce the bycatch of small cetaceans. These are lines that are shorter than the height of the fishing net, with terminal ends attached to the float line and lead line along the net, at equal horizontal distances.
- Increasing the visibility & stiffness of the net by using thicker yarns, colouring the net etc
- Using alternate panels of small mesh is helpful in alerting the dolphins about the presence of gillnets as dolphins are able to detect small mesh than large mesh webbing.

3. Seabird bycatch

Very little research has been carried out to explore technical means of reducing avian bycatch in gillnets. Few suggested options are:

- Spatiotemporal closures such as seasonal closure of gillnet fishery during the arrival of migratory birds.
- For diving sea birds: ensuring a minimum fishing depth and minimum distance from the coast.
- For surface feeding birds: using scaring lines, avoiding release of wastewater from the vessel during fishing operation
- Visual alerts: increased visibility of the upper net panel reduces seabird bycatch though it affects the catch efficiency of the net too.
- Attending deployed nets frequently during fishing, and safely removing and releasing caught birds alive.
- Illuminating fishing nets with green light emitting diodes (LEDs) –particularly useful as it is suitable for multiple taxa (seabirds and sea turtles)
- Regulating the depths at which gillnetting occurs could substantially reduce bird mortalities as seabird bycatch occurs in depths of less than 20 m and hence with increasing water depth this can be reduced.

4. Preventing juvenile catch by

- Seasonal use of resource specific gillnets using optimum mesh size can limit juvenile catch to a great extent.
- Mesh sizes below 32 mm should not be used on a regular basis.
- As the successful spawning period of most of the fishes is during May to July, fishing during this period has to be regulated
- The use of mesh sizes in succession as per the availability of the resource render gill netting a more ecofriendly fishing method for the inshore waters.
- Fishermen may be made aware of the importance of meeting MLS during gillnetting and the need for sustainability of the resource.

5. Control of shark bycatch

- By adopting mesh size regulations, reducing soaking time of net and by making nets stiffer- (shark bounce off the netting) shark bycatch can be reduced.

Other operational issues

Apart from bycatch, large scale operation of gillnets, use of synthetic netting and widespread use of monofilament gillnets lead to a relatively new problem of gear loss and consequent ghost fishing.

ALDFG: Abandoned, lost or otherwise discarded fishing gear (ALDFG) is the internationally recognized name for abandoned, lost or otherwise discarded fishing gear, derelict fishing gear. ALDFG drifts and entangle with animals including endangered species (ghost fishing) leading to their mortality. Fishing gear loss became an issue due to the shift from natural gear materials to synthetics. Gillnets are more prone to become ALDFG and to ghost fish than many other gears. Increased volume of gear deployed and widespread use of monofilament nets aggravate the chances of gear loss in gillnet fishing sector.

ALDFG in India: The first study on ALDFG relating to gillnets and trammels nets in Indian waters by ICAR-CIFT in 2017 covering 4 states and 583 fishing vessels indicated that around 25% of the total gear used per gillnet vessel is lost per year. So, the chances of ghost fishing of marine mammals, turtles, sharks etc due to lost gillnets are very high in India. Gear loss can be prevented by:

- Fishing gear marking for authenticity and trace back purposes.
- Providing offshore collection facilities for damaged gear
- Discouraging use of damaged or old gear
- Reduction of gear volume
- Reduction in soaking time of gear
- Procedures for reporting of lost fishing gears
- Plastic free gear (Use of biodegradable and less durable gear)

Conclusion

Gillnet dimensions are increasing continuously in terms of length and height. Even in India, gillnet sector has showed a significant growth in terms of the size of the fishing unit. Gear exclusively operated manually till one decade ago, is switching over to mechanized means. Increased gear size, widespread use of monofilament yarn etc were instrumental in occurrence of gillnet bycatch. There is a lack of information in India on the severity of gillnet bycatch problem. Regular monitoring and documentation are essential for controlling gillnet bycatch specially mammal and turtle bycatch in the Indian gillnet fishery. A strong database generated from continuous monitoring and evaluation of incidental mortality is necessary for the adoption of spatial and temporal restrictions. Once vulnerable areas and seasons are identified, it should be possible to evolve and adopt suitable measures with the active participation of fisher folk. Fishermen may be made aware of the need for sustainable operation of the gear. If proper care is taken to responsibly design and operate, gillnetting is a very sustainable fishing method. Precautionary measures along with effective regulatory mechanisms could ensure judicious exploitation of the resources using this fishing system.

Fishing vessels in India: An update

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Introduction

According to CMFRI, 2016 the total number of fishing vessels in India is 1,66,333. Of this 30,772 are mechanized trawlers, 6,548 are gill netters 3,396 are Dolnetters. The total mechanized fishing vessels are 42,985. The total number of motorised fishing vessels is 97,659.

Types of fishing vessels

The fishing vessels can be classified as follows:

1. Artisanal fishing vessels
2. Traditional fishing vessels
3. Motorised vessels
4. Mechanised vessels
5. Training/ Research/ Survey vessels

Artisanal Fishing vessel: Small-scale, low-technology, low-capital, low- energy, relatively small fishing vessels, making short fishing trips, close to shore by individual fishers of coastal or island ethnic fishers and mainly for local consumption. In practice, definition varies between countries- India wooden dugout canoes and catamaran (Fig.1).

Fig.1. Artisanal canoes of Andaman and some coastal sates.

Traditional fishing vessel: Traditional vessels use small engines for propulsion, but there is no insulated or cold storage for fish. The traditional gillnetters and liners used in Andaman is shown below (Fig.2)

:

Fig.2. Traditional fishing vessels of Andaman

Fig.3. A traditional plank built canoe

These are vessels using traditional methods for fishing and use no deck equipment such as winch. No insulated/cold storage onboard these vessels. No wheel house and accommodation onboard. In general, these boats are simple traditional fishing vessels only.

Motorised vessels: Vessels fitted with motors for propulsion, like the ring seiners- inboard engine fitted as shown below.

Fig.4. Motorised fishing vessels

Mechanised vessels: Mechanised vessels use engine power for cruising and fishing. They use mechanical/hydraulic/electric power for fishing gear handling. These vessels are installed with insulated/cold storage/freezer storage onboard.

Accommodation, galley and toilet are also made in the modern for multiday commercial fishing vessels. Communication, life saving, fire control, light and sound signals, etc. onboard. The most common commercial fishing vessels are trawler, gillnetters, Liners, seiners and combination fishing vessels. Trawlers include stern trawlers, side trawlers, factory trawlers and pair trawlers. Liners consist of hand liners, long liners and pole and liners. Seiners are purse seiners and ring seiners.

Types of mechanised fishing vessels are:

1. Trawler

1.1. Side trawler

1.2. Stern trawler

Fig. 5. Stern trawler

Fig. 6. Hydraulic trawl winch

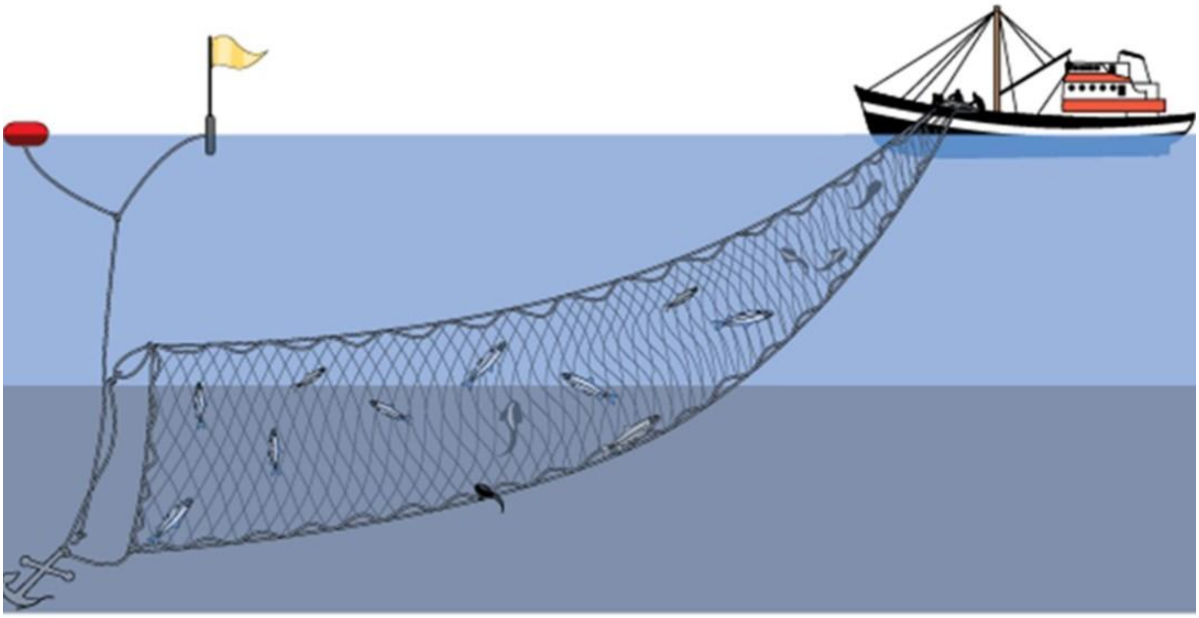
2.Seiner

2.1. Purse seiner: A commercial Purse seiner operating in Goa is shown below.

2.2. Ring Seiner: A traditional Ring seiner is shown below.

3. Gill netters

Boats and canoes use gill net in inland waters. The decked small gill netters fish in coastal waters and medium sized vessels operate gillnets in offshore. Small gillnetters have their wheelhouse either aft or forward. On medium sized vessels, using drifting gillnets and called drifters, the bridge is usually located aft.



On small vessels setting and hauling operations are performed by hand. Larger vessels are often equipped with hydraulic net haulers or net drums. A gillnetter is shown above

Fig.4. A gillnetter

4. Liner

4.1. Hand liner

4.2. Long liner

4.3. Pole and liner; In Lakshadweep, Pole and liner are used to catch tunas shown below.

Fig.5. A pole and liner from Lakshadweep

5. Trollers: Use many lines with hook attached to the mast. The vessels move forward and fish tries to catch the baited hook and gets caught as shown below.

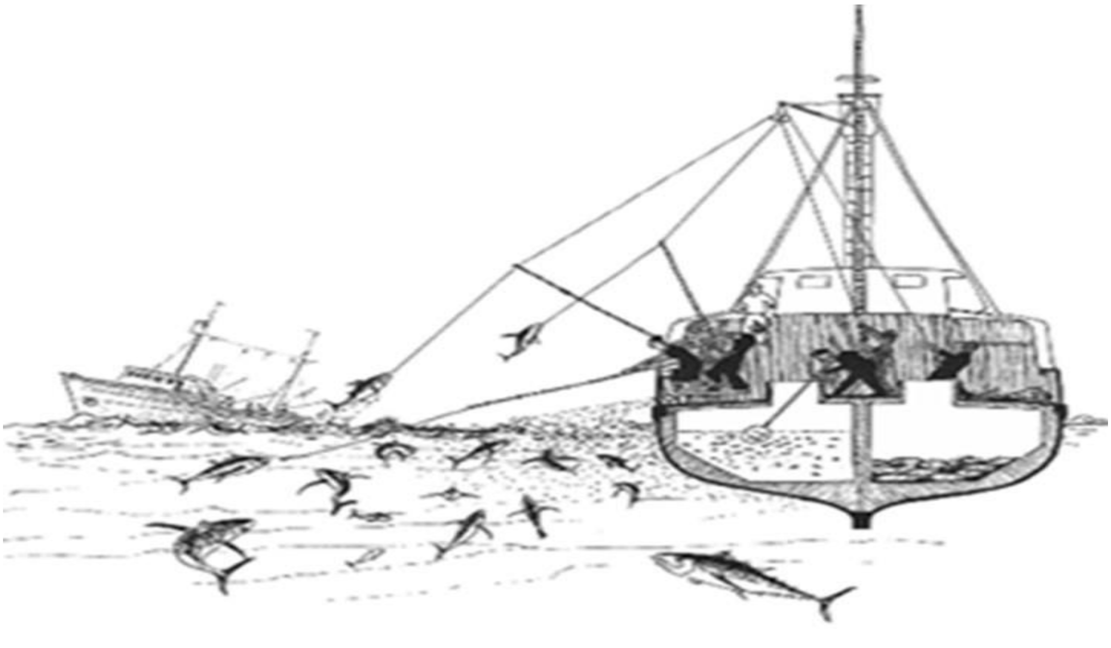


Fig. 6. A pole and line vessel in operation

6. Multipurpose fishing vessels: A most common combination is Gill netter cum Long liner and Trawler cum Long liner. is shown below

Fig.7. A multipurpose fishing vessel operates gill net and long line

There are also fishery research, carriers, fishery training vessels and fishery survey vessels. A research vessel of CIFT is given below.

Fig.8. F.V. Sagar Harita, research vessel

Design and construction of fishing vessels

The sea going boats and ships are designed and constructed based on the rules of the classification societies and the registering authorities of the flag nation. This ensures the structural and operational safety of the vessel as well as the crew, cargo and other items onboard. Class or National Standard organisation approved raw materials only shall be used for the construction. Main engine, valves and other machinery ate to be approved type. Design of fishing vessel plays a vital role in fuel efficiency. Optimization of hull forms is the most effective and logical way to reduce the drag force for increasing fuel efficiency and the result is minimal carbon emission and considerable saving in expenditure of fishing operations.

The design and construction of fishing vessel is to be carried out as per classification rules and according to the registration rules of the country. But generally, this has not been followed till the last three years. Under the Blue Revolution and PMMSY schemes the boats are designed and constructed as per the rules as mentioned. The comparison of traditional design and class approved design of a commercial deep sea fishing vessel is given below (Fig. 11).

Fig. 10. Modern combination fishing vessel in India

Alternate energy application in fishing vessel propulsion

The commercial fishing vessels require an engine for propulsion. The trawler, gill netter and long liner uses main engine power to function the winch for hauling the fishing gear. Economic speed of fishing vessels depends on the speed and length of the vessel. For propulsion the following are used as fuel.

1. Petrol
2. Diesel
3. Kerosene+ Petrol – are the common type of fuel used for commercial fishing.

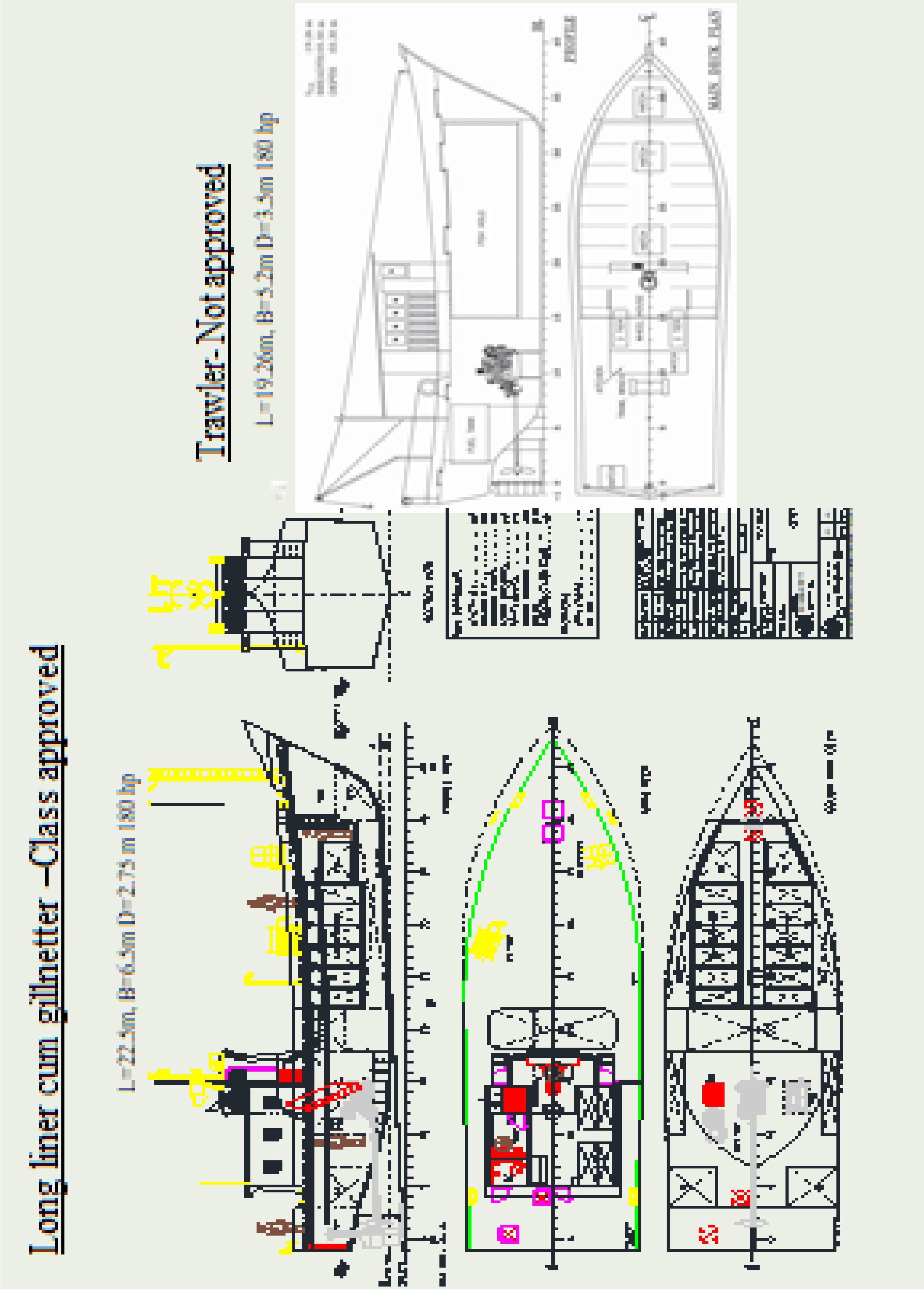


Fig. 11. design of a commercial deep sea fishing vessel

But recently ICAR-CIFT has started experiments with solar power and LNG. CIFT Solar fishing boat is shown in this picture. Solar panel mounted on top also act as a protection from sun and rain.

Fig. 12. Solar boat developed by ICAR-CIFT

There is no atmospheric pollution from solar boats since no fossil fuel is used in this. The sound pollution is also very low. Solar power for inland fisheries and LNG/LPG combination for marine fisheries as fusel for propulsion has been found to be successful after trials.

Fig. 13. LNG powered vessel

Fig. 14. LNG tank inside fishing vessel

Materials of vessel construction

The popular materials used in the construction of boats and ships are wood, steel, Aluminium, and Fiberglass reinforcement plastic. Among these wood utilizes least energy and is the most efficient material. But wood is costly now maintenance of wooden vessel is very expensive. Steel is the most popular material and has been used worldwide for ships and deep sea fishing vessels. This is corrosive in the marine environment and requires high care and maintenance. FRP is suitable for small vessels especially beach landing type fishing vessels due to its lightweight.

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Marine traps operation, bycatch issues and mitigation measures

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Introduction

Traps are simple, passive fishing gear that allow fish to enter and then make it hard for them to escape. This is often achieved by putting chambers in the trap or pot that can be closed once the fish enters; having a funnel that makes it difficult for the fish to escape. Traps are energy efficient fishing gears which have economic advantages over other fishing methods. Traps are selective, both for species as well as size, and if operated responsibly can lead to sustainable fishery in the long run (Vadziutsina and Riera, 2020).

How do Traps and Pots work

Fish that enter a trap or pot find it difficult to get out and this gives the fisher time to take the fish that are caught. Traps can vary, from simple structures such as rock corrals able to hold various fish species passing by, to highly specialized equipment such as lobster pots. An advantage of trapping is that it allows some control over the species and sizes of the fish you catch. The trap entrance, or funnel, can be regulated to control the maximum size of fish that enter. The size of the holes, or mesh, in the body of the trap can regulate the minimum size that is retained (Sary et al., 1997; Robichaud et al., 1999).

Where do operate Traps and Pots

Traps can be operated in areas with underwater obstructions, like shipwrecks, rocky and coral reef grounds, where other gears can't be operated. The fish, cephalopods and crustaceans which include snappers, emperors, groupers, parrot fish, surgeon fish, squirrelfish, angelfish, tropical rock lobsters and others. Pot fishery is widespread in mangrove creeks and estuarine areas for various crabs (mud crabs, swimmer crabs, spanner crabs, etc.), adult prawns (mud shrimp, yellow shrimp, etc.) and a number of offshore shrimps.

Trap fishing of Indian marine waters

Trap fishing is one of the ancient fishing methods and it has been widely practised throughout the world in both tropical and temperate waters. In India, though the coral reefs are found in Gulf of Mannar, Gulf of Kutchch, Lakshadweep and Andaman and Nicobar Islands, trap fishing has been constrained to Gulf of Mannar. The first study on the trap fisheries along Indian waters by Prabhu (1954) given detailed account on perch fishery of Gulf of Mannar, south-east coast of India. Similarly, Miyamoto and Shariff (1961) described in detail on indigenous lobsters traps (Colachal type) used in south-west coast of India. Despite there has been subsistence level trap fishing throughout the Indian coast, the commercial trap fishing in marine water has been restricted to these two regions, mainly targeting lobsters (south-west coast) and reef associated fishes (south-east coast).

Factors influencing efficiency of traps

1. Rigging

Once a pot or trap has been constructed, it must be prepared for the fishing operation. Buoys or floats will mark the location of the pot, so buoy lines and bridles must be attached to the trap or pot for setting

and hauling. Appropriate rigging is also important to ensure that the pot or trap lands the right way up on the bottom. The length of the buoy line will vary with the trap type, the tidal range and currents in the fishing area. The usual length of the buoy line is about one-and-a-half times to twice the water depth being fished, but may be greater if there are strong currents. Floats or buoys are attached to the line so that you can find your trap or pot again and pick up the buoy line to remove the catch.

Fig. 1. Map showing the locations of marine traps operated along the Indian coast (yellow dots indicates crab ring operation location; red dots indicates the fish trap operation location).

2. Baiting

As stated earlier, some traps and pots (e.g. eel traps, octopus pots, pelagic traps and some Caribbean traps) do not require bait for their operation but attract fish by appearing to provide shelter. However, in most cases the placing of bait in the trap or pot gives an added reason for the fish to enter. The relationship between the funnel and the positioning of the bait is critical in getting good catches. The bait has to be positioned so that a fish entering to take it cannot back out through the funnel or find the funnel exit and escape. A good bait is effective at attracting the target fish; easy to secure in the trap; long-lasting; freely available when needed; not excessively expensive; easy to preserve and transport.

3. Setting

A key factor in successful fishing with traps and pots is the location in which you set them. This positioning will depend on the types of fish you are targeting. It is very important that you develop the capacity to understand how the fish will react to your trap or pot. For fish that live under reefs or rocks and do not venture far from their shelter (e.g. rock lobsters, tropical cod), you must place the trap close to where they are sheltering. In these cases, considering the tide and current, the location of your trap is critical and may make the difference between a good catch and no catch

4. Soak time

As with many aspects of trap and pot fishing, fishing time will vary with the target species and their behaviour. Some fish feed actively only at night so, if you are using baited traps, night fishing is indicated. Other fish feed mainly during the day and can only be taken during daylight. Non-baited traps and pots such as the pelagic fish trap and those used in the Caribbean should be set for short periods at times when the target fish are seeking shelter. The duration of each set will also vary with the behaviour of the target fish and the durability of the bait. When fish are feeding very actively, the fishing time of each set may only need to be a few minutes. Some tropical snappers off northern Australia can be taken in only 30 minutes between setting and hauling. In other fisheries, the soak time may be several days depending on the fish and conditions. It has been found in the Caribbean that a soak time of two to three days is usual and that after four to five days the catch may actually decrease, possibly because the fish learn how to escape from the trap. Normally, depending on local conditions, traps are hauled every one to three hours in shallow waters, while at greater depths they are frequently set for longer. In some areas, new traps and pots are soaked in the water for some time before they are used for fishing to eliminate any foreign odours coming from the materials used or, in the case of cane and wooden pots, to eliminate any trapped air.

Disadvantages of Trap Fishing

Traps often are considered to have fewer holistic environmental impacts than active fishing gears (Stevens, 2020). However, in addition to the targeted catches, traps still cause unwanted mortalities due to (i) discarding, (ii) ghost fishing of derelict gear, (iii) depredation, (iv) escaping or dropping out of gear, (v) habitat damage, and potentially (vi) avoiding gear and predation and (vii) infection of injuries sustained from most of the above (Uhlmann and Broadhurst, 2013).

1. Ghost fishing

As with other fishing gear, special care must be taken to reduce the number of traps and pots can lost during fishing operations. Further, the lost gear may continue to attract fish for days or months, which is wasteful and reduces fish stocks without any return. In some fisheries, legislation has been passed to make it obligatory for fishers to design their gear with a section that will corrode quickly and make an opening for fish to escape from lost pots (Gomes et al., 2014).

2. Juvenile fishing

Trap fishing also poses a threat to juvenile fish because of the small mesh sizes used, particularly to high-bodied species such as surgeonfish (Acanthuridae). In areas with high levels of trapping, juveniles can represent a significant proportion of the catch and trapping can lead to reduced productivity through growth over-fishing, i.e. premature removal of fish leading to lower catches (Ben-Hasan et al., 2021).

Possible technical gear modifications

Examples of gear modifications that reduce unwanted by-catch

a) Square mesh escape window to release small fish and to increase the size selectivity
b) Encircling square mesh selection panel in a pontoon trap for better size selection
c) Size sorting grid to avoid the small and juvenile fish capture
d) Installing bent-tunnel openings in crustacean traps to reduce the rockfish.
e) Escape gaps in lobster traps reduce catch rates of undersized lobsters
f) Permanent magnets reduce bycatch of benthic sharks in an ocean trap fishery

Recommendations

1. Modifications of fishing gears has significantly helped to reduce by-catches
2. Economic rewards should be offered for the creation and use of gear modifications that reduce by-catches and minimize impacts on habitats
3. Co-operation between fishing industry, scientists and other stake holders is fundamental
4. Reduction of impact on grounds that has a “rich” biodiversity should be given highest priority
5. Fishing practice that has reduced bottom interaction should be promoted

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Fabrication of square mesh codends

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Introduction

Square mesh codend is type of bycatch reduction device (BRD) which is highly effective in trawl fisheries as the mesh size and shape stay constant. Square mesh cod ends are very efficient which allow the easy release of small round fish but retaining all the larger fish. The square mesh codend is not only effective for fishes but also to protect the sea snakes. The research found square mesh codend BRDs to be highly effective, reducing sea snake catch by 60% (Courtney et al. 2006). With the square open meshes being at the aft end of the trawl where there is a much-reduced water flow the small fish have time to recover from being captured and swept down the trawl. By being exposed to the square mesh for the trawling duration of the tow they have adequate time to find the way to escape through the open meshes unlike a square mesh panel. To further improve the selectivity of a square mesh cod end it can be made using 4 panels instead of the normal two as this helps the extension stay more open allowing the fish more space to swim in before escape. According to the study by Sunil et al., (2009) the average escaped fish due to 40 mm cod-end mesh is roughly 20% of the catch. The average loss per haul in is about 1.3% of the total revenue realized per haul, this loss does not make any significant impact on vessel economics and overall profitability of operations. Not only the ecological point of view but because of square mesh the lumen area is more which helps in better water filtration hence reduced drag and fuel consumption. So, in long term sustainable fish harvesting using square mesh in fishing net is need for the hour.

Different methods used for fabrication of square mesh cod end for trawl gear.

Method-1

In this method after taking piece of webbing (fig. 1) required dimension is shaped by all bar cut (Fig.2). After all bar cut the remaining piece of webbing with mesh will be of square in shape.

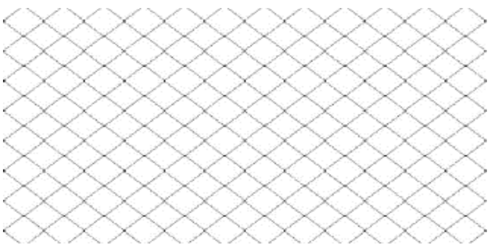

Fig.1. Piece of webbing

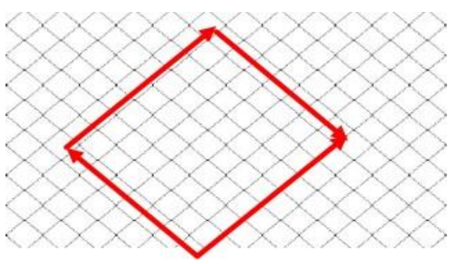

Fig. 2. Direction of bar cut

Method-2

In this method the piece of webbing is shaped with bar cut and made of two pieces as shown in Fig. 3 and 4. The dissected small piece of webbing is joined with larger piece of webbing but with another end (Fig.5). After joining, a cylindrical shape structure would be formed, which could be converted to webbing with square mesh after all bar cut.

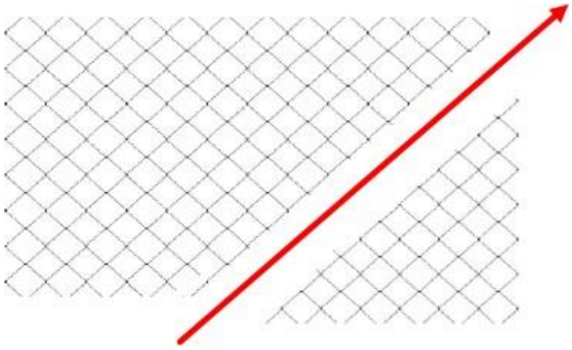

Fig. 3. Direction if bar cut

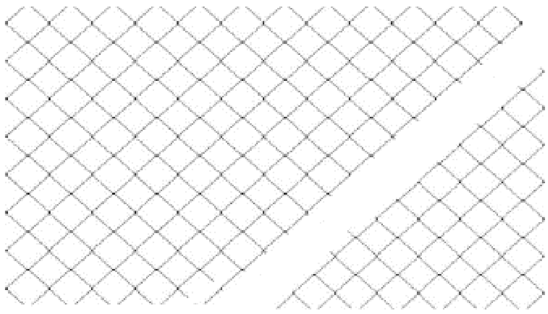

Fig. 4. Two pieces of webbing

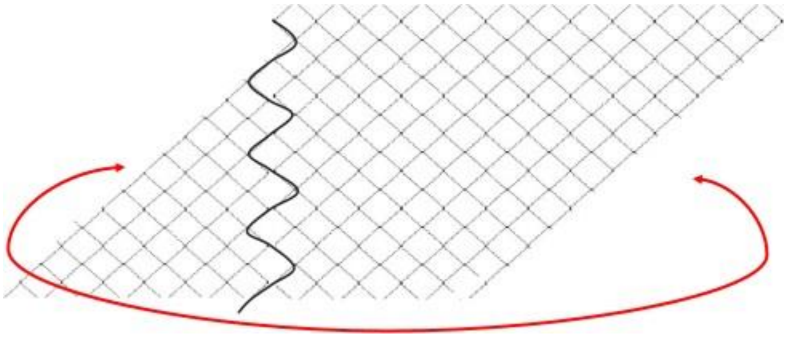

Fig. 5. Joining of webbing to opposite direction

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Marine mammal interaction in pelagic fishing gears and its mitigation

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Introduction

Ocean covers 70% of the earth surface and is the largest living space which accommodates verities of flora and fauna. Marine biodiversity is very complex and special. It ranges from single celled or microscopic communities to the gigantic blue whale. The known species diversity in the ocean is less than 13% of the all living species currently described. The oceanic environment plays direct and indirect role in the human life by regulating earth system, providing social and economic goods and services, supply of living and non-living resources etc. Fisheries is the one of the major resources which plays an important role in ocean biodiversity, growth and development of many of the countries and also ensures the food security of millions of coastal communities (Srinivasan et al., 2010; FAO, 2011). Unlike other natural resources, they are renewable (capable of growth) if managed properly. Due to several factors, fishery resources are difficult to manage effectively (Munro and Scott, 1985). There are several issues associated with the management of the fishery resources, which includes over exploitation of targeted and non-targeted species, ecosystem degradation, ghost fishing, pollution, as well as the carbon foot print of the fishing operations (Ardill and Gillett 2011). Interaction of marine mega fauna with fisheries is the one of the recent critical issue addressed by the fishery managers and marine biologists of the globe. The incidence of protected marine species in Indian gillnet fishery is estimated as 0-3 number per operation (Koya et al., 2018). Fisheries is the major reason for the non-natural mortality of large marine vertebrates such as marine mammals, turtles, sharks, rays, skates etc. among these, marine mammals are the charismatic animals exerts major influence on marine food web, structure and function of the marine ecosystem. Many of the marine mammals are categorized as protected species. In a complex fishery with verities of vessel gear combinations, the chances of mammal interaction with fishery is very high. The balance between the conservation of vulnerable species and responsible utilization of fishery resource is a challenging topic. Which need to be taken care rightly with proper management measures.

Biological features of marine mammals

Mammals are highly developed animal groups stand on the apex of the animal kingdom. They have a diverse distribution with suitable adaptation to live in the respective geographical realms. Mammals lives in aquatic environment are morphologically and anatomically adopted for the life in water. Hydrodynamic body, modified appendages for reducing drag and maximizing propulsion, efficient respiratory system with high oxygen retention, better thermoregulatory mechanisms, specialised sensory and communication mechanism makes them unique from other group of mammals. 'Marine mammal' is a general term to address the members of 5 different groups Viz cetaceans, sirenians, pinnipeds, sea otters, and the polar bears. A common feature for all the marine mammals is that they spent their entire life in ocean or nearby related ecosystems and derive all of their food from aquatic habitat (Jefferson et al 1993).

Kingdom: Animalia	
Phylum : Chordata	
Class : Mammalia	
Order: Cetacea	Whales, Dolphins and porpoises
Order: Sirenia	Dugongs and Manatees
Order: Carnivora	Pinnipids (Seals, Sea lions and walrus) and other marine carnivore (Polar bear, Otters)

Table: 1 Classification of Marine mammals

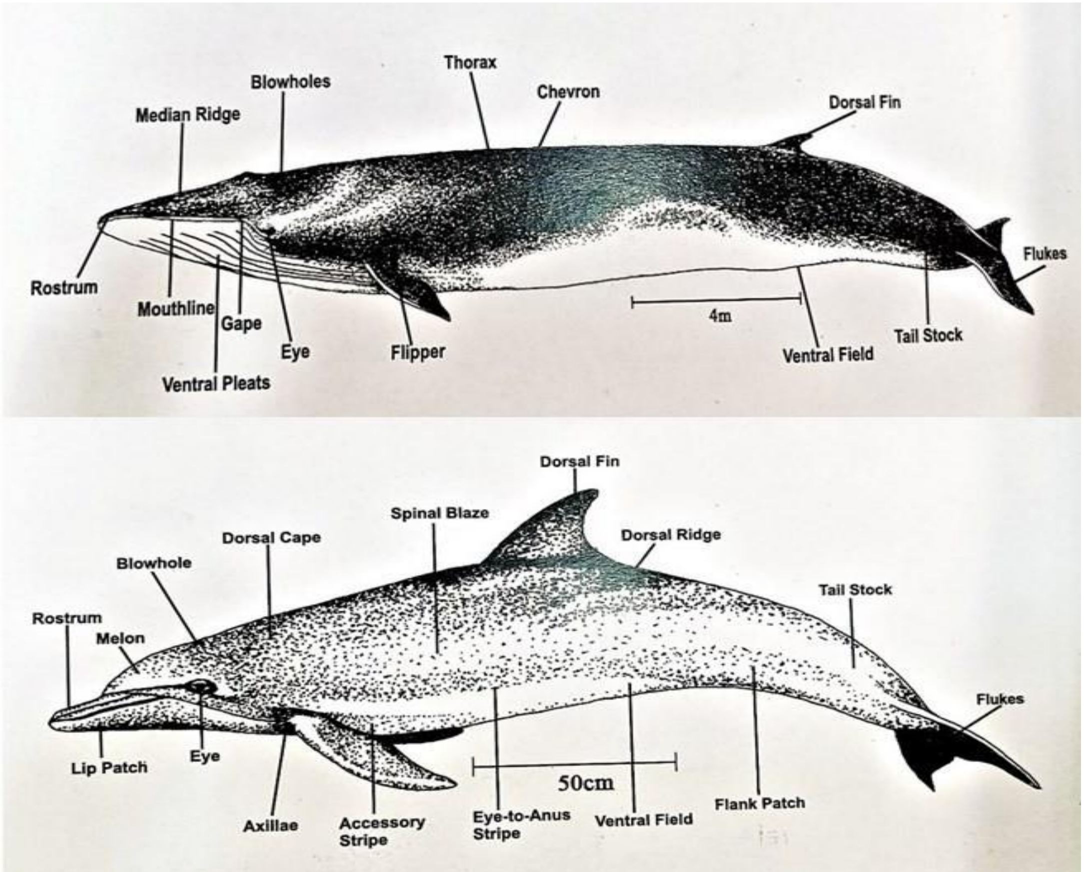


Fig.1. Morphological features of a typical cetaceans (Vivekanandan and Jeyabaskaran,2012)

Marine mammals of India.

Worldwide 130 species of marine mammals are identified from various oceanic regions viz. tropical, subtropical, temperate and polar regions **(**Jefferson et al 2008). Indian seas accommodate verities of marine mammals belongs to two orders, cetaceans and sirenian. Which includes baleen whales, toothed whales, dolphins porpoises and dugongs. (Vivekanandan and Jeyabaskaran,2012). Out of 130 species reported worldwide, 25 species of cetaceans are reported from Indian waters of which five are Mysticeti (Baleen whales) and the rest are Odontoceti, which includes Delphinidae, Physeteridae, Kogiidae, Ziphiidae,Phocoenidae and Platanistdae (Kumaran, 2002)**.** Only one species of sirenian

(Dugong dugon) is reported. All the marine mammals of India are protected by law and positioned under Wildlife (Protection) Act, 1972. Out of which three species Gangetic dolphin (*Platanista gangetica*), Irrawaddy dolphin (*Orcaella brevirostris*) and dugong (Dugong dugon) are protected under Schedule I and rest are placed under Schedule II. As per the act, Schedule I and Part II of Schedule provide absolute protection. Capture, use and trade of animals under this schedule prescribed the highest penalties. India is the first country in the world having a cetacean fauna as National aquatic animal. Gangetic dolphin *Platanista gangetica gangetica* is declared as the National Aquatic Animal by the Prime minster of India in the First Meeting of the National Ganga River Basin Authority (NGRBA) on the 5th of October 2009.

Interaction of marine mammals with fishing systems

Cetaceans coming under family Dephinidae shows more interaction with coastal fisheries in India. Dolphins are the members of this family. Active movement, overlapping with the feeding and activity zones of other commercially targeted nektonic groups are the some of the reasons for this higher interaction. While analysing the depth wise and zone wise distribution of marine mammals of India, there are several species with active distribution in the coastal fishing zones. Four species of dolphis viz *Stenella longirostris* (Spinner dolphin) *Tursiops aduncus* (The Indo-Pacific bottlenose dolphin), *Delphinus capensis* (The long-beaked common dolphin) *Sousa chinensis* (The Indo-Pacific humpback dolphin) are the four major dolphin species abundant in the coastal waters (Jayapraksh et al., 1995). (Table: 2).

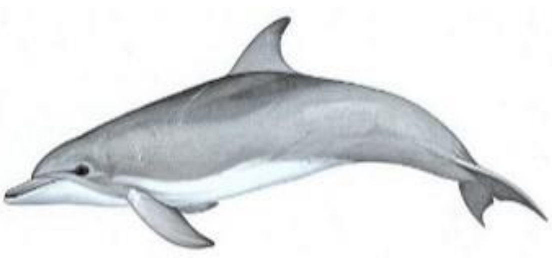
Stenella longirostris 	***Delphinus capensis*** 
Tursiops aduncus 	***Sousa chinensis*** 

Table.2. Major dolphin species with higher interaction with fishing systems.

The mammal-fishery interactions are of several kind viz. biological/ ecological and direct/operational interactions (Wickens, 1994). In mammal- fishery interaction, most of the interactions are reported as predatory type. Fish is one of the most important diet of marine mammals and many are competing with fishermen for the catch. Some of the dolphins forage exclusively on fishes (Barros and Wells, 1998, Panicker and Sutaria, Sule at al 2015).

Major pelagic fishing systems with marine mammal interaction

Indian fisheries are multispecies-multi gear in nature and characterized by a heterogenous fishery management system (Najmudeen and Sathiadhas, 2008). Fishing is carried out with more than 20 gear and vessel combinations. Out of the various gear operated, gillnets and seine nets are more vulnerable to the marine mammal interaction (Cockcroft and Krohn, 1994; Perrin et al., 1994; Archer et al., 2001; Wise et al., 2001; Read et al., 2006, Joseph et al., 2021).

Gillnets have either a single shot/unit of net or a number of units tied end to end to form a full fleet of length ranging from 600 to 16500 m with a hung depth of 3 to 20 m. Based on mesh size, Indian gillnets are classified into small meshed nets with 14 to 45 mm mesh size and large meshed nets with 45 to 500 mm mesh size which target verities of species viz. sardine, mackerel, anchovy, seer fish, shark, tuna, pomfret, hilsa, barracuda, billfish, carangid, perch, elasmobranch. etc. Fishing is normally conducted at a depth of 20-1000 m. study by ICAR-Central Institute of Fisheries Technology, Cochin from 20 major fishing harbours along Indian coast reports, coastal gillnets are more prone to cetacean interaction. As gill nets are stretched wall of net with very low visibility in water, the net will obstruct the movement of animals comes in the range of operation and lead to entanglement. Depredation may another reason for the interaction. There are many reports that marine mammals feed on fish caught by fishing gears (Gonener and Ozdemir, 2012). While examining the inshore and off shore gill net bycatch composition, finless porpoise, humpback dolphin and Indo-Pacific bottle nose dolphins are caught in the coastal gillnet targeting tuna and seer fishes. Whereas spinner dolphins, Risso's dolphin and dwarf sperm whale are the species reported from the offshore drift gillnet (Anderson et al., 2020, Yousuf et al*.,* 2009)

Marine mammal interaction in gillnets

Almost 84% of the global cetacean by catch is reported from gill net fishery (Read et al., 2006). Most of the fishery-mammal interactions are reported during late 1980s (Northridge, 1984). due increase in incidental catch of protected species in gill nets, operation of gillnets in the high seas is banned by many countries by law (He, 2006). In India, technological advancement and modernization in the gillnet sector resulted in an increase in the quantum of gillnets taken for operation even in distant and oceanic waters (Thomas,2019). These escalation in the size of the gillnets increased the chances of marine mammal encounters. The modernisation also resulted in shifting of area operation of gillnets from coastal waters to deep sea so there have been a change in the species composition of cetacean bycatch in drift gillnets also (Anderson, 2014). Almost three decades of observation from Indian waters reports 98.8 % mammal mortality reported were due to entanglement in gillnets (Jeyabaskaran et al*.* 2016).Among the major fishing systems operated along Indian coast, cetacean interaction is reported maximum from gillnets (57.7%) particulary in the small meshed gillnets operated in the coastal waters. Joseph et al*.* (2021). In India finless porpoise, humpback dolphin and Indo-Pacific bottle nose dolphins must have been caught in tuna/seer gillnets operated in inshore waters while spinner dolphins, Risso's dolphin and dwarf sperm whale among other species dominated the offshore drift gillnet bycatch (Anderson et al. 2020, Yousuf et al. 2009). The annual cetacean mortality caused by the Indian gillnet fishery is estimated in the range of 1000-10,000/year (Lal Mohan. 1994, Yousuf et al. 2009, Kumaran, 2002) and most of the moralities are associated with pelagic fishery of yellowfin tuna (*Thunnus albacares*), sharks, and seerfish (*Scomberomorus commerson* and *S. guttatus*).

Marine mammal interaction in seine nets

In India, after gillnets, seine nets are most prone to marine mammal interaction **(**Joseph et al, 2021). Unlike gillnet fishery, seine fishery in India is highly regional and restricted to southern coast. surrounding nets are mainly employed to catch the shoaling pelagic fishes like sardines, mackerel, tuna etc. Purse sines and Ring sines (mini purse seines) are the two major seine nets in India. Ring seines, otherwise known as mini-purse seines, are a group of lightly constructed seines adapted for operation in the traditional motorised sector. The total length of a seine net ranges from 600-1000 m with a depth of 83-100 m and is operation is confined to a depth of less than 75 m. The operation of a seine net consists of all the aspects of hunting, scouting the fish, chase and interception of the fish school etc. cetaceans are the major bycatch reported in seine fisheries, especially the members belongs to family Delphinidae (dolphins) are more vulnerable to fishery interaction.

The dolphin species which has more access to coastal waters showed more interaction with fishing systems. 84.8% of the interaction with fishing systems was exhibited by four species *Stenella longirostris, Tursiops aduncus, Delphinus capensis, Sousa chinensis,* which are abundant in the coastal waters (Table.2). (Joseph et al. 2021, Raphael et al., 2017; Edwin et al., 2017; Koya et al., 2018). Larger herd size, active swimming behaviour, sharing of common ecological niche with the fishes which are targeted by seine fishing makes dolphins more susceptible to capture and entanglement in the fishing nets. There are reports of targeted capture and landing of dolphins from seine nets in India (Jayaprakash et al. 1995, Yousaf at al., 2009). During 1984, almost 42 common dolphin *Delphinus delphis were landed in Kochi by* 12.5m purse seiner and animals were sold to local market 27.5INR/specimen. Similarly, in 1995 and 2009, finless porpoise, *Neophocaena phocaenoides were landed by* purse seines from off Mangalore coast of Karnataka and Gulf of manner region. Dolphin fishery interaction in India is mainly associated with small pelagic fishery (especially oil sardine) in near shore shallow waters (Yousaf at al., 2009). Majority of the cetaceans- seine net interactions were reported from the states like Kerala, Karnataka, and Goa where the higher landing of small pelagic are reported. (Prathibha et al., 2018, Yohannan and Sivadas, 2003, Joseph et al.2021, Yousaf at al., 2009, Edwin et al.2017, Raphael et al., 2017, Prajith et al 2014).

Depredation is another reason for the mammal- seine net interaction. Cetaceans especially dolphins considered fishing nets as an easily accessible and available source of food. when the catch concentrates to the bund area of the net, dolphins approaches the net and remove the catch by biting and tearing off the net. Removal or damage of the harvested catch in commercial or recreational fishing by predator which leads to the damage of the fishing gear is referred as depredation. Depredation directly cause economic loss by damaging fishing gear. The indirect loss is by reducing the quality of the catch.

Mitigation

The mitigation measures to minimize the marine mammal fishery of active and passive type. Making alterations in the structural features, increasing the visibility of fishing gear by means of using thick twines, incorporation of add-on reflectors, colouring the netting panels are the major passive methods. Whereas mechanical sounds generation using crackers, explosives, gunshots etc. are come under active type (Jeffersons and Curry, 1996). Indian fishermen follow both active and passive mitigation measures to deter marine mammals from the fishing operation and to safeguard their catch and gear. which can be further classified as indigenous and modern methods. The major indigenous mitigation strategies adopted by the Indian fishermen to minimize cetacean bycatch/interaction are selection of suitable grounds, structural modifications in the gear, sound generation using crackers, vessel chasses, use of boat noises making loud noise, throwing bait to distract the mammals and jumping into water to scare them. While practising these indigenous methods, fishers are cautious to avoid injury to the animals. They even patrol in the fishing ground with small boats and alter the attention of mammals with the help of objects like tyres, boat anchors, stones covered in plastic bags etc. The major modern mitigation methods are the use of acoustic deterrent devices like pingers. Besides this several government agencies and research institutes of the country are engaged in various outreach programs to create awareness among fishers about the protected marine species and their importance in the ecosystems.

Dolphin wall nets (DWN)

Dolphin wall nets are the indigenously fabricated wall of nets which creates a barrier between the seine net and the dolphins during fishing operation. The net is 1000-1500m long with plastic cans as float and large steel rings as sinkers. The DWN is an innovation from the side of local fishers of Kerala, Southernmost state of India which reduce the operational damages and resulted catch loss during fishing. besides this, unknowingly the net ensures protection of mammals from the incidental catch and mortality (Prajith et al. 2014)

Medina panels

This is a panel of relatively small mesh netting (50 mm or less) sewn into the purse seine at the distance of about 1/3 of the float line length from the bunt-end tip, to surround the apex of the backdown area where porpoises are most likely to come in contact with the net. Usually it is one or two strips deep and 330 m long. The longer Medina panel the more effective it is, especially fitted into the net throughout the bunches area and as near the bunt as practical. The system is named after the Californian skipper who first used it. (FAO 2022)

Pingers

Sound has significant role in the lives of marine mammals and sound is the prime mode of information transformation used for communication. As an adaptation to live in a vast aquatic environment, the acoustic system of marine mammals is well developed. Understanding this advantage of communication mechanisms using sound, use of aquatics pingers is the most suitable and efficient mechanism to distract cetaceans from the fishing gears (Fig. 3). Pingers sometime referred as net alarms is one of the best options to reduce injury and resulted mortality of marine mammals. Dolphin pingers are the devices that produces ultrasound which alert and keep the dolphins and porpoises away from the nets. Pinger is designed to work by emitting a sound wave signal beyond 70 kHz that is known to be in the best hearing range of most dolphin species. The signal acts as an alarm and in some cases the pinger stimulates dolphins to use their echolocation which alerts them to the presence of the pingers and fishing nets. This sound wave is not audible to human beings, but it creates disturbance to dolphins and alert dolphins the presence of nets. Pingers are efficient to minimize cetacean interaction both in gillnets and seine nets.

Fig. 2. A typical banana pinger used in gill nets and seine nets

Conclusion

Global survey report of United Nations in 2005 reports 70% of the dolphin species are at risk due to various human activities. Removal of the apex predators like cetaceans by incidental or purposeful killing may leads to imbalance in the ecosystem. Marine mammal fishery research in India is still in infancy stage. Most of the studies are based on the stranding events. Research to formulate suitable mechanism to reduce or avoid mammal interaction with fishing system is the need of the hour. Ecology, behaviour and biology of marine cetaceans need better understanding. To reduce marine mammal incidental catch and kill, there should be a management system or consortia which comprises of government agencies, academicians, researchers and fishermen. Understanding the fishermen perception is essential while formulating the research. A refinement in in the existing indigenous mitigation measures by the application of suitable scientific approach with the involvement of fishermen is needed. Besides this awareness about the importance of marine mammals and other mega fauna should be created among fishers, general public, school students etc. through various outreach and extension programmes.

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Design and operation of Turtle Excluder Devices (TED)

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Introduction

Sea turtles are endangered species which are protected under schedule I of the Indian wildlife protection act 1972 and its amendment in 1991. Sea Turtles are listed as critically endangered or threatened on world conservation Union Red list. Sea turtles interact with trawl gears, pelagic long line gear on the high seas, and beach seine, gillnet and shrimp trawl gears in coastal waters. These interactions can lead to death, most frequently through drowning, when the turtles cannot climb to the surface of the ocean to breathe after becoming hooked or entangled in the fishing gear. New types of gear or ways of fishing can significantly reduce the rate of interactions between turtles and gear or the mortality rate after an interaction has already occurred.

The code of conduct of responsible fisheries (FAO 1995) gives guidelines for sustainable development of fisheries, prescribes the need for protecting endangered species like sea turtles. As a signatory to the code, India is bound to conduct research, develop appropriate devices and practices and implement regulatory measures for protection of endangered turtles. The fundamental objective of responsible fishing is to maximise economic returns to the fishermen without affecting the long-term sustainability of fishery resources and with minimum impact of ecosystem

Trawling and sea turtle interactions

Trawling is considered to be a very effective method of fishing for demersal population in terms of investment and yield. Trawl nets are towed gears consisting of funnel shaped body of netting closed by a bag or cod end extended sideways in front to form wings. Trawling targets at mainly shrimps gained popularity over the years and led to the development of an organised fishing industry. Trawlers form nearly 80 % of the small-scale mechanised fleet in India. Even though bottom trawl is an efficient fishing method for targeting demersal resources, it is less a selective fishing technique. Along with the targeted resources a large number of non-target resources which include protected and endangered species such a s sea turtles are also caught during trawling. Rajagopalan *et al* (1996) reported that trawls accounted for 17.8% of the incidental catch along the Indian coasts. Along the east coast this problem has been aggravated due to rapid expansion of the mechanised fishing industry. Incidental mortalities of turtles is highest in Orrisa due to presence of large congregations of marine turtles.

An US law (section 609 of public law no. 101 -162) introduced in May 1996 restricted imports of shrimp harvested with fishing equipment such as trawls nets not equipped with Turtle excluder devices (TEDs). The subsequent shrimp turtle case brought environmental requirements in the WTO into the mainstream, through its interpretation of relevant WTO articles. In view of these concerns, with respect to trade and the environment, the Department of Animal Husbandry and Dairying, Ministry of Agriculture, Govt of India constituted an expert panel to conduct detailed investigations on marine turtle distribution in Indian waters, their incidental mortality in fishing nets and use of TED in trawl nets.

TED for Indian Fisheries

The Turtle excluder devices consist of panels of large mesh nettings (soft TED) or a frame consisting of a grid deflector bars (hard TED), installed before the cod end of the trawl net at an angle leading upward or downward into an escape opening. Small animals such as shrimp slip through the mesh lumen of the netting panel or gap between the deflector bars and are retained in the while large fishes and elasmobranchs are stopped by the netting or the grid of the deflector bars and can escape through the opening (Fig 1). Thus air – breathing marine turtles were prevented from capture and subsequent death after prolonged entrapment in the trawl.

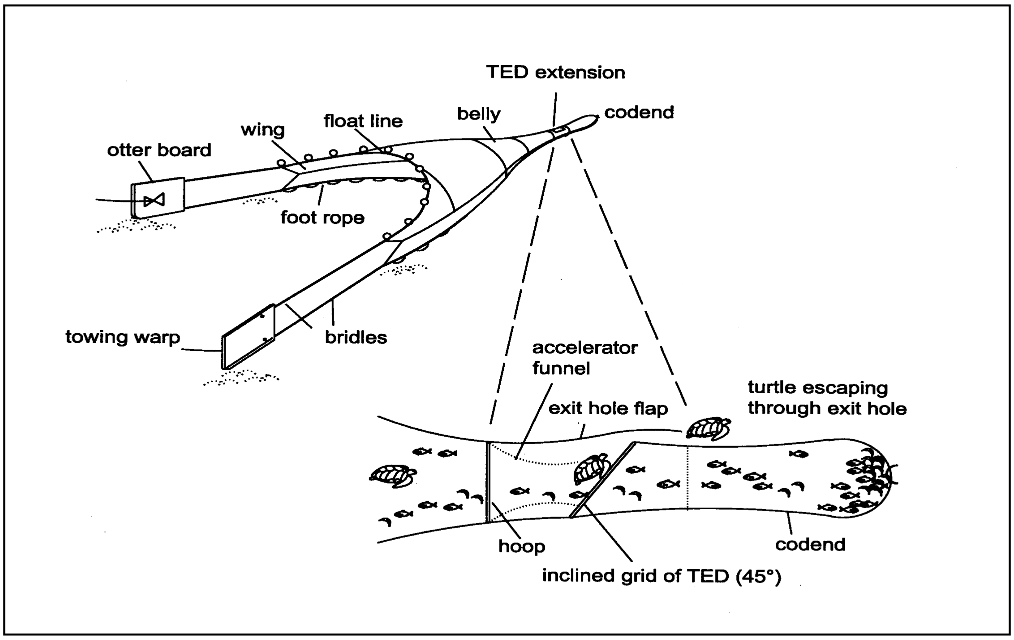

Fig. 1. Principle of TED operation

Different designs of TED are available today and they vary with regard to their construction, principle of operation and materials for construction depending on the target groups and fishing conditions (Fig. 2). Soft TED and Hard TEDs are the two types that are used worldwide (Mitchell et al 1995, Anon 2002a) The hard TED is rigid frame device installed ahead of the cod end to separately and exclude turtles from the trawl catch. Designs of hard Ted include Gorgia Jumper, NMFS hooped TED, Fixed angle TED, Antony Weedless, Flounder TED, Super Shooter (Watson and Taylor 1988), Cameron TED, Jones TED, Thai turtle free device.

Modifications of the basic TED design have been carried out by different nations. Thai Turtle free device was developed by Kasetsart University and SEAFDEC/TD, in Thailand (Chokensanguan et al 1996, Chokesanguan 2000). The AusTED (Australlian trawling efficiency device) was developed in Australia (Mounsey et al 1995, Ribon-Troeger and Dedge 1995, Brewer et al 1998, Robins- Troeger and McGilvray 1999, McGilvray *et al* 1999) and CIFT –TED in India (Dawson 2001).

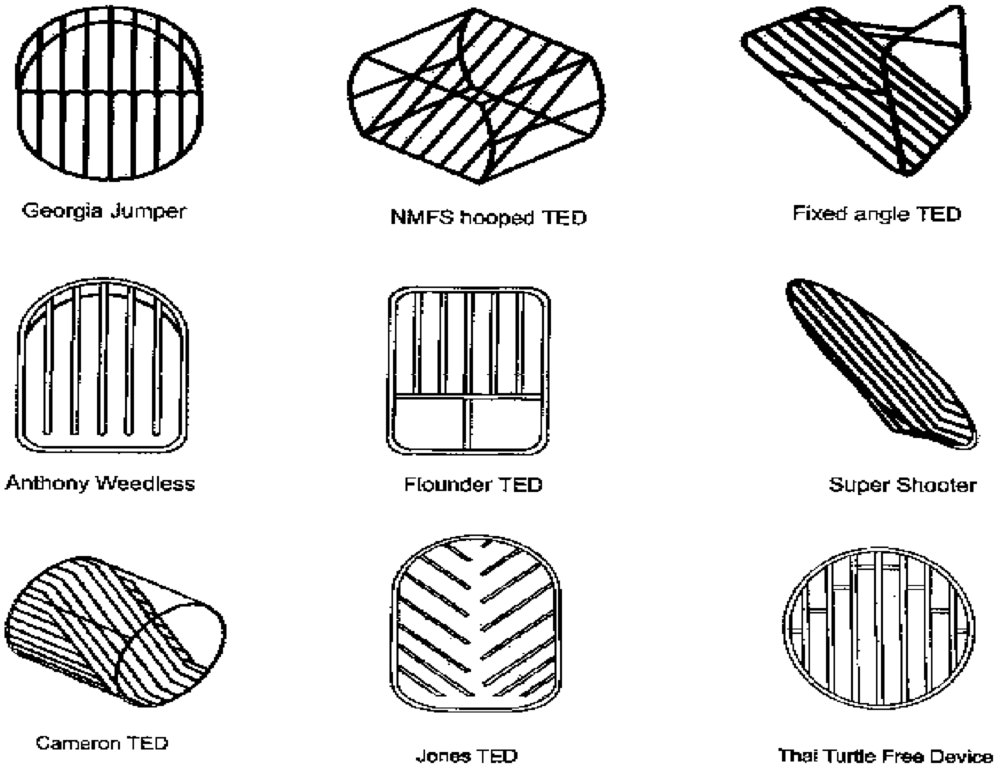

Fig. 2 Variation in single grid hard TED designs

CIFT was closely associated with evaluation of Super shooter TED designs of US origin. as envisaged under the mandate of expert scientific panel along with CIFNET with the support of MPEDA and FSI. Results of the experiments conducted by CIFT to evaluate the Super Shooter TED imported by MPEDA on Matsya Shikari has been detailed. (Boopendranath et al, 2003). The Shooter TED was of 1030 x 850 mm size with a deflector bar gap of 90 mm. 6 Fishing operations were conducted off Andhra, off Kalingapatnam at a depth of 45 – 55 m. The catch retained in the cod end comprised of catfish, perches, pomfret, seer and carangids. No turtle was retained in the experiment.

Experiments continued along the Bheemili and Chilka with an addition al exit hole cod end provided at the exit hole to retain the catch excluded due to the installation of TED in the trawl net (Fig 3). During the 5 operations which was done at a depth of 45 -140 m a total of 676 kg was landed of which 469 kgs was retained in the main cod end. The results indicated an overall escapement of 30.8 % fin fish. Turtles were not retained in the main cod end or exit hole covered cod end (Ramarao, 1995 a).

During the operations off Andhra Pradesh using Super shooter TED on board MV Skipper in the depth range of 36 -50 m (Kirubakaran et al, 2002) two turtles were excluded during the operation. The TED operations with Exit hole at the top of the net resulted in a catch loss of 13.7 %, while operations with exit hole at the bottom resulted in a catch loss of 43.3%. (Kirubakaran et al, 2002).

Unlike fishers in USA, Australia and other advanced maritime nations, fishers on the Indian coast target both shrimp and non-shrimp resources. Experiments with TED designs which have a deflector gap of less than 90 mm in Indian waters, though successful in excluding turtles showed poor performance in retention of targeted non-shrimp catch components. Hence these TEDs are not considered suitable for Indian conditions, nor were they acceptable to Indian trawler owners and operators (Mishera and Behara 2001)

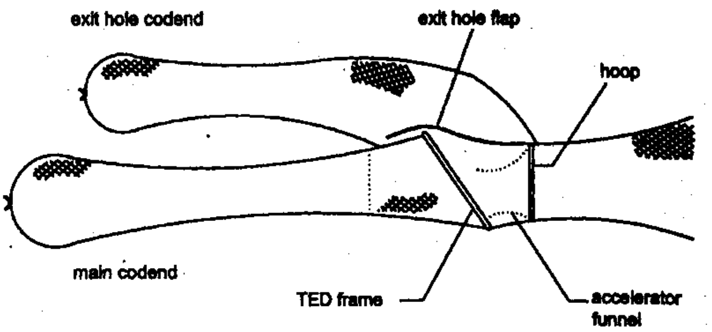

Fig. 3. Details of rigging of exit hole cod end for experimental operations

Development of CIFT-TED

An Indigenous design of TED was developed at CIFT with a focus on reducing by catch loss. THE CIFT-TED is a simple single grid hard TED with a top opening. The device can be fabricated and installed with minimum training using locally available infrastructure and net making skills at a cost of approximately Rs. 2500. The design, construction, installation and operation of CIFT-Ted have been elaborated by Dawson & Boopendranath (2002) (fig 4 -8).

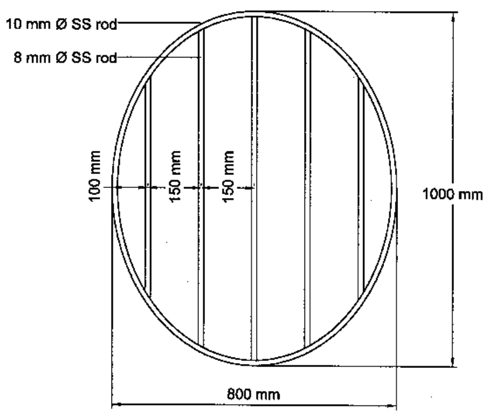

Fig 4. 1000 x 800 mm CIFT-TED

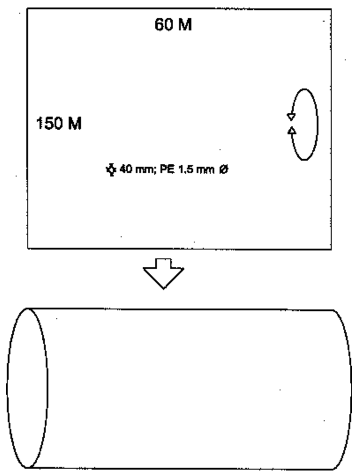

Fig 5. Construction of CIFT TED Extension

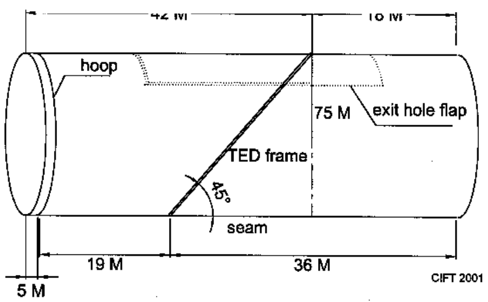

Fig 6. Fixing the grid at the correct angle

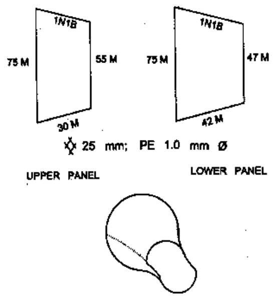

Fig 7. Construction of accelerator funnel

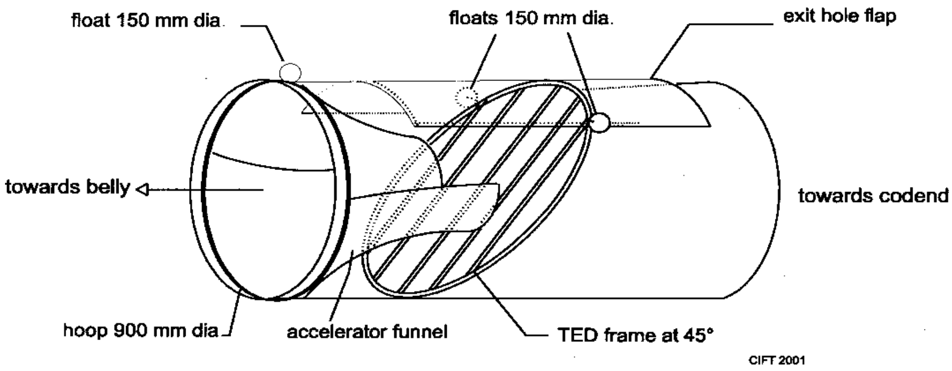

Fig 8. Perspective view of TED Extension

Area	No of hauls	No of hours	Catch retained(kg)	Catch loss(kg)	Catch loss (%)
Paradeep (Orissa)	7	7	422.6	14.3	3.3
Dhamara (Orissa)	1	1	79.23	0.07	0.08
Astrang (Orissa)	1	1	50	0.05	0.1
Bahabalpur (Orissa)	1	1	22	0.3	1.36
Balaramagad (Orissa)	1	1	44	0.8	1.81
Visakhapatnam (A.P)	5	5	69	0.13	0.18
Kakinada (A.P)	6	6	133	1.8	1.35
Nizampatnam (A.P)	2	2	35	0.25	0.71
Krishnapatnam (A.P)	1	1	25	0.7	2.8
Vadarevu (A.P)			10	0.2	2
Total	25	25	889.83	18.6	2.09

Table 1. Details of TED installed trawl operations along east coast coast

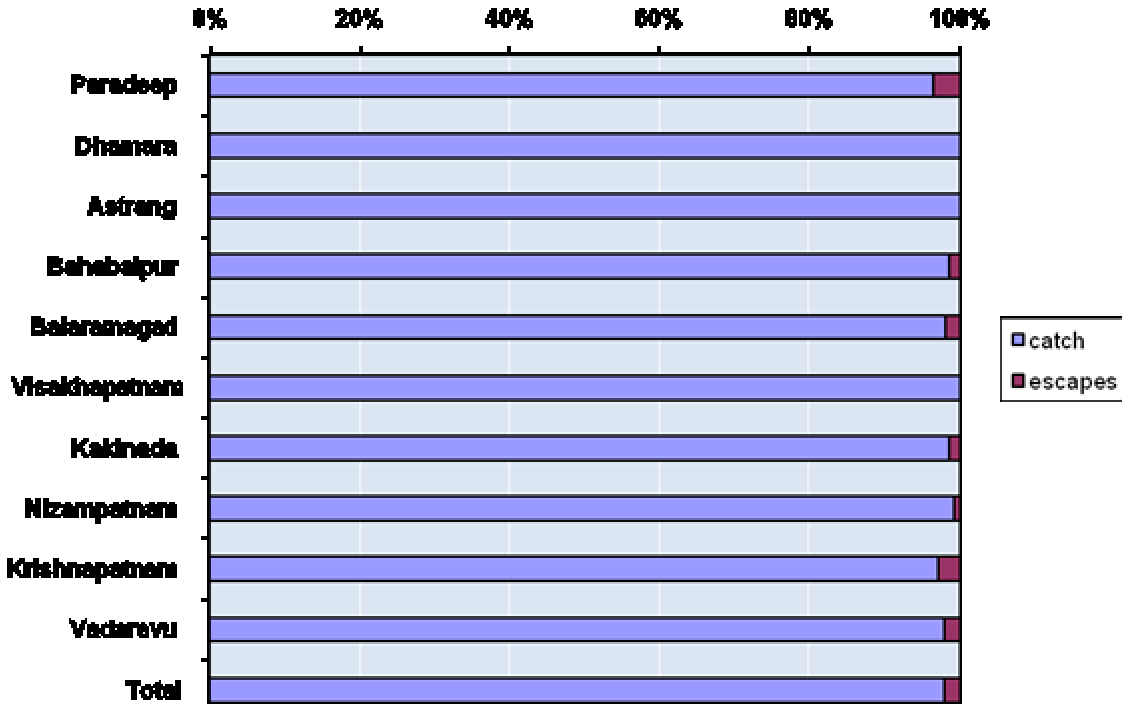

Fig 9. Relative exclusion and retention rates during CIFT-TED installed operations along the east coast of India

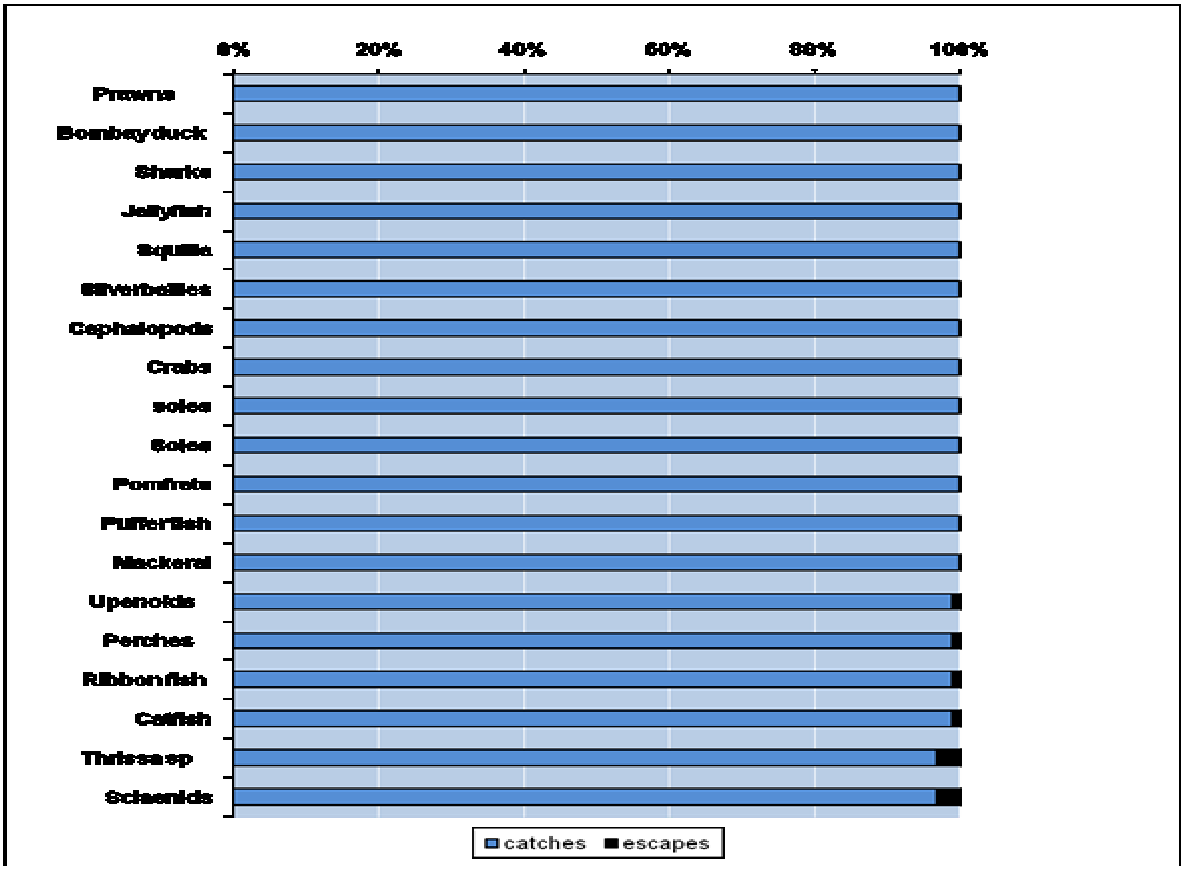

Fig 10. Relative exclusion rates of different species groups after installation of CIFT-TED during experimental trawling along east coast of India

Field trials and demonstration with CIFT-TED along the east coast of India

Field trials with CIFT-TED along the east coast of India so far have shown a mean catch loss in the range of 0.52-0.97% for shrimp and 2.44-3.27% for non-shrimp resources, which is considerably less than the loss incurred during the operations with imported TED designs. The loss of finfish catch is expected to vary from zone to zone and from season to season, depending on the percentage representation of large finfishes and elasmobranchs in the trawl catch. As turtle exclusion in TED is dependent on a physical separation process based primarily on size differences, there is no way available to retain finfishes larger than that could be et in through deflector bar spacing. It is to be noted, however, that large species that are excluded due to installation of TED are not lost to the fishery as a whole, as they can be caught by other fishing techniques in vogue in the fishing area. Studies conducted under a WII project during November 2001 – March 2002, off Gahirmatha, Paradip and Debi (Orissa) between 11 to 24 m depth have further substantiated the efficacy of the CIFT-TED in saving sea turtles with minimal catch loss (Gopi et al., 2002). Results of 51 hauls showed 100% escapement of 21 sea turtles that entered the trawl, and catch loss ranging from 2.3 to 10.3%. Demonstrations conducted by SIFT, Kakinada, from commercial trawlers in 25–40 m depth have shown that the reduction in catch due to installation of TED is minimal. The percentage loss of catch of finfish and shellfish during the 15 demonstrations off Andhra Pradesh ranged from 0.5 to 3.6% (Sankar and Raju, 2003).

Challenges and prospects

Use of the TED among trawler fishermen has been constrained by a lack of incentive-disincentive scheme to facilitate its adoption. Though several maritime states such as West Bengal, Orissa, Andhra Pradesh and Kerala have TED regulations under the Marine Fisheries Regulation Acts, its implementation has not been sufficiently effective so far. This points to the need for a sufficiently attractive incentive scheme for encouraging the use of TEDs. This may take the form of better price realisation for the produce derived from TED-installed operations or TED-use linked subsidy scheme for fuel, as well as effective changes in the enforcement, preferably under a co-management regime, involving all concerned stakeholders.

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Bycatch issues in longline operations and mitigation strategies

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Introduction

Long line fishing is employed by both artisanal and mechanized sectors (Kurien and Willmann, 1982). It is considered as one of the best methods of fishing that ensures sustainability due to the least impact exerted on the surrounding environment and the catch can be selective (Rouxel, 2017). For example, any fish too small, or not the right species can be placed back into the water, without harm. These gears make it possible to operate in places with rocky or uneven bottom where it is impossible to deploy gears like ring seine or trawls (Mathai, 2009). Long lining can be used to target both pelagic and demersal fish with the lines being rigged and set at a position in the water column to suit the particular species. A basic long line consists of a long length of line, light rope or more common now is heavy nylon monofilament, the 'main line', this can be many miles in length depending on the fishery. To this main line, multiple branch lines with baited hooks on (snoods) are attached at regular intervals. This rig is set either on the seabed (demersal) or in midwater (pelagic) with a 'dhan' bouy at either end, and allowed to fish for a period.

Longlines can be further classified as 1. Set longlines: These are stationary lines that are anchored to the vessel, the seafloor or to an anchored buoy. Setting can be practised either horizontally or vertically. 2. Drift longlines: these are attached to floats that drift freely with the ocean currents.

Species Targeted in Long line fishing

In the Indian seas, longline fishery is mainly targeting yellowfin and bigeye tunas. As reported elsewhere (Shivasubramaniam, 1963; Pillai and Honma, 1978) the bycatches, especially sharks constitute a major portion of the longline catch in the Indian waters also. Mechanized sectors of Kerala, Tamil Nadu, and Andhra Pradesh rely on longlining for high value fishes like tuna, marlin, sail fish and sharks. In Kerala, landings from hooks and lines fishery contribute about 3.3% of the total fishery. Seerfish landings registered an upward trend with 83.3% increase from 2010 to 2011, out of which 54.7% was contributed by longline in Kerala (CMFRI, 2012). During 2011, 50.8% of elasmobranch catch was contributed by line fishing and grouper contributed about 15% by longline. In Tamil Nadu, 10.6% of seerfish, 1.2% of tuna and 4.2% of elasmobranchs were contributed by hook and line (CMFRI, 2012). In Visakhapatnam, annual catch of tuna recorded by hooks and lines was 2714 t during 2011 constituting dominant species, *Thunnus albacares* (53%), *Katsuwonus pelamis* (31%) and *Euthynnus affinis* (16%) (CMFRI, 2012). According to CMFRI (2012), a total of 29 longliners are operating in Kerala coast, 380 in Tamil Nadu and 21 in Andhra Pradesh during 2010 (Vipin et al., 2014).

Bycatch scenario in longline fishing

Since the numbers of species caught are less in a single operation, average mortality rate is assumed to be less than other fishing methods considering population parameters. Line fishing catches desired fishes during operation and unlike trawls, it avoids contact with the sea bottom hence it is assumed that very few species are affected other than targeted species. In a multispecies fishery like India, bycatch reduction has always been challenging (Lobo, 2012). Since the selectivity of line fishing is prominent, concern for bycatch is considerably less alarming.

Surface long lines for dolphinfish practised in the Atlantic had a high bycatch of seabirds (0.147 birds/1000 hooks). However, the traditional pelagic longline captures seabirds during winter months (Neves et al., 2006), while the surface longline for Dolphinfish takes place during summer in the Atlantic (Swimmer et al., 2005). A range of characteristics including low depth, deployment during daylight hours, and use of small hooks make it particularly dangerous for seabirds by being available throughout fishing and not only during deployment as in the longline for Swordfish and tuna. Catch rate of sea turtles was also high in the surface longline for Dolphinfish (1.08 turtles/1000 hooks) comparable to rates reported in the pelagic longline fishery for Swordfish in the SW Atlantic of 0.68–2.85 turtles/1000 hooks (Domingo et al., 2006).

Sharks and cetaceans cause significant damage worldwide in pelagic longline fishery operations. Damages are in the form of bite-offs, loss of gear, catch displacement, reduced gear efficiency, and depredation of the catch (Yano & Dahlheim, 1994; Secchi and Vaske, 1998; Garrison, 2007). The experimental longlines operated in Indian waters showed a very high shark catch during the post-monsoon season in the Bay of Bengal (John and Neelakandan, 2004).

Advantage of longline fishing

Long line is more selective than other types of fishing in terms of species and size, and provides high quality fish (Erzini et al., 1996). The method can be used in spawning fish as they normally only bite after completion of spawning (Farmer et al., 2017). Lines are set for a relatively short time so that any unwanted species can often be returned live to the sea. Advantages of longline fishing is listed below

a. **Quality of end product:** while comparing meat quality from long line fishing and trawl caught fishes, line caught fishes exhibit firmer as well as whiter meat. The better quality may be due to better bleeding and less compression damage. Both the compression damage and the poor bleeding out are caused because trawling brings up from five to twenty tons of fish onto the deck each time, while with long-lining the fish are brought on board one by one.

b. **Lower fuel consumption:** A significant advantage that longliners have over trawlers is the relatively low fuel consumption per unit of catch. For example, it was established that a trawler expends 0.6-1.5 tonnes of fuel per tonne of raw fish caught, while a longliner expends 0.1-0.3 tonnes (Karpenko, 1997; Makeev and Shentyakov, 1981; Pavlov and Makeev, 1987; Glukhov, 1994; Chumakov and Glukhov, 1994a, 1994b; Sorokin and Chumakov, 1995). With regards the amount of fuel used over time, the longliner spends 2.7 times less fuel every hour than a trawler (Zherebenkova and Makarova, 1990). The results of modern-day research in the Barents Sea show that a longliner spends 0.3-0.6

tonnes of fuel per tonne of raw fish caught (Grekov, 2007a). This is approximately 20-40 % of the fuel consumption of a similar type trawler (Bjordal and Lokkeborg, 1996).

c. **Species selectivity:** In general, neither the trawl nor the longline can be considered as fishing gears that have a high selectivity towards some species of fish. Trawl can hardly be called a selective fishing gear as it takes almost everything that comes into a forenet (Bjordal and Løkkeborg, 1996). As for the longline, it is more selective because of its passivity. The catch depends mostly on the behaviour, biology and physiology of the fish. In particular, most fish cannot be caught by a longline as they are simply unable to swallow a hook (Lokkeborg, 2000). According to the work carried out at Barrent Sea, twenty-nine species of fish are harvested by longline. When carrying out trawler-acoustic counting of ground fish stocks, up to 70 types of fish were recorded in trawls (Grekov, 2007).

d. **Size selectivity:** As the number of hooks on a longline is limited, the hooking of a large fish reduces the number of free hooks and so lowers the chances of catching juveniles. Furthermore, the hook itself is selective regarding fish size as small-sized fish can swallow a baited hook of no larger than a certain size. By changing the size of the hook and bait, therefore, one can satisfactorily control the volume of by-catch of small-sized fish (Grekov, 2007).

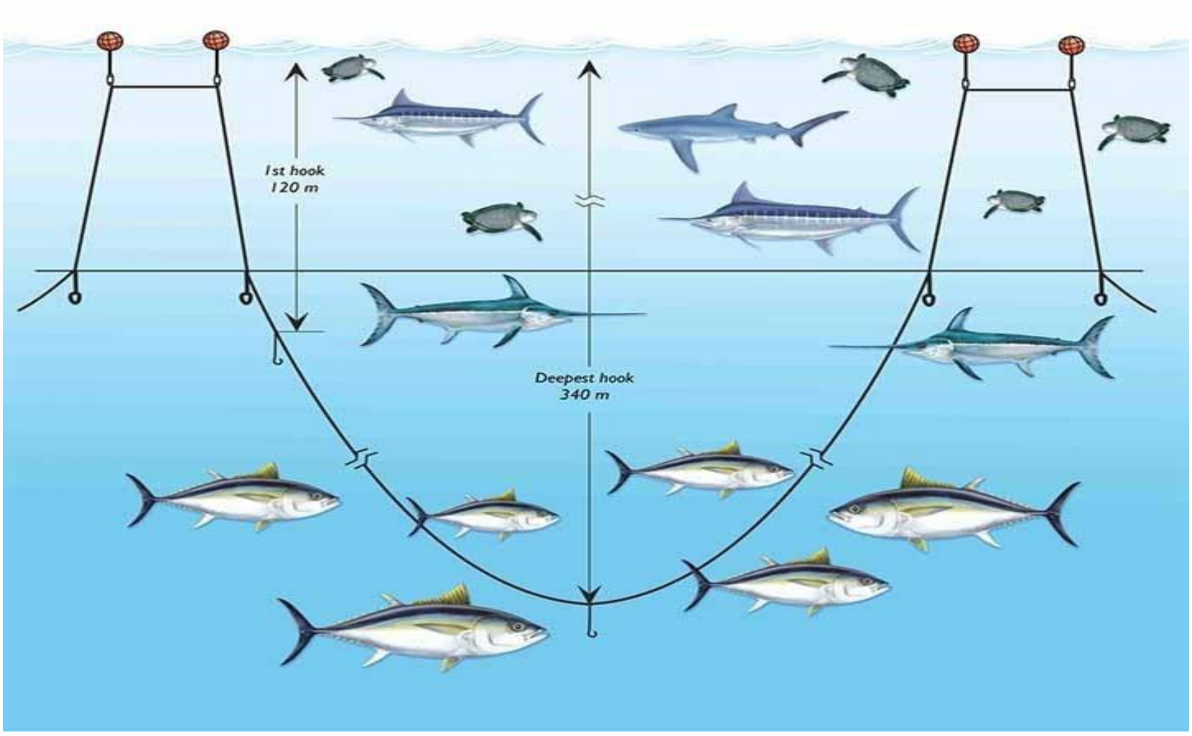
e. **Value of fish products:** In general, the larger the fish, the higher its value. There are more large fish in logline catches and longliners tend to catch more products of large size. Consequently, more income is generated. According to verbal information provided by ship owners, the market value of fish produced by longliners is 15-20 % higher than for trawlers, largely because of the higher quality of product harvested by longliners

Conservation of non-targeted resources

Major bycatch in line fishing are turtles, seabirds, sharks and non-targeted fishes. The most discussed case is the incident of turtles in tuna long line. There are many methods adopted by sector all around the world for the conservation of these resources. Methodologies developed specifically for each organism. These methodologies are listed below:

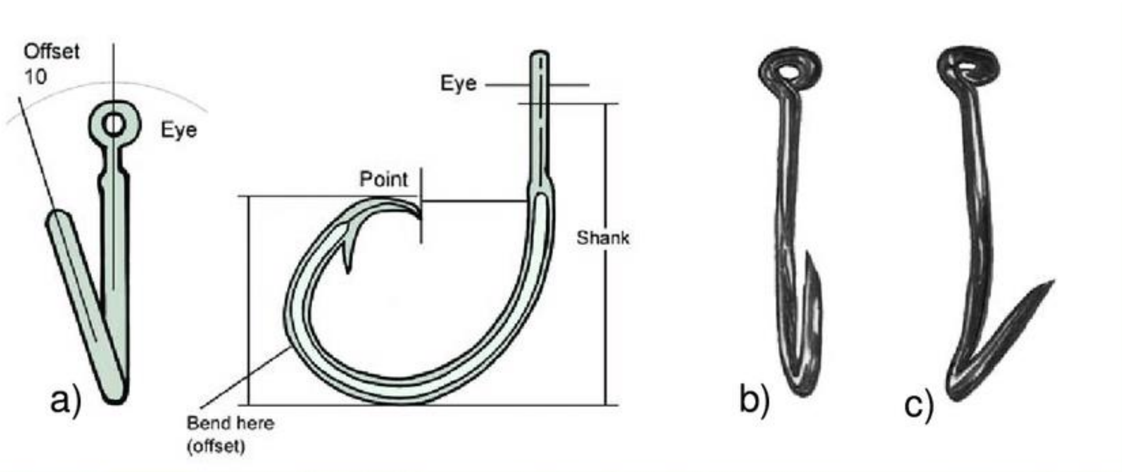
a. **Avoid hotspots:** Hotspots are the location where the unwanted species are caught in large quantities. There is currently no quantification of what constitutes a hotspot. This would be left to the fishermen to determine if they are fishing in an area that is resulting in the incidental capture of sharks, sea turtles, sea birds, marine mammals or unwanted fishes.

b. **Set operational depth to deeper or shallow waters**: This may work in case of shark species which swim to the surface waters. Setting line deeper than 100m will avoid most of the species and only yellow fin tuna may come in contact.



Deep and shallow water setting of long lines. Courtesy: Swot,2006

c. **Use circle hook with offset:** Circle hooks have a rounded shape with a point oriented toward the shank, which is different than the J hook that has a point oriented parallel to the shaft. Circle hooks are wider and therefore more difficult for sea turtles to become hooked on. The offset creates a larger gap between the point and the shank hence the turtles can escape from accidental hooking. Similar to other species, circle hooks are wider and more difficult for some marine mammals to bite and become hooked on. Bill fishes are also known to escape from circle hooks without incidents of hooking. Use of wider circle hooks in place of narrower J and tuna hooks to reduce turtle bycatch rates and mortality in longline fisheries has also been found to reduce seabird bycatch rates by about 80% (Gilman, 2011)



Courtesy: FAO, 2009

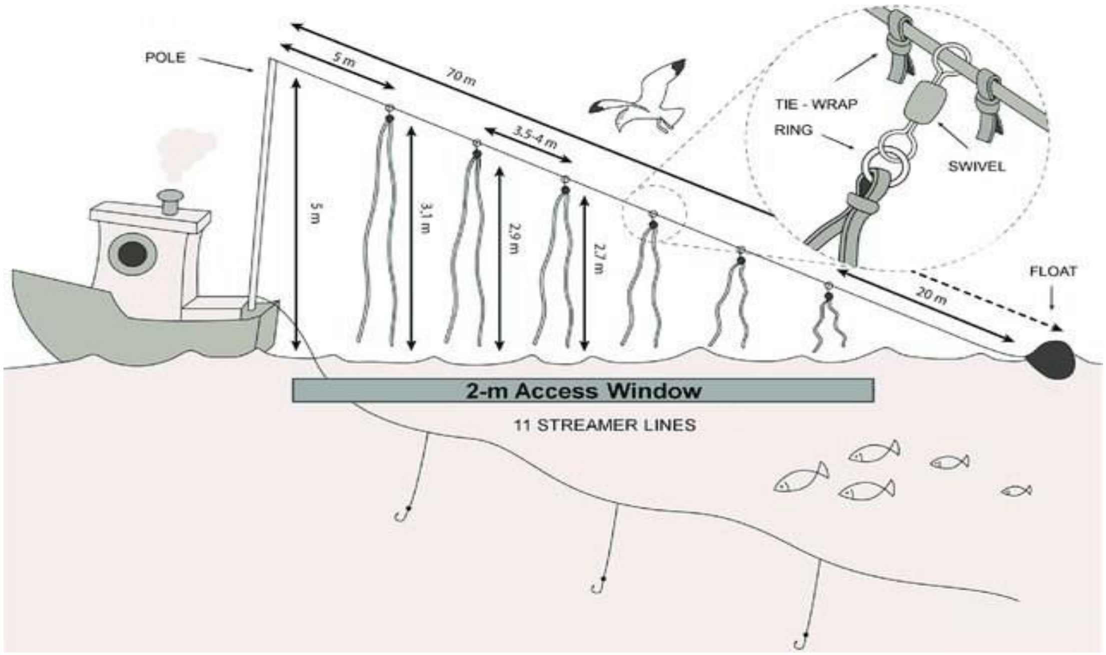
d. Line weighting: Weights are added to the branch line so hooks are quickly deployed to the target fishing depths. This reduces bycatch of seabirds by moving the baited hooks out of the diving range of seabirds. The effectiveness of line weighting depends on the distance between the weight and the hook (a short distance accelerates the initial sink rate) and the amount of weight added (greater weight accelerates the subsequent sink rate). This mitigation measure must be used in conjunction with properly deployed streamer lines or night setting in case of seabird interaction. Using weight or lead swivels of minimum weight 45g within 1m of the hook may reduce sea turtle interaction also.

e. Use of finfish bait: Using finfish instead of squid for bait has been shown to reduce sea turtle interactions. This may be more effective for leatherback sea turtles compared to other species. Using finfish instead of squid for bait has been shown to reduce interactions with some but not all shark species

f. Night setting: Night setting is the practice of setting and hauling fishing gear between dusk and dawn. No modifications to fishing gear are needed and this has been proved to avoid sea bird interaction to logline.

g. Shorter soak time: This reduces the amount of time the gear is in the water, reducing potential interactions. It also may reduce mortality in incidentally captured turtles because they remain hooked for a shorter period of time Adequate soak time reductions would be species/fishery specific. The challenging part is to determine soaking time for specific species with experimental fishing.

h. Streamer line (tori or bird scaring line): An extra line will be dropped behind the boat with streamers that is towed from a high point as the baited hooks are deployed (usually near the stern). An aerial segment with streamers suspended at regular intervals is formed as the vessel moves forward, creating drag on the streamer line. The mitigation measure works by maintaining the streamer line over the sinking baited hooks, therefore preventing seabirds from attacking the bait and becoming hooked.



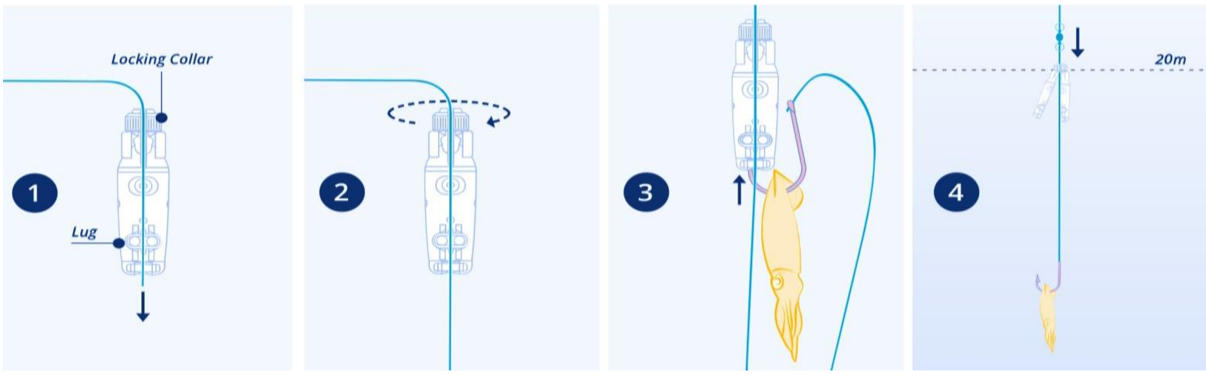
Courtesy:Vero & Jacob, 2018

i. **Conduct fleet communications:** This will allow fishermen and policy makers to determine where marine mammal sightings may have occurred and move fishing locations when interactions occur

j. **Prohibit the use of wire leaders and shark lines:** Shark lines are attached to the floats and stay above mainline of longline. Wire leaders prevent sharks from being able to bite through and escape after accidental capture. Shark lines may attract more sharks to the fishing gear.

k. **Removing the first and/or second hooks closest to the float in each basket:** The hooks closest to the float fish in shallower water and therefore have a higher likelihood of incidentally capturing sea turtles.

l. **Hook-shielding devices:** These are devices that encase the point and barb of baited hooks. This prevents seabird attacks during the setting process. Hooks are released after the hook has reached a minimum of 10m depth or has been in the water for a minimum of 10 minutes. The Hook Pod and Smart Tuna Hook are two devices assessed as having met ACAP (Agreement on the Conservation of Albatrosses and Petrels) performance requirements.



Hook pod being detached after deployment. *Courtesy: Hookpod Limited, Devon, UK*

The shield gets fitted to a baited Smart Tuna Hook. *Courtesy: ACAP, 2015*

m. **Use 'weak' hooks:** These are specially designed hooks that break or bend when certain amount of pressure is applied, allowing incidentally captured species the ability to escape. Mostly used in case of marine mammal incidents as they are stronger than fishes.

n. **Restrict the use of light sticks:** This may reduce billfish interactions by lessening the ability to see baited hooks. Turtles are also found attracted to light sticks.

o. **Use of monofilament for the mainline and branch line:** Monofilament line reduces the risk of entanglement compared to multifilament lines. Monofilament is less flexible, making it easier to release entangled sea turtles (i.e. reduces knotting of the line).

p. **Time/area closures:** Time-area closures and restrictions on the timing of setting could further reduce seabird bycatch as these factors have been observed to have significant effects on seabird catch rates

q. **Cover the point of the hook:** This will reduce the ability of sea turtles to bite and become hooked.

r. **Avoid using light sources:** This may reduce sea turtle interactions by lessening the ability of turtle to see baited hooks.

s. **Fisheries certification:** It is important to recognise and reward good fishing practices in the market place. Among the most popular seafood certification organisations is the Marine Stewardship Council. The Council certifies fisheries based on the sustainability of fish stocks, the level of environmental impact (one of the parameters is that the fisheries should have negligible/low levels of bycatch), and whether the fishery is being effectively managed. A fishery that comes close to meeting these criteria of sustainability is the pole and line skipjack tuna fishery in the Lakshadweep. However, it is important to recognize the dynamic nature of what constitutes bycatch and evolve incentive systems which recognise the moral, social, and economic implications of bycatch along with its ecological impacts. It is equally important to understand that certification alone is not likely to bring about major improvements in the conservation of bycatch species. So far certification has primarily been effective in raising awareness among consumers (Ward, 2008). Its shortcomings are that it is seen primarily to market opportunities, and has rarely, if ever, helped the recovery of depleted species (Jacquet et al. 2009; Jacquet et al. 2010).

Conclusion

Line fishing methods especially longline and pole and line widely used in Indian waters has advantages in biological and economical aspects as discussed earlier. Considering the current production from line fishing where tuna is targeted, production level has to fill in the huge gap with estimated potential of tuna from coastal fishing and island fishing. However, it is also to be noted that line fishing has the clear drawback of needing to use additional biological resources in the form of bait especially live bait for. The large scale development of the line fishery is one of the means of optimizing exploitation of resources from Indian waters. At the same time, it is necessary to understand that development of the fleet must not only be aimed at increasing size but also at increasing efficiency.

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Methods for checking conformity of fishing gears to legal sizes/shapes

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Introduction

India, the second largest producer of fish in the world, employs over 14 million people in fishing and aquaculture. The marine capture fisheries is characterized by almost stagnant or at times declining fish catches, overfishing, overcapacity, increasing landing of bycatch/discards, increasing conflict over fish resources, mounting investment needs, and export market fluctuations. Since the last decade most of the major commercially exploited stocks are showing signs of over exploitation. However, demand for fish and fishery product is increasing considerably, both at the domestic and export front. It is therefore necessary to have some measures to control fishing in order to ensure the optimum utilization of the resources and reasonable economic returns to the fishermen. The principal purpose of fishery regulations and controls is to ensure a high, but sustainable yield to the fishery.

In situations where fishing effort is unregulated, there is the possibility that effort may become so high that there is a danger of a stock collapse, due to a depleted spawning stock and a resultant recruitment failure. If this danger exists, and it is not practical to regulate fishing effort directly, an increase in mesh size may be a useful alternative means of conserving the spawning stock. A suitable choice of mesh size should reduce the rate of capture of juveniles, and make it more likely that an individual will survive to the size of first maturity and have an opportunity of spawning at least once. A change of mesh size can usually be regarded as beneficial if it causes catches, in the long-term, to be greater than they otherwise would have been. A mesh regulation does not necessarily lead to an increase in the absolute level of catches, however, since these will continue to be influenced largely by natural variations in the level of recruitment.

Basic terms in netting

Fibre*:* It is the basic material of netting. Its length should be at least 100 times its diameter.

Netting yarn**:** Standardized universal term for all textile material which is suitable for the manufacture of netting for fishing gears and which can be knitted into netting by machine or by hand without having to undergo further process. Yarn is made into a netting by twisting or braiding. Monofilaments are used directly for making into netting without further process.

Netting twine/ folded yarn: is a netting yarn which is made of two or more single yarns or monofilaments by only one twisting operation.

Cabled netting twine: Combines two or more netting twines by one or two further twisting operations. Fibres are combined to form single yarns. Several single yarns are twisted together to form a netting twine. Several of these folded yarns or netting twines are twisted together by a secondary twisting operation to form a cabled netting twine.

Braided netting yarns**:** These are produced by interlacing a number of strands in such a way that they cross each other in diagonal direction. These braids are usually in the form of tubes. The braided netting yarns are available with or without core. Core is the term used for single yarn, twisted yarn or monofilaments which do not belong to the braided tube but fills the space inside the tube.

***Netting*:** Netting is defined by ISO as a meshed structure of indefinite shape & size, composed of one yarn or one or more systems of yarns inter laced or joined or obtained by other means for example by stamping or cutting from sheet material or by extrusion

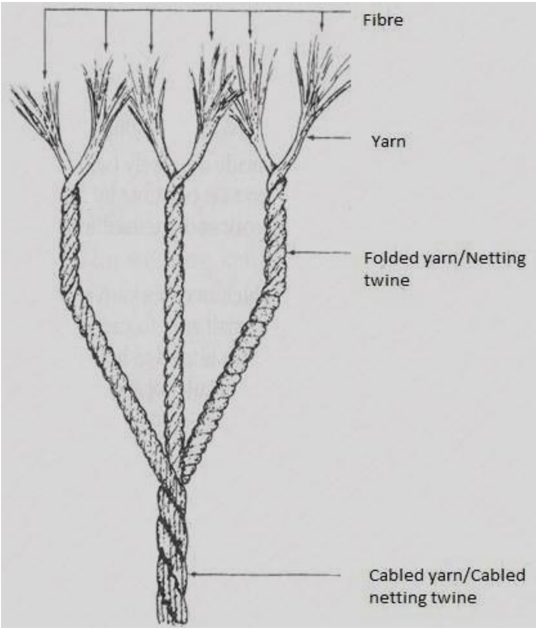

Fig.1. Basic structure of netting twine

Mesh: a design-formed opening, surrounded by netting material

Diamond mesh: a mesh composed of four sides of the same length

Square mesh: a diamond mesh in which adjacent sides are at right angles

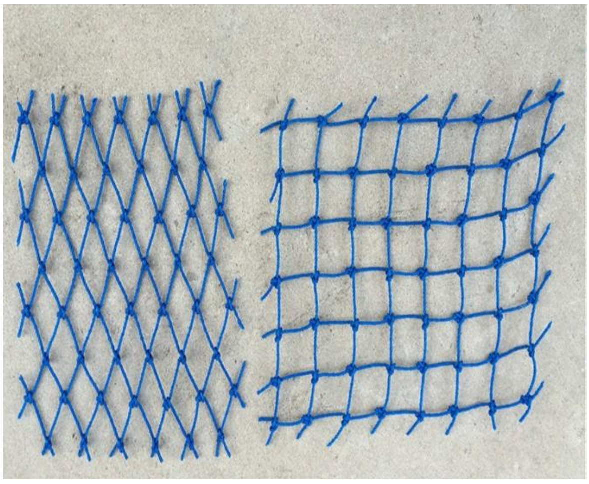

Fig.2. Diamond mesh and square mesh

N-direction: the direction at right angles to the general course of the netting yarn

T-direction: the direction parallel to the general course of the netting yarn

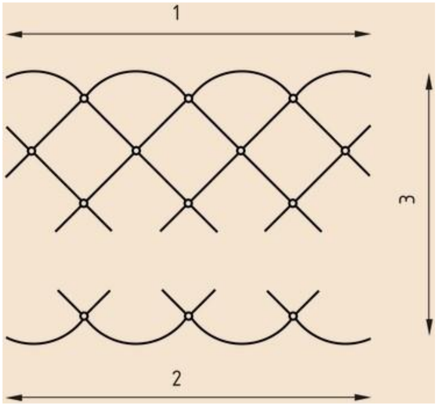

Fig.3. 1-T-direction (length wise); 2-General course of the netting yarn; 3-N-direction (depth wise)

Length of mesh side /half mesh/mesh bar: The distance between two sequential knots or joints, measured from centre to centre when the yarn between those points is fully extended.

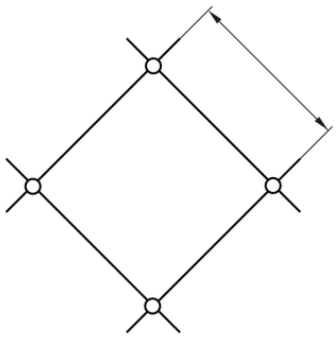

Fig.4. Length of mesh side/half mesh/mesh bar

Mesh size/length of mesh - The distance between the centres of two opposite knots in the same mesh when fully extended in the N direction. For square mesh, mesh bar is usually measured and mesh size is obtained by multiplying by 2.

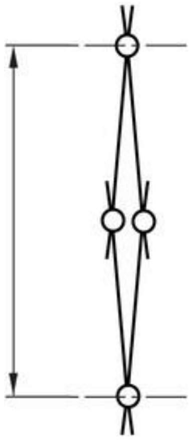

Fig.5. length of a mesh

Opening of mesh/mesh lumen - The longest distance between two opposite knots in the same mesh when fully extended in the N direction. For square mesh, opening of mesh is the distance between centres of two opposite mesh sides or mesh bars.

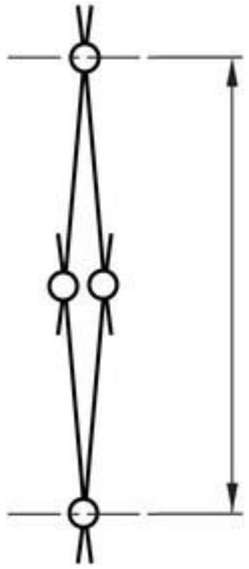

Fig.6. Diamond mesh opening

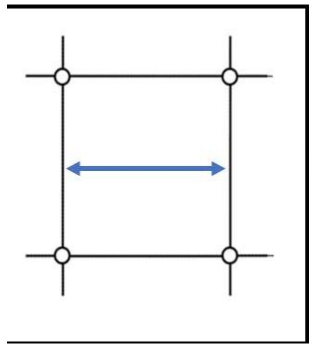

Fig.7. Square mesh opening

Method for determining mesh size-length of mesh

The Indian Standard,IS 15789: 2008: *Method of test for the determination of mesh size-length of mesh* can be followed for measurement of mesh size. The specimen to be tested in the dry state shall be exposed to the standard atmosphere at 65 ± 2 percent relative humidity and $27^0 \pm 2^0$C temperature until they reach a moisture equilibrium for a period of 24h. Samples to be tested in the wet state shall be immersed in tap water, at a temperature of (20 ± 2^0C) for a period of not less than 12h. Surplus water shall be shaken off.

Straighten the netting manually in the N-direction. Using a ruler, the distance from the first knot or joint inclusive shall be measured with an accuracy of 1mm upto 10knot (exclusive). The mesh length is obtained by dividing the measured length by 5. At least 10 single measurements from different parts of netting shall be carried out. Record the size of the mesh in millimeters for each measurement and calculate the average size of the length of mesh rounded upto next millimeter. The mesh size is expressed as millimeter and the coefficient of variation and the confidence interval is also often given.

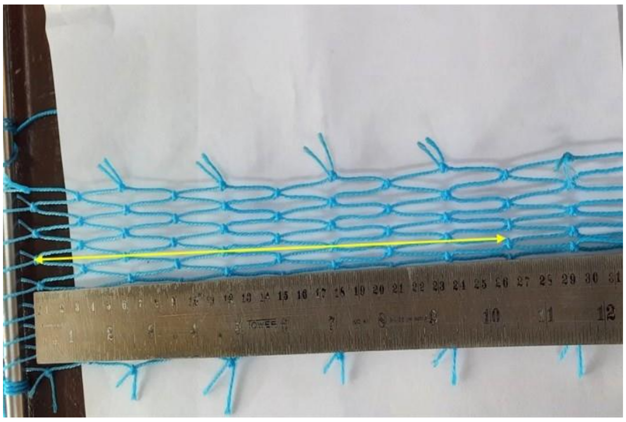

Fig.8. Mesh size measurement

Method for determining mesh size- opening of mesh (mesh lumen)

A mesh gauge is usually used for measuring opening of mesh. Indian standard IS 15789: 2008: *Method of test for the determination of mesh size-Opening of mesh* can be followed for determination of opening of mesh . A flat wedge gauge is inserted perpendicularly to the netting plane in the N direction for knotted netting by applying a constant force. The gauge shall be of 2mm thick, flat and shall have 2 tapering edges with a taper of one to eight. They shall have a hole at the narrow end. The edges of the gauge shall be rounded with a radius of 1mm. Either printed or engraved markers ending 2mm from the edges shall be used. The scale shall be graduated at intervals of 1mm, 5mm and 10mm. Different sizes of gauges are required to cover various ranges of mesh sizes.

The mesh opening will depend on the force exerted on the gauge and hence measuring force is also specified. Insert a gauge by its narrow end into the mesh opening perpendicular to stretched netting plane. Insert the gauge into the widest mesh opening using a suitable measuring force until it is stopped by the resistance of mesh. For netting of a mesh size of 50mm or less, a force equivalent to a mass of 2kg shall be applied. For mesh size above 50mm upto 120mm, a force equivalent to a mass of 5kg shall be applied and for netting of above mesh size of 120mm, a force equivalent to a mass of 8kg shall be used. Measure a minimum of 20 consecutive meshes. The size of each mesh shall be the width of the gauge at the point where gauge is stopped. The width shall be read at the top of the twine making sure that the same readings are obtained at both edges of the gauge. Record the size of opening of the mesh in millimeters for each measurement and calculate the average size of the opening of the mesh rounded upto next millimeter.

OMEGA mesh gauge

The OMEGA gauge is a new objective mesh gauge which can make precise and objective measurements of mesh opening that are free of human influence, on a wide range of netting material (Fonteyne et al., 2007). The OMEGA mesh gauge is an electric driven instrument that applies a pre-set longitudinal force to the mesh to be measured (Fonteyne, R. 2005). Once this force is achieved, the exact opening of the gauge is measured automatically. Mesh opening and measuring force are simultaneously shown on the digital display. When a series of measurements has been finalized, the mean mesh opening and number of measurements made will be displayed. OMEGA gauge was developed under an EU funded Combined R&D and Demonstration Project to make objective mesh measurements according to the protocol recommended by the ICES.

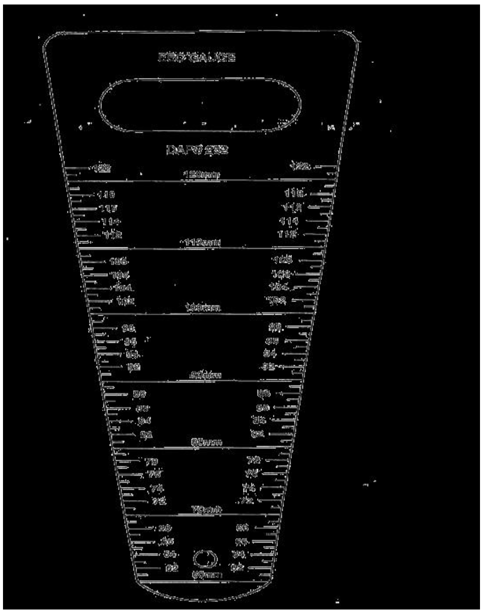

Fig.10.OMEGA mesh gauge

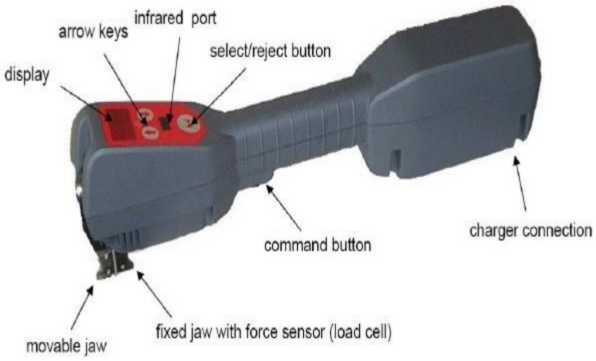

Fig.9. Flat mesh gauge

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Identification of fishing gear materials and testing procedures

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Introduction

Netting materials for fabrication of fishing gear are either of textile or non-textile origin. The raw material for fish netting consists of fibres which can be distinguished into two groups: natural fibres and man-made fibres. Different kinds of fibres originating from plant and animal body parts have been used for production of textiles and other products are termed as natural fibres. Traditional fishing gears used earlier, till 1950s were mainly with natural fibres such as cotton, manila, sisal, jute and coir. Natural polymers and synthetic polymers constitute man-made fibres. Natural polymers are manufactured by the alteration of natural polymers like cellulose and protein while synthetic polymers are obtained by synthesis or chemical process. Man-made fibres derived from cellulose eg: rayon, are susceptible to microbial deterioration while synthetic fibres are very resistant to biodeterioration. In the late 1950s, with the introduction of man-made synthetic fibres, natural fibres used for the fishing gears have been substituted by these synthetic materials. This transition was mainly due to the highly positive properties of these fibres such as highly non-biodegradable nature, high breaking strength, better uniformity in characteristics, high abrasion resistance, low maintenance cost and long service life.

Synthetic fibres

Synthetic fibres are produced entirely by chemical process or synthesis from simple basic substances such as phenol, benzene, acetylene etc. The chemical process involves the production of macromolecular compounds by polycondensation or polymerization of simple molecules of a monomer. The raw materials are petroleum, coal, coke and hydrocarbon. Depending on the type of polymer, synthetic fibres are classified into different groups and are known by different names in different countries. Altogether seven groups of polymers are developed; most important polymer/synthetic fibres used in fishing gears are polyamide (PA), polyester (PES), polyethylene (PE) and polypropylene (PP). Other synthetic fibres, which are less widely used and generally restricted to Japanese fisheries, are polyvinyl alcohol (PVA), polyvinyl chloride (PVC) and polyvinylidene chloride (PVD). Aramid fibres, Ultra high molecular weight polyethylene (UHMWPE) and liquid crystal polymer are later additions to this group.

1. ***Polyamide (PA)*:** Polyamide, a synthetic polymer, popularly known as nylon, invented in 1935 refers to a family of polymers called linear polyamides. Nylon consists of repeating units of amide with peptide linkages between them. Depending on the raw material and method of making two types of nylon viz., PA 6 and PA 66 are available for fibre applications. PA 66, widely used for fibres is made from adipic acid and hexamethylene diamine while PA 6 is built with caprolactam. With regard to the fisheries, there is no difference between PA 66 and PA 6, while in India, for fishing purposes PA 6 is used. The softness, lightness, elastic recovery, stretchability and high abrasion and temperature resistance are superior properties inherent to nylon. However, high moisture absorption

along with dimensional instability and requirement of UV stabilization are its disadvantages. On wetting, nylon loses up to 30% of tensile strength and 50% of tensile modulus.

2. ***Polyolefines:*** Polypropylene (PP) and Polyethylene (PE) are often collectively called "polyolefines". Polyolefin fibres are long-chain polymers composed (at least 85% by weight) of ethylene, propylene or other olefin units. Polyolefin fibres are made by melt spinning. They do not absorb moisture and have a high resistance to UV degradation.
3. ***Polyethylene* (PE):** PE fibre is defined as: “fibres composed of linear macromolecules made up of saturated aliphatic hydrocarbons”. PE fibres, used for fishing gear, are produced by a method developed by Ziegler, in the early 1950s.The monomer ethylene, the basic substance of polyethylene, is normally obtained by cracking petroleum. Linear polyethylene or high-density polyethylene has high crystallinity, melting temperature, hardness and tensile strength. In India, PE is used for manufacture of netting and ropes.
4. ***Polypropylene* (PP):** PP fibre is defined as: “fibres composed of linear macromolecules made up of saturated aliphatic carbon units in which one carbon atom in two carries a methyl side group”. This is an additive polymer of propylene. PP was commercialized in 1956 by polymerizing propylene using catalysis. Though PP netting and ropes are available, in India, PP is mainly used for ropes.
5. ***Polyester* (PES):** The principal PES fibres are made from polymerization of terephthalic acid and ethylene alcohol. It was first synthesized by Whinfield and Dickson of Great Britain in 1940-41 and named the fibre "Terylene”.

Recent advances in synthetic fibres

Introduction of synthetic materials with high tensile strength properties has made it possible to bring out changes in the design and size of fishing nets. As the fishing industry became highly competitive, the search and research for new generation materials which give better strength for less thickness resulted in invention of new materials. Aramid fibres, Kevlar, UHMWPE, biodegradable plastic etc are recent introductions to the fishing gear material sector. These materials have advantages, especially less drag which results in fuel efficiency. The performance of UHMWPE webbing and rope in the Indian context is being studied by ICAR-CIFT. Among the new fibre types, only Sapphire and UHMWPE are used on a commercial basis for fishing gear viz., trawls and purse seines in Australia and Alaskan waters. Sapphire is also used on a limited scale in large mesh gillnets targeting large pelagics in Maharashtra region of India.

1. **Aramid fibres:** Aramid fibres are fibres in which the base material is a long-chain synthetic polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings. Two types of aramid fibres are produced by the DuPont Company: Kevlar (para-aramid) and Nomex (meta-aramid), which differ primarily in the substitution positions on the aromatic ring. Generally, aramid fibres have medium to very high tensile strength, medium to low elongation-to-break, and moderate to very high modulus.
2. ***KEVLAR® polyphenylene terephthalamide (PPTA):*** A polymer containing aromatic and amide molecular groups is one of the most important man-made organic fibre ever developed. Because of its unique combination of properties, KEVLAR® is used in the

fishing sector as netting, fishing rod and fishing line. Fibres of KEVLAR® consist of long molecular chains produced from poly (p-phenylene terephthalamide). The chains are highly oriented with strong interchain bonding, which result in a unique combination of properties. The strength to weight ratio of Kevlar is high; on a weight basis, it is five times as strong as steel and ten times as strong as aluminum. It has high tensile strength at low weight, low elongation to break, high toughness (work-to-break), and excellent dimensional stability. In sea water, ropes with KEVLAR® are upto 95% lighter than steel ropes of comparable strength.

3. **Ultra high molecular weight polyethylene(UHMWPE):** UHMWPE is a type of polyolefin synthesized from monomer of ethylene processed by different methods such as compression molding, ram extrusion, gel spinning, and sintering. Polyethylene with an ultra high molecular weight (UHMWPE) is used as the starting material. In normal polyethylene, the molecules are not orientated and are easily torn apart. The fibres made by gel spinning have a high degree of molecular orientation with very high tensile strength. The fibre is made up of extremely long chains of polyethylene, which attains a parallel orientation > 95% and a level of crystallinity of up to 85%. The extremely long chains have molecular weight usually between 3.1 and 5.67 million while HDPE molecule has only 700 to 1,800 monomer units per molecule.

   UHMWPE, also known as high modulus polyethylene (HMPE) or high performance polyethylene (HPPE) is a thermoplastic. It has extremely low moisture absorption, very low coefficient of friction, is self-lubricating and is highly resistant to abrasion (10 times more resistant to abrasion than carbon steel). This is available as Dyneema and Spectra produced by two different companies. Commercial grades of dyneema fibres SK 60 and SK 75 are specially designed for ropes, cordage, fisheries and textile applications

   UHMWPE is 15 times stronger than steel and up to 40% stronger than Kevlar. UHMWPE netting is 3 times stronger than nylon with the same dimension, and increases the net's strength while the abrasion resistance increases the net's life. Netting can be used for trawl nets, purse seine nets and aquaculture nets. Nylon purse seines last for about 2-3 years while UHMWPE netting ensures 2-3 times more life for the net. The netting twines made with dyneema fibre can be reduced by upto a factor of 2 on thickness (diameter basis) and on weight basis by a factor of 4. This allows fishing vessels to increase their catch potentially by as much as 80% by trawling faster or using larger nets, or to reduce fuel consumption. Besides, less deck space is required due to lower bulk volume of the net. Purse seines made of dyneema would facilitate 40% increase in sinking speed due to better filtering and reduced drag. Larger net for the same weight can be made. The net has better durability with negligible wear & tear.

   Ropes made from UHMWPE have a higher breaking strength than that of steel wire ropes of the same thickness, but have only one-tenth the weight. Fishing uses for these high-strength polyethylene ropes include warp lines, bridles and headlines. By using UHMWPE ropes, the frequent oiling & greasing required for wire ropes can be avoided which would facilitate a clean and safe deck and free the crew from greasing the rope frequently. It also helps in a clean catch devoid of oil and grease contamination.

Liquid Crystal Polymer Fibre: Vectran®, a high-performance thermoplastic multifilament yarn spun from Vectra® liquid crystal polymer (LCP), is the only commercially available melt-spun LCP Fibre in the world. Vectran fibre is five times stronger than steel and 10 times stronger than aluminum. Vectran fibre is 4 times stronger than polyethylene fibre or nylon fibre. The unique properties that characterize Vectran fibre include: high strength and modulus; high abrasion resistance; minimal moisture absorption; and high impact resistance. Although Vectran is lacking UV resistance, this limitation can be overcome by using polyester as a protective covering. It is very suitable for trawl nets and ropes.

Fluorocarbon fibre: Fluorocarbon fibre is a new material that can be used in angling and high-speed jigging lines. It has very high knot strength, almost invisible in water, has high breaking strength and abrasion resistance.

4. **Sapphire:** Sapphire PE netting manufactured from specialized polymers available in twisted and braided form is suitable for trawl nets and for cage culture. It has the highest knot breaking strength, knot stability and dimensional uniformity. Braided twine having compact construction restricts mud penetration and provides lesser drag. Sapphire is used on a limited scale for fabrication of large mesh gillnets targeting large pelagics in Maharashtra region of India. Sapphire ultracore is a knotless HDPE star netting with an outer layer of heavier sapphire ultracore which features strands of marine grade stainless steel as an integral part of the netting twine. The stiffness and cut resistance enable it to be used as a predator protection net cum cage bag net where the predation problem is very high.

Identification of synthetic fibres

Identification of synthetic fibres by appearance alone is not easy and correct. Different groups of synthetic fibres can be identified by various methods.

1. ***Water test:*** Identification of synthetic fibres can be started with this test. In a short piece of netting yarn, tie a simple overhand knot and put the piece into a vessel filled with water. Air bubbles in the material must be squeezed out by hand underwater. Based on water test, netting materials can be classified into two groups; (1) synthetic fibres which float in water (PE & PP) (2) fibres which sink (all other synthetic fibres).
2. ***Burning test:*** In the burning test, the nature of burning and smoke in the flame as well as after leaving the flame are observed. The netting material can be brought near to the flame and after removal from the flame, observe the smell of smoke and the residue. Synthetic fibres shrink and melt in the flame, the melting substance drips from the flame mostly forming a bead or a hard-irregular residue. The changes in different synthetic fibres during burning test is given in table 1

Material	PA	PES	PE	PP
In flame	Melts, burns with light flame, white smoke, melting drops fall down.	Melts, burns with light flame, sooty black smoke, melting drops fall down.	Shrinks, curls, melts and burns with light flame, drops of melting fall down.	Shrinks, melts and burns with light flame melting drops fall down.
After leaving the flame	Stops burning, melting drops can be stretched into fine thread.	Stops burning, melting bead may be stretch into fine thread.	Continues to burn rapidly, hot melting substance cannot be stretched.	Continues to burn slowly, hot melting substance can be stretched.

Table 1. Burning characteristics of synthetic fibres

3. ***Solubility test:*** Solubility test is a relatively simple chemical test. Fibres of the sample to be tested should be in a loose form. The netting yarn must be untwisted and the fibres can be cut into small pieces of 1cm length. Coarse material like split fibres and especially monofilaments should be cut to very small pieces. Take 10-15ml of the solvent into the test tube and put the sample pieces into it. The results of the reactions are shown in table 2.

Reagent	Type of fibre			
	PA 6	PES	PE	PP
Hydrochloric acid/HCL (37%) 30 minutes at room temperature	+	o	o	o
Sulphuric acid/H_2SO_4 (97-98%) 30 minutes at room temperature	+	+	o	o
(1) Dimethylformamide/HCON $(CH_3)_2$ 5 minutes boiling	+	+	o (2)	o (2)
Formic acid/HCOOH (96-100%) 30 minutes at room temperature	+	o	o	o
Glacial acetic acid/CH_3-COOH 5 minutes boiling	+	o	o	o
Xylene/C_6H_4 $(CH_3)_2$ 5 minutes boiling (inflammable)	o	o	+	+
Pyridine 30 minutes at room temperature	o	o	o	o

Table 2. Identification of synthetic fibres by solubility test (+ = soluble, o = not soluble, (1) = Dimethylformamide is decomposed by exposure to light even when stored in a brown bottle, needs to be stored away from light preferably in a cool place, (2) Destroyed but not soluble

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Management and Sustainable Harvest of Deep-sea Trawl Resources

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Introduction

Fishing has been crucial to mankind right from the Palaeolithic period (Yellen, et al., 1995). At the beginning, it was a passive exercise, but nowadays, it has taken the form as an enterprise, in particular because of the motorization of crafts, which in turn has brought about the evolution of energetic fishing strategies which include trawling. The diverse fishing strategies have progressed step by step over the millennia. Marine fisheries play a crucial position in India's economy. The industry gives employment and profits to almost a million people. The boom in marine fisheries in the course of the Nineteen Fifties and Seventies has been quicker compared to the inland fisheries. However, in the Eighties and 1990s, the trend has been reversed because the capture fisheries have declined compared to the inland fisheries. During the nineties, the marine fisheries reached a plateau. The present trawling is restricted to 150m depth as 90% of craft operating in Indian water are of 15m OAL and cannot trawl in deeper waters. Most of the commercially important species that are being exploited are displaying symptoms of over-exploitation. The demand for sea food is growing day by day. The present scenario suggests that the current level of marine fish production from the exploited zone has to be sustained by closely monitoring the landings and the fishing effort and by strictly implementing scientific management measures and strategies.

Fishing efforts in coastal waters have begun to increase over the years, primarily due to increased demand and the introduction of new technologies. This eventually reduced the catch per boat. Perhaps, with the exception of some industries, the misconceptions about the inexhaustible nature of coastal fishing are largely over. The world's total catch has decreased by about 500,000 tonnes annually since 1988 (Bhathal, 2005). This threatens global food security, especially the supply of animal protein in developing countries. Here, alternative fish stocks appear in the scenario. Deep sea fishing is an alternative to animal protein. In the current situation, it is necessary to introduce deep-sea fishing vessels equipped with resource-specific fishing vessels such as tuna longline vessels, purse-seining vessels and squid jiggers. These vessels operate offshore only in the Exclusive Economic Zone (EEZ) and beyond on the high seas. There would be no scope of conflict with the traditional sector. However, such a deep-sea fishing fleet would be capital intensive and needs to be encouraged through foreign equity participation as well through technology transfer. The extent of sustainable exploitation of deep-sea resources is doubtful, since the deep-sea ecosystem is very fragile when compared to the coastal zone. Exploitation of offshore resources in the EEZ will have to be reconsidered in terms of not only the resources available, but also in terms of infrastructure. To avoid over capitalisation and ensure a cautious growth of the infrastructure and investments, a rationalised approach will be essential in determining the number and size of fishing vessels, their resource-specific gear as well as the technology to be made available. The development of the deep-sea fishery industry is of concern to the entire marine fishery sector because it would have considerable impact on the management of nearshore fisheries, shore-based infrastructure utilisation and postharvest activities, both for domestic marketing and export. With the pressure to expand world fisheries and exploitation of new stocks, attention off India has expanded into deeper waters, with additional species being added to our known fauna, especially those from deep waters off the Continental Slope (200-1200m) of Indian EEZ and central Indian Ocean. This article briefly describes deep-sea trawlable fishery resources, reviews aspects of their sustainability, and discusses alternative strategies for sustainable exploitation.

The Present Scenario

Deepsea fisheries are those that take place at great depths (up to 1600metres). Many deep-sea fisheries take place in waters beyond national jurisdiction (such as the exclusive economic zone [EEZ]), which is on the high seas. For some, the deep seas have become the iconic last frontier for the expansion of marine fisheries. The great depths and distances from the coast at which marine living resources are caught by deep-sea fisheries in the high seas pose scientific and technical challenges, particularly in providing scientific support for management. A number of governmental and non-governmental organizations with mandates relating to conservation of the environment, biodiversity and management of fisheries have expressed concerns about the likely, known or feared consequences of deep-sea fishing in terms of its effects and impacts on target stocks, associated species and habitats. These concerns are reflected in resolutions adopted by the United Nations General Assembly and led to the adoption of specific recommendations by the FAO Committee on Fisheries at its twenty-seventh session, in March 2007, which prompted the subsequent development and adoption (in August 2008) of the FAO International Guidelines for the Management of Deepsea Fisheries in the High Seas. The types of fishing gear and vessels used in deep-sea fisheries vary greatly, depending on the species targeted and their behaviour. In general, these fisheries are conducted at depths beyond 200 m, on continental slopes or isolated oceanic topographic structures such as seamounts, ridge systems and banks. Some vessels involved in deep-sea fisheries in the high seas may fish exclusively in the high seas, but others also operate within EEZs during the course of the year, either in deep seas or in shallower waters. Most vessels target various species throughout the year and some regularly change fishing gear. These fisheries are competitive and require a high level of investment.

The Past

Small-scale deep-sea fishing using hooks and lines was developed in the early 18th century, and deep-sea trawl nets using factory frozen trawlers began in the mid-1950s. With the expansion of the EEZ since the 1970s, some fleets have lost access to coastal or near-coastal fishing grounds. Some simply stopped operations, while others started deep-sea fishing on the high seas. Since the mid-1990s, depletion of fish stocks within the EEZ, quota restrictions, and technological advances have led vessel operators to seek alternative fishing opportunities outside the EEZ. Until the last few decades, there was little activity or interest in the deep-sea, except for occasional adventures by scientists. For decades, deep-sea fishing has continued to have potential interest in countries where coastal fishing has been completed or overfished (Hopper, 1995). High has been developed on the upper continental shelf (up to 600 m) and is now an important part of commercial fishing in many countries. The industry thrives in developed countries and continents such as Europe, the Soviet Union, the United States, Canada, New Zealand and Australia (Moore, 1999; Koslow et al., 2000; Roberts, 2002). Some of the popular deep-sea fisheries across these nations are, orange roughy (*Hoplostethus atlanticus*), oreos (*Allocyttus niger*, *Pseudocyttus maculatus*), roundnose grenadier (*Coryphaenoides rupestris*), rough head grenadier (*Macrourus berglax*), blue ling (*Molva dypterygia*), black scabbard fish (*Aphanopus carbo*), redfish (*Sebastes mentella*, *S. marinus*), Greenland halibut (*Reinhardtius hippoglossoides*) and deep-water dogfish (*Centroscymnus coelolepis*) Norwegian long-line fishery for ling (*Molva molva*) and the Spanish deep-water long-line fisheries for forkbeard (*Phycis blennoides*) and common mora (*Mora moro*) (Hopper, 1995; Gordon, 2001; Pineiro et al., 2001). The commercially exploited deep-water crustaceans include species such as the red shrimp (*Aristeus antennatus*), the giant red shrimp (*Aristeomorpha foliacea*) and Norway lobster (*Nephrops norvegicus*) from the Mediterranean and adjacent seas (Maria et al., 2001). he situation on the Indian coast for deep ocean trawling has been terribly meagre. Excluding some trails by government vessels, it's virtually negligible.

Catching methods for Deep-sea fishery

Longlines, bottom trawls, bottom trawls, gillnets and traps/pots are employed for fishing in the high seas. Trawling is the predominant bottom fishing method, representing nearly 70 % of vessels on the high seas. Some fisheries, such as orange roughy (*Hoplostethus atlanticus*), usually use technologically advanced fish detection and net monitoring equipment: in these aimed-trawling fisheries, the trawl gear can hardly hit the bottom, whereas different deep-sea trawl fisheries need the trawl to form bottom contact for many hours.

The ecological condition of deep-sea

Ecologically, the word ‘deep-sea’ will be outlined as part of the ocean deeper than 200m. However, deep-sea trawl fishing is usually about fishing conducted for bottom habitation species below 400 m on the continental slope, seamounts, deep-sea ridges and plateaus and associated underwater features. With current technologies and other fishing methods, fishing has manifested itself right down to depths of roughly 2,000 meters. The ocean floor is roofed by huge plains of sediment created from fine detritus and particles that drift down from the surface. It's the biggest surroundings on earth wherever deep-demersal fish comprise regarding 6.4% of the overall variety of species of fishes that are well-known (Merrett and Haedrich, 1997). The sea atmosphere is dark, cold and less productive. The distribution, habits and physiology of deep-sea organisms are influenced by the everyday environmental conditions of the habitat. The chief physical factors that have an effect on the ichthyofauna within the deep-sea are temperature, light, pressure, seabed and therefore the currents (Fujita et al., 1995; Jacob et al., 1998). Salinity and the quantity of dissolved gas are the most chemical factors that will influence the distribution of fishes (Jacob et al., 1998). On the far side, physical and chemical factors, biological factors conjointly play a key role within the distribution of various faunal assemblages, that embody resource availability, predator-prey relationships, and interspecies competition (Moranta et al., 1998). Fish that live in this advanced atmosphere sometimes develop different physical and physiological adaptations. The oversized portion of deep-sea catch is taken in the North Atlantic., within the East Atlantic, for example, vessels can typically target a spread of species, resembling ling (*Molva dypterygia*), Kalaallit Nunaat halibut (*Reinhardtius hippoglossoides*), roundnose grenadier (*Coryphaenoides rupestris*), black scabbardfish (*Aphanopus carbo*), many species of sharks and additional recently exploited species such as Baird's slickhead (*Alepocephalus bairdii*) and sea red crab (*Chaceon affinis*). The bulk of deep-sea fisheries in this space involve bottom trawlers which can operate deeper water trawls as well, but longliners are smaller in numbers. In other regions, the vessels target a much more limited number of species. For example, in the Southern Ocean, where the fisheries (using longlines) are mainly targeting toothfish (*Dissostichus eleginoides* and *D. mawsoni*). In the South Pacific and the Indian Ocean, many of the bottom fisheries take place over rough geological features (e.g., seamounts and ridges). Bottom trawling for orange roughy is generally done as aimed trawling. Mid-water trawlers, which may operate nets close to the seabed, mainly target alfonsino (*Beryx splendens*). Longliners in the South Pacific typically target species such as hapuka (*Polyprion* spp.), bluenose warehou (*Hyperoglyphe antarctica*) and morwongs (*Nemadactylus* spp.).

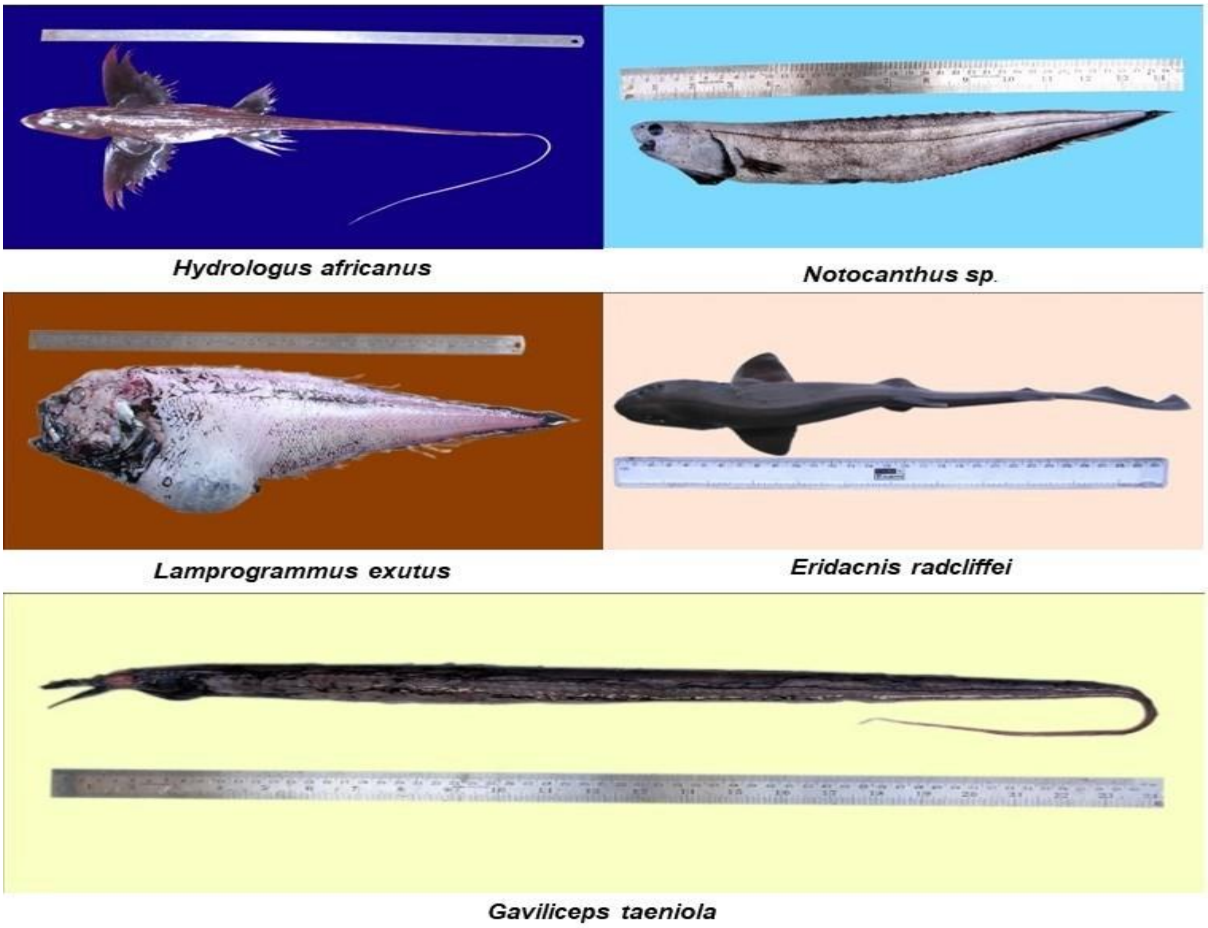

Fig. 1. Deep Sea fishes from Indian waters

Efforts to study deep-sea resources by ICAR-CIFT

Studies have been undertaken via various means by ICAR-CIFT on diverse cruises of FORV Sagar Sampada. Sampling was mainly executed using the EXPO version of fish trawl and ICAR-CIFT's HSDT (Fish & Crustacean Versions). Stocks had been envisioned longitude wise, depth wise and intensity wise alongside the continental slope of the East and West coast of the

Indian EEZ. Eels inclusive of *Bathyuroconger braueri*, *Coloconger rancieps*, *Gavialiceps taeniola* and *Evermannell indica* ruled the catches. Next to the eels were *Echinorhinus brucus* (Bramble shark) and the broad nose cat shark (*Apristurus investigatoris*). Other reasonably considerable resources were Moridae and Chlorophthalamidae. Chlorophthalamidae consisted of *Chlorophthalamus bicornis* and *C. punctatus*. The species that had been recovered past 700m in good intensity were *Lamprogrammus exutus*, *Gaviliceps taeniola*, *Echinorhinus brucus* and *Hydrologus africanus*. Some of the deep-sea non-traditional fish species which figure within the regular catches include *Priacanthus hamrur*, *Chlorophthalamus agassizi*, *Neopenula orientalis* and *Rexea prometheoides* are recognized as capable of unconventional food resources, but value-added products need to be made from those resources. Certain species landed predominantly beyond 500m in Indian territorial waters are *Myctophum* spp., *B. vicinus*, *Halielutaea* sp., *B. moresbyi*, *C. macrolophus*, *A. bicolor*, *Lophiomus* sp., *B. caudimaculata*, *C. raniceps*, *Uranoscopus* sp., *N. pinnata*, *P. cyanea*, *E. radclifei* and *Luciobrotula* spp.

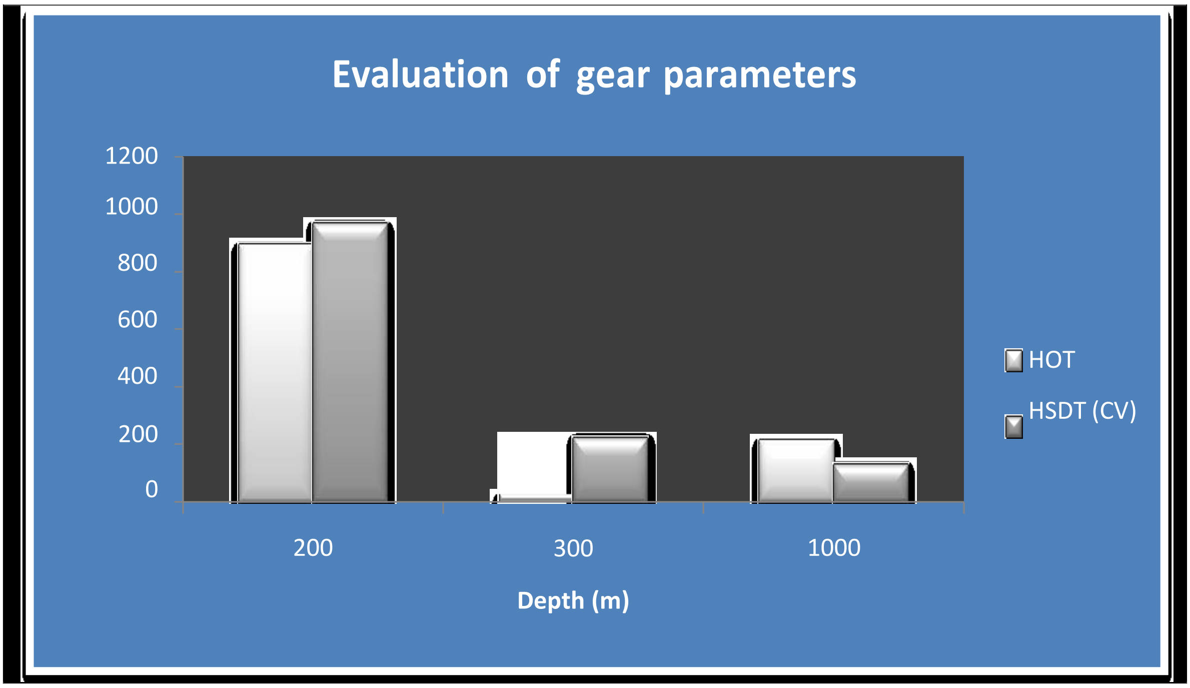

Fig 2. Comparison in catch between High Speed Demersal Trawl Crustacean Version High Opening Trawl

Trawl	No. of fishing operations	Depth	Average of CPUE (Kg/hr)
HSDT (CV)	10	200	968.708
	2	300	222.685
	9	1000	132.393
HOT	3	200	896.639
	8	300	24.1878
	1	1000	214.5

Table 1. Catch details of HDST CV and HOT

Trawl efficiency and performance can be affected by various aspects of gear design and construction and the size of the vessel, which cause selectivity to be size and/or species dependent. Comparison of gear geometry measured during surveys with the HSDT CV (High Speed Demersal Trawl Crustacean Version) trawl and HOT (High Opening Trawl). A total of 38 fishing operations were covered during the four cruises, 26 fishing operations were conducted with HSDT (CV) and 12 fishing operations were conducted with HOT nets.

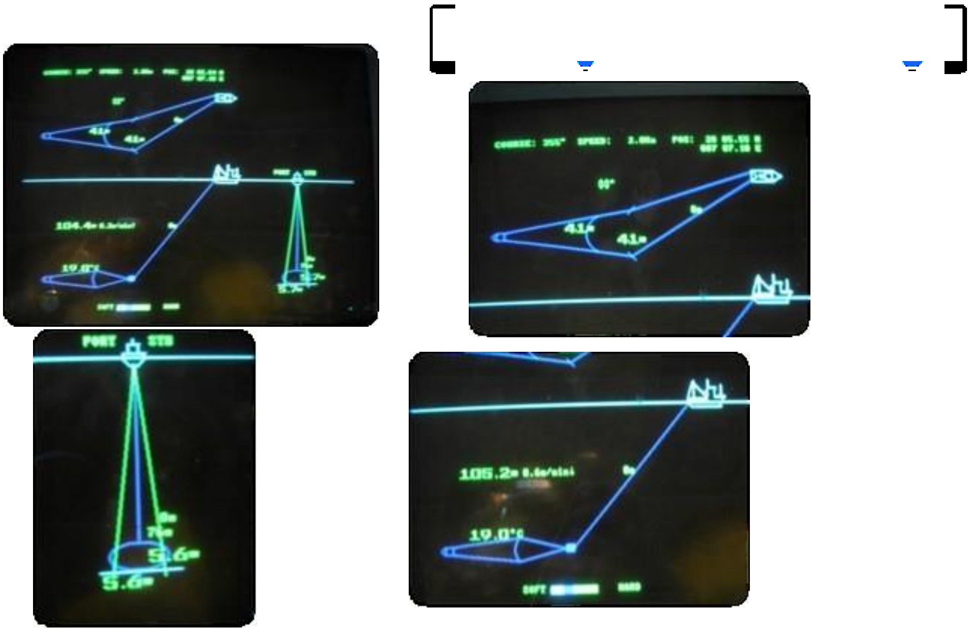

Fig. 3. Gear Parameter study

Vulnerability of the habitat

Human activities, such as fishing, can have a negative impact not only on living marine resources but also on related ecosystems. Species groups, communities or habitats that are easily damaged and take a long time to recover are considered vulnerable. The vulnerability of an ecosystem is related to the vulnerability of its constituent populations, communities or habitats. Features of an ecosystem may be physically vulnerable (i.e. structural elements of the ecosystem may be damaged through direct contact by fishing gear) or functionally vulnerable (i.e. selective removal of a species may change the manner in which the ecosystem functions). The most vulnerable ecosystems are those that are both easily disturbed and slow to recover. Examples of species groups and communities that are considered sensitive and potentially vulnerable include certain coldwater corals and hydroids, some types of sponge-dominated communities and seep or vent communities comprised of unique invertebrate and microbial species. These species and communities may be associated with submerged edges and slopes of the continental shelf, summits and flanks of seamounts, guyots, banks, knolls, and hills, canyons and trenches, hydrothermal vents and cold seeps. The ecological characteristics of deep water fishes can make them vulnerable to over-exploitation, and slow to recover from it. The deep-sea species often have a slow growth rate, high longevity, low fecundity, and hence low productivity. The history of orange roughy fisheries in New Zealand and Australia illustrates the rapid development to a relatively high level, and then an equally dramatic decline (Clark, 2001). The black scabbard fish (*Aphanopus carbo*) is the target of the oldest deep-sea fishery in the world, which takes place off the island of Madeira, Portugal (Merret and Haedrich, 1997; Haedrich et al., 2001). For centuries, this fishery, which only supplied the local markets, seemed to be sustainable. However, since the onset of export, the fishery expanded and the landings have decreased considerably (Merrett and Haedrich, 1997). However, it is not possible to generalize about biological characteristics, as rubyfish (*Plagiogeneion rubiginosum*) are relatively short-lived and fast growing compared with orange roughy. But, it is widely recognized that this deep-sea species is less productive and more vulnerable to fishing pressure than shelf species (Japp & Wilkinson, 2007; Sissenwine & Mace, 2007).

In a global review of deep-water fisheries, Koslow et al. (2000) concluded that deep-water fish stocks are "typically fished down, often within 5-10 years, to the point of commercial extinction or very low levels". Rogers (1994), in reviewing data on fisheries on seamounts worldwide over the previous two decades, concluded that fish stocks associated with seamounts/deep-seas have been consistently exploited at unsustainable levels. The most common reasons given are that there is often little or no understanding of the biology of the target and by-catch fish populations; management measures, where they exist, are often based on poor data; and highly efficient trawl fishing on aggregations of fish on or just above seamounts results in intensive fishing pressure. A common additional problem is the fact that the management regime is either weak or non-existent, a problem which continues today.

Management of Deep-Sea resources

Several renowned fisheries research institutions from the North Atlantic region have undertaken unsurpassed investigations into estimating the biological characteristics and maximum sustainable yields by following standard stock assessment techniques (Gianni, 2004). But, the outcome of basic statistics on catches and effort are of poor quality and in some cases lacking. There is often insufficient information on the general biology of these species, in particular on age and growth, seasonal behaviour, migration, and stock discrimination. These factors always lead to imprecise stock assessments, which ultimately affect the sustainability of the deep-sea fisheries. This concept was well described by Francis & Clark (2005) in the case of orange roughy based on the New Zealand experience. Punt (2005) and Sissenwine & Mace (2007) also discussed the difficulties of orange roughy and how uncertain such stock assessments are likely to be. This uncertainty in fisheries science has, at times, led to insufficient management of resources. The standard management strategies (estimating Maximum Sustainable Yields) applied in several deep-sea fisheries (e.g., orange roughy) has been proven risky and insufficiently conservative.

Future Directions

The ecosystem-based management (EBM) approach is a possible paramount to rescue the deep-sea resources immediately. Various EBM actions now include closed areas, fishing method or gear restrictions, depth limits, catch quotas, by-catch quotas (Probert et al., 2007). The closed areas can help protect, recover and maintain fish stocks, population size, distribution, trophic complexity, ecosystem resilience, habitat structure, biological diversity as well as species feeding, breeding, spawning and nursery grounds. In the management of deep-sea closed areas, there will be a need for science-based criteria and transparent processes for identifying areas appropriate for fishing as well as vulnerable marine ecosystems. Protection of vulnerable deep-sea living resources may require a combination of management tools, which includes complete abandon of bottom contacting trawls, using-off bottom trawls, modification of gears for size selective or species selective, use of much selective long lining, and trap fishing.

Although the North Atlantic deep-sea fisheries have been exploited for a century or more, new deep-sea fisheries are still developing on a global scale. In many countries, like India, the deep-sea fisheries are barely exploited. In recent years, scientists in India have attained interest in deep-sea fisheries as the coastal fisheries have been over exploited and the advancement of harvesting technologies. By considering the past experiences of vulnerability to readily over-exploitation of deep-sea fishes, the upcoming deep-sea fisheries (e.g., Indian deep-sea fisheries) have to adopt strategies combined from standard fisheries management methods as well ecosystem-based management approach.

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Utility of Minimum Legal Size (MLS) of capture in Indian Marine Fisheries

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Background

The MLS came into existence as a law in India for the first time in Kerala in 2014 based on the recommendations of the CMFRI (Mohamed et al., 2014). It was first promulgated as an ordinance for 14 commercially important species, and later in June 2017, it was enacted as a separate subsection of the Kerala Marine Fisheries Regulation Act (KMFRA) covering 58 species. A minimum legal size (MLS) is seen as a fisheries management tool with the ability to protect juvenile fish, maintain spawning stocks and control the sizes of fish caught. The MLS sets the smallest size at which a particular species can be legally retained if caught. MLS could be used to protect immature fish ensuring that enough fish survive to grow and spawn, control the numbers and sizes of fish landed, maximize marketing and economic benefits and promote the aesthetic values of fish.

In recent times, a considerable amount of juveniles of small pelagics have been captured along the Kerala coast in a targeted manner to meet the demand from fish meal plants. The exploitation of juvenile fish results in considerable economic loss, in terms of what could have been obtained, had the fishers waited for a few months and allowed the animal to grow in size and weight. This phenomenon called growth overfishing also causes serious damage to the fish stock in terms of the long-term sustainability of the resources.

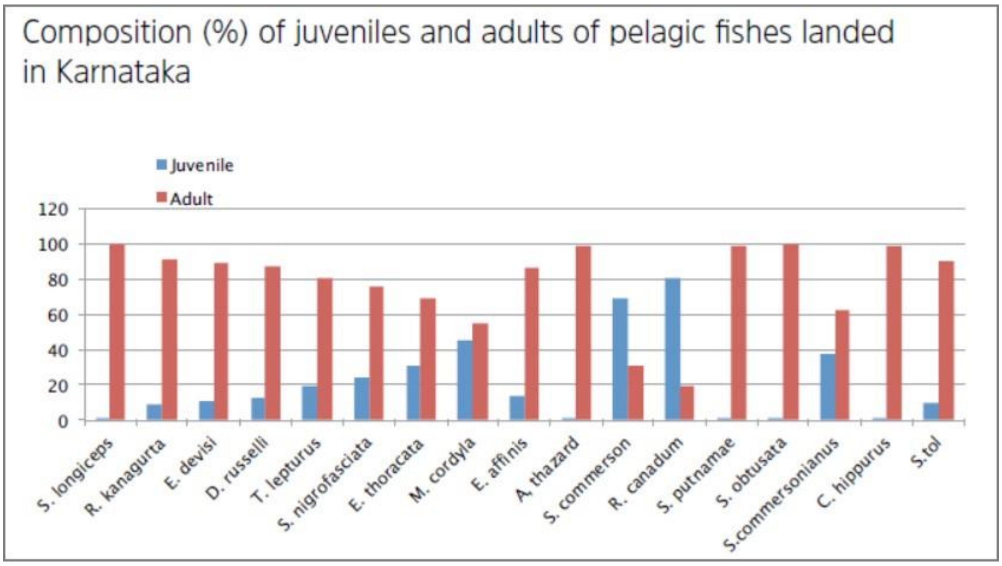

Fig.1. Percentage of juveniles among pelagic fishes landed in Karnataka during 2017-18 (from CMFRI Annual Report 2017-18

Setting an MLS and implementing the same would increase the economic efficiency of the fishery besides affording protection to juveniles and allowing them to grow in weight and length. Because of the relatively fast growth rates in tropical species (as in Kerala), higher weights can be reached very quickly within a few months resulting in higher harvest biomass, and therefore, higher incomes to fishers.

Objectives

Some of the objectives for introducing a law on MLS are:

- To prevent growth overfishing and partially recruitment overfishing.
- Maintain healthy stocks of marine fishes.
- Ensure better incomes to marine fishers on a sustainable basis.

Determination of MLS

Analyses were carried out with length-wise maturity data. SFM (size at first maturity or size at which 50% of fish are mature) and MSM (minimum size at maturity or size of the smallest mature fish) were determined by logistic curve method. Only female fishes have been considered in this analysis, as males mature at earlier sizes and are reproductively more active.

CRITERIA	EXPLANATION	DECISION LOGIC
SSD	Size at sexual differentiation into male and female	This metric can be used to prevent juvenile exploitation and growth overfishing in those stocks which are very abundant, have high reproductive potential and whose biomasses are not affected by high fishing pressure.
MSM	Minimum size at maturity or size of smallest mature fish	This metric can be used to prevent growth overfishing in stocks that are moderately resilient to fishing pressure.
SFM	Size at first maturity or size at which 50% of the fishes are mature	Conventionally used as a metric to prevent growth overfishing completely and recruitment overfishing partially. Can be used in situations where the stock is depleted or rebuilding.
SCM	Size at complete maturity or size at which 100% of the fish are mature	Can be used to prevent recruitment overfishing by capping the maximum legal size of capture. Seasonally applicable to fishes that grow to large sizes and exhibit slow growth rates.

Table 1. Strategy in determining MLS

After Kerala, the CMFRI has recommended MLS to the states of Karnataka, Tamil Nadu, Andhra Pradesh and Maharashtra. The Government of Karnataka has also made it part of the rules although implementation is an issue.

State	No of species	Status
Kerala	58	Rule change made Strict enforcement in place
Karnataka	72	Recommendation pending with state
Tamil Nadu	113	Recommendation pending with state
Andhra Pradesh	61	Recommendations made by CMFRI

Table.2. Status of MLS implementation in various states of India

Implementation of MLS and Benefits and Issues

In Kerala during 2017, the loss due to catch below MLS was estimated as Rs. 500 crores. In 2018, initial estimates indicate that it is one-fourth of 2017, indicating good enforcement by DOF. Without a doubt, the MLS regulation has created awareness among fishers in Kerala about the negative impacts of the capture of juveniles of commercially important species. There has also been considerable publicity through print and visual media too.

The quantum of fines collected through violation of the MLS rule is reportedly in several crores and fishers have become very wary of landing below MLS catches in ports. There are also reports of mid-sea transfers and landing of below MLS catch in private ports to escape punishment. It is well known that tropical fishes breed throughout the year with multiple peaks, and therefore, juveniles can be expected to be found in fishing grounds all through the year. Keeping this in mind, the CMFRI had recommended that the MLS rule be a violation only when 50% of the catch of a species exceeds the MLS. However, this clause was omitted during rulemaking by the GOK. Consequently, even one fish below MLS becomes a violation, and this has resulted in considerable bitterness against the DOF among fishers.

Several studies have been made to check whether the implementation of the MLS rule has helped in conserving and sustaining the stocks. As an example, the size range of *Amphioctopus neglectus* (webfoot octopus) caught by trawls in Kerala and Karnataka is shown in Fig.2. Webfoot octopus is a species that is in high demand for exports to Europe.

As can be clearly seen from Fig.2, the implementation of MLS has not made a significant impact in reducing catches below MLS. It is well known that the size of an animal in a trawl catch is a function of the net codend mesh size. Larger mesh sizes or square mesh codend allow for escape of juveniles. While legal mesh sizes have been prescribed for all major gears in Kerala, these have been poorly implemented. The MLS would become successful only in conjunction with the implementation of the legal mesh sizes. The DOF-GOK should actively pursue this strategy.

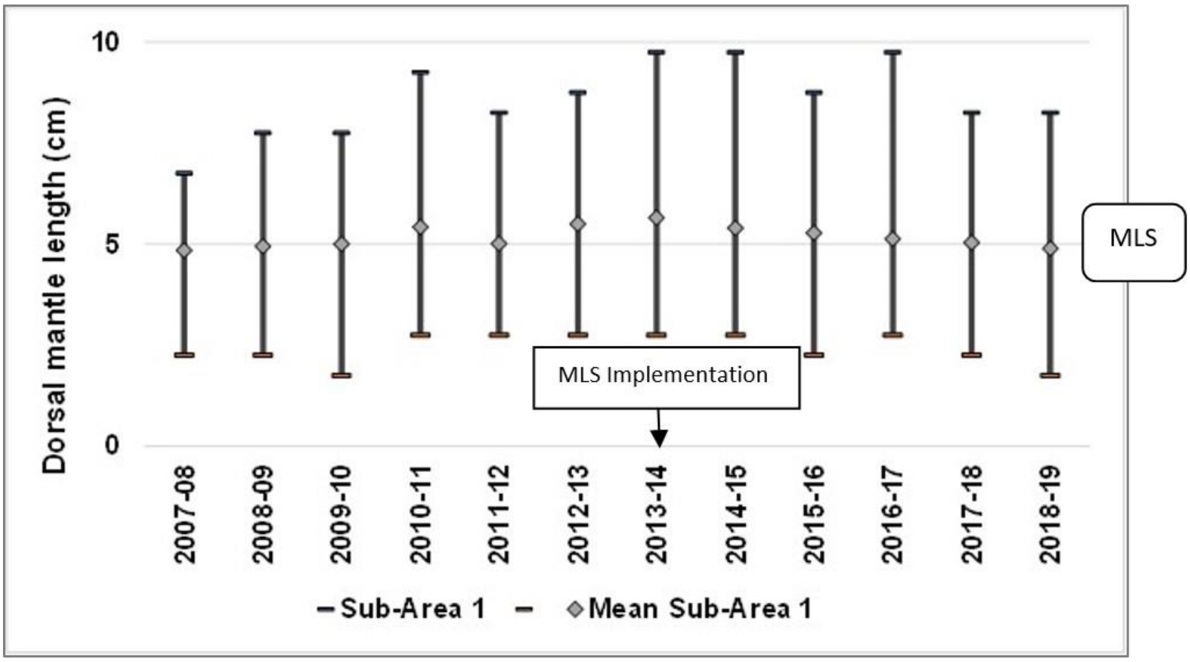

Fig.2. Size range, mean size and MLS (grey line) of the webfoot octopus caught by trawls in Southeastern Arabian Sea (SEAS) zone, subarea 1 (Kerala). There is no significant impact of the implantation of the MLS rule on the mean size and below MLS catches. (Sasikumar et al., 2022, MS).

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Recent advances in the utilization of bycatch as quality protein

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Introduction

Fishing has been shown to affect marine ecosystems through modifications in community structure and diversity, changes in trophic interactions, degradation of benthic habitat, and increasing mortality of unwanted bycatch species in addition to the direct impact on the abundance and productivity of targeted fish stocks. By catch or non-targeted fishes are also caught along with targeted species which have no demand on the market or should not be caught because their capture is against the goals responsible fisheries for management of the fish stocks. In addition to the direct impact on the abundance and productivity of targeted fish stocks, most of these fishes are discarded at on board itself. According to report of FAO, a total of 11,207,761 Mt of bycatch is estimated globally, and of these 84.86% is discarded. An interesting fact is that, more than 21% of global bycatch is contributed by Indian ocean region (FAO fisheries technical paper 339). Wild shrimp fisheries are responsible for roughly 50% and 80% of regional discard totals in the West Indian Ocean and West Central Atlantic, respectively. In the West Indian Ocean, Indian and Pakistani shrimp fisheries represented the largest sources of discards, whereas in the West Central Atlantic, shrimp fisheries off the south-eastern U.S. and in the Gulf of Mexico are responsible for most of the reported bycatch. Crab fisheries also added substantial quantities of discards to the West Central Atlantic total, while various species of carangids and mugilids, considered together, made a sizable contribution to aggregate removals from the West Indian Ocean. Efforts are being made to reduce the capture of this fish through technical changes to fishing operations and through management measures.

In most coastal states of India, a large proportion of bycatch from local fishing vessels which was previously discarded is now commonly bought at very low rates. The majority of it is dried with or without salt depending on the species and quality of raw material. It is then supplied as feed to the poultry and aquaculture industries and also used as manure (Aaron, 2007). The non-target species are *Acetes indicus*, *Oratosquilla nepa*, *Lagocephalus inermis*, *Dussumieria acuta*, *Nemipterus randali*, *Leiognathus bindus*, *Tetradon sp*. *Cynoglossus sp*, *Stolephorus sp* and a number of skate species (Dineshbabu et al., 2013). Although these species are collectively referred to as “non-target species” or “by-catch”. In general, by-catch is considered to be a valuable part of the trawl catch and a number of bycatch species can be utilized for food security as they are nutritionally good. Although discards of bycatch may have come down significantly, the current knowledge of their nutritional quality and composition is a matter of individual opinion rather than a verifiable fact.

Bycatch and discards: Indian coast

On the west coast of India, most of the bycatch from shrimp trawlers is landed, albeit often in a poor condition (Gordon, 1991). Bostock (1986) noted that trash occupies about 62% of the total trawler catch and none of this material is discarded at sea. King (1989) also found discarding to sea happens in very limited cases. However, the proportion of quality fish landed had increased significantly as a result of demand from the Gulf countries for fresh fish (Ames & Ward, 1995). CIFT (1997) found that with increasing export demand for fresh fish, availability of traditional varieties for drying is very much reduced. Alarge proportion of bycatch from the east coast is carried to the west coast as the demand for fresh fish is high. Large quantities of fishmeal, containing squilla, Acetes, and other trash fish, is brought from west coast to east coast for poultry industry.

On the other hand, Gordon (1991) estimated that around 90,000 to 130,000 tonnes of bycatch were discarded in 1988-89 on the east coast of India, based on discards by Visakhapatnam trawlers. The discards were mainly fish of less than 20 cm, and included shrimp. Rao (1998) made a fresh estimate of discards for the same period, using the shrimp-bycatch ratio, and concluded that the discards could not have been more than 32,000 tonnes from the Visakhapatnam trawlers. With the increase in finfish exports in 1990s, he suggested that the proportion of discards would have further declined. The bycatch landing of commercial shrimp trawlers In different maritime states of India during 1979 are demonstrated in fig. 1

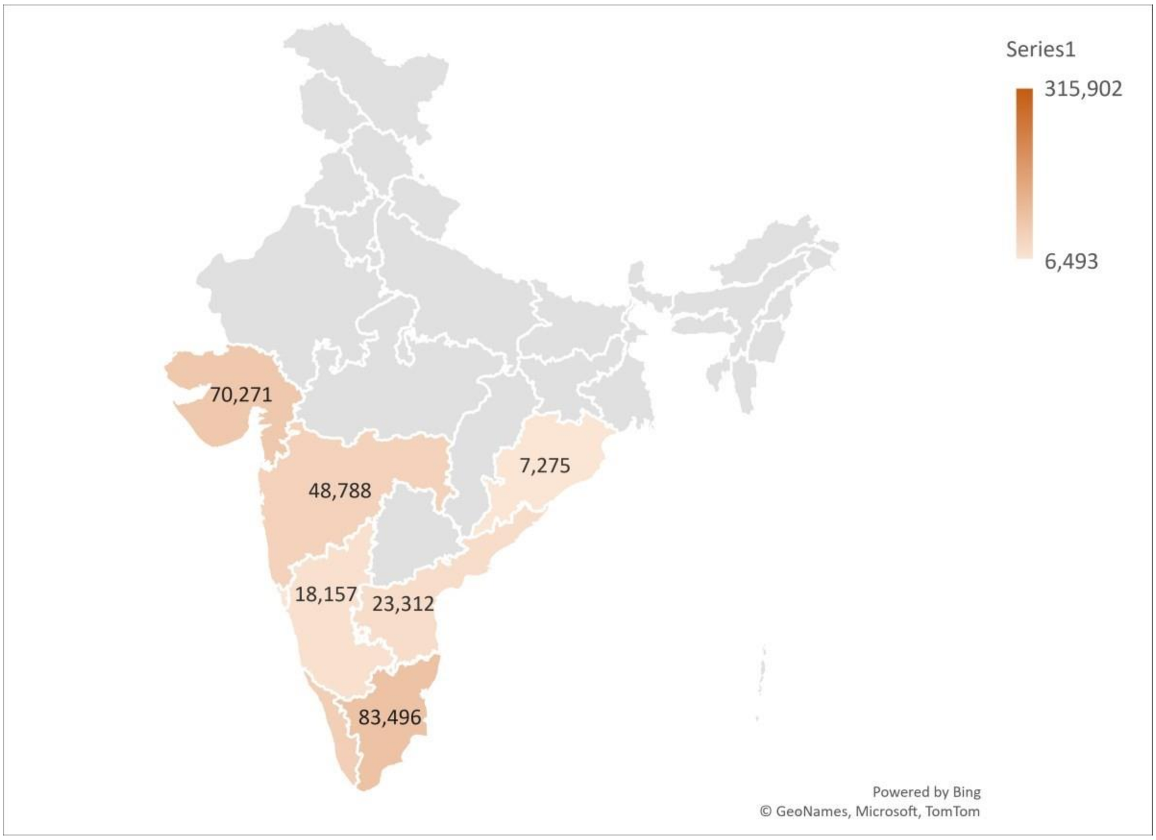

Fig 1: Landings of by-catches from commercial shrimp trawlers in different maritime states during 1979(CMFRI ,1981)

Current trends in utilization of Bycatch

In earlier times, major proportion of bycatch fishes are utilized for the production of fish meal However, as an industry, fishmeal production is not very successful, because most of the poultry units tend to make their own feed. During the peak period of brackish water aquaculture, there was a demand for 300,000 tonnes of fish for feed formulations. Waste from shrimp processing units, such as shrimp heads, which was discarded on the beaches or in sand pits, now command sufficiently good prices for being reduced to fishmeal. There is very little data on the demand characteristics for the fishmeal from the poultry or aquaculture sectors, and it is difficult to decide how the supply-demand situation is poised. In the short term, it could be assumed that the demand from the poultry industry has been a major factor in ensuring that more bycatch is landed (Pritchard et al., 1995).

The Integrated Fisheries Project (IFP) has utilised bycatch for commercial production of value-added products for a long time, but the response from the private sector to the initiative is muted, which makes it difficult to judge its success. The Central Institute of Fisheries Technology (CIFT) has demonstrated a number of new products utilising the trawler bycatches, again the uptake of the technologies has been low. Almost all problem species in the trawl bycatch were studied for making them useful, with little uptake by the commercial sector. A lot of work has been done to utilise squilla, which constitutes 3.12% of the total marine landings, with little success. Commercial Chitin/Chitosan production is taking place in Kerala, utilising the shrimp shell waste, technology was taken from ICAR-Central Institute of Fisheries technology, Cochin.

Bycatch fish: An excellent source of protein for rural folk

Small prawns and low-value fishes of marketable size are abundant in fishing bycatch. Non-penaeid prawns from daily trip boats, such as Acetes spp., Nematopalaemon sp., and others, can be hygienically dried and sold. Dried fish and prawns are in high demand and fetch a good price. Fresh Acetes indicus is used as an ingredient for variety of items including as cutlets, wafers, spirals, soup powder, and more (Zynudheen et al. 1998). Protein powder is made from Acetes by drying heat-coagulated pulp in the sun and under a vacuum and can be used as flavouring agent for various preparations (Garg et al. 1977). Mince extracted from tiny sciaenid, engraulid, and carangid fishes, can be used to make fish balls, crackers, and burgers (Yu and Siah 1996).

Anchovies are one of such by catch fishes and the landing of Anchovies in India shows a high potential and this low value fish has a high liking in the costal population. Anchovies are small saltwater fish that grow up to 20 cm (8 in.) and prefer the warmer waters around the world. Anchovies belong to the family *Engraulidae* and there are 144 species in 17 genera, found in the Atlantic, Indian, and Pacific Oceans. The ICAR-Central Institute Fisheries Technology (CIFT) has developed a technology for the production of dried and powdered anchovies. It has better nutritional properties and good source of quality proteins and contains polyunsaturated fatty acids, vitamins and minerals.

Anchovy and its nutritional Importance

Zero hunger is one of the Sustainable Development Goals (SDGs) of the United Nations, and it continues to gain a lot of attention because the number of people suffering by malnutrition grew by 38 million from 2015 to 2016, to 815 million. All of the most frequent nutritional deficiencies may be avoided by include particular foods in one's diet, and one preventative item that is common to all of them is fish. Because there has been a shift in fishing techniques and the promotion of sustainable fisheries is on the rise, combating hunger and malnutrition via sustainable fishing is a realistic option.

The raw material used for the development of dried fish and fish powder is Anchovy fish (*Stolephorous spp.*) (locally known as Nethili in Tamil Nadu) belong to lean fish category (Fig.2). Anchovies are common fish found in marine water environment which are an incredible source of omega-3 fatty to which promote the health of brain and heart. The proximate composition is a term usually used in the field of food or feed and its main components include moisture, ash, lipid, protein, and carbohydrate content which are expressed in percentage. Proximate composition analysis of anchovies revealed 16% protein, 2% fat. A variety of many other minor constituents are also present in small quantities like vitamins, free amino acids and non-protein nitrogenous compounds.

Fig 2: *Stolephorous spp*

Process of developing fish dry powder

The procured raw material for the purpose of product development was thoroughly cleaned to remove the extraneous materials present and was prepared for sorting and drying. The sorted and dried sample were then pulverised to obtain fine powder and done vacuum packing for extended storage life. The product was developed for supplying to 50 Anganwadi Centres of Mayurbhanj District, Odisha including the dried and powdered anchovy in collaboration with World fish centre, Malaysia and Govt. of Odisha. The detailed steps for the product development are illustrated in Fig. 3.

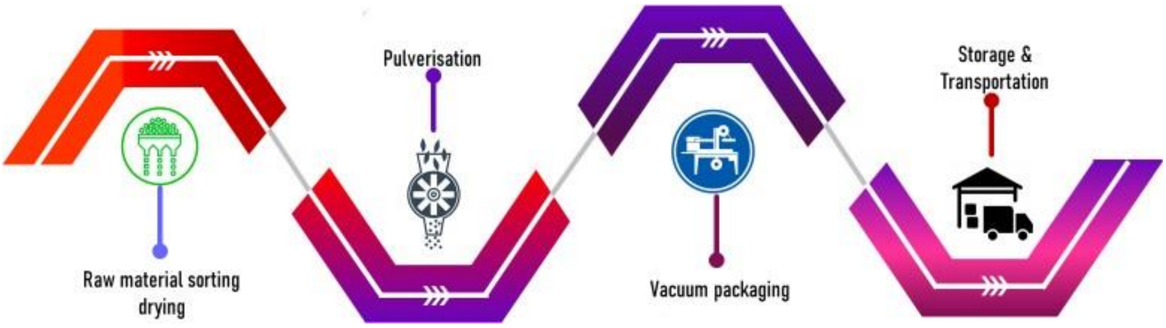

Fig 3: Process of development of fish dry powder

The products developed for the consumption purpose was distributed with the help of a private entrepreneur under the technical guidance of ZTMC-ABI and as per the guidelines of from ICDS, Govt of Odisha. A six-month study in children of 3-6years gave very encouraging results, as it improved the health status significantly. Not only anchovies, but other bycatch also can be utilized in a similar measure which will reduce the problem of malnutrition in our country.

Conclusion

Commercial fishing has an impact not only on the species targeted, but also on numerous other species captured by chance. One of the most effective methods to reduce the effects of bycatch is to use it more effectively. Fish has a high nutritional value due to its inexpensive and high-quality protein, which has a biological value of 15-23 percent. The high amount of health-promoting omega-3 PUFAs, notably eicosapentaenoic acid (20:5n-3, EPA) and docosahexaenoic acid (20:5n-3, DHA), has sparked renewed interest in fish eating (22:6n-3, DHA). Furthermore, fish is an excellent supply of vital amino acids, especially lysine, which is lacking in grains, contributing to the overall nutritional quality of a varied diet.

So rather than on board discarding of bycatch it can be effectively utilize for the nutritional security of our nation Anchovy a low value by catch fish demonstrated a high nutrient complement and hence can be an effective nutrient supplement for daily food. The higher content of essential amino acids, PUFA, MUFA and low sodium and high potassium and calcium could make a better nutrient for the consumers at a cheaper rate. The high-quality protein and essential fatty acids, vitamins and minerals found in fish and the effects of adding fish to traditional bland staple diets can stimulate appetite and increase nutrient rich food consumption of the young and the aged. Effective utilization of bycatch for addressing the problem of malnutrition in our country has to be addressed especially in fish consuming states in India.

Acknowledgement

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Design considerations and fabrication of bycatch reduction devices

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Introduction

With the development and wider availability of synthetic gear materials, recent advances in vessel technology, navigational electronics, gear handling machinery, fish detection methods and fish behaviour studies, large-scale changes have taken place in the design, fabrication, operation and catching capacity of modern fishing gears such as trawls, purse seines and long lines. Widely used traditional fishing gears such as entangling nets, hook and lines and traps have also benefited by way of design upgradation and efficiency improvement in the recent years. New innovative fishing systems such as electrical fishing, light-assisted fishing, FAD-assisted fishing and fish pumps have also been developed and accepted in different parts of the world. Design process for fishing gear has been greatly influenced in the recent years by the resource management and conservation, environmental safety and energy efficiency imperatives.

Mechanisms of fish capture

There are different systems of fish harvesting used in the world which is ranging from primitive to highly sophisticated systems. Fishing gear vary with structure, materials used, principle of capture process and method of operation. The selection of fishing gears mostly dependent on fish species, environmental factors and fishing ground condition. Fishing gear use five mechanism to capture fishes

1. Gilling and Tangling
2. Trapping
3. Filtering
4. Hooking and spearing
5. Pumping

The most commercially used fishing gears are – Purse seine and Trawl net followed by gillnet, entangling nets and traps. Based on the usage of material of construction the fishing gears are grouped into – 1. Net fishing gear – Fishing with netting which is constructed with webbing – Gillnets, Trawl nets, Purse seines etc. 2. Tackles – fishing gear in which hooks are an important part and catch fish individually – Hooks and lines 3. Miscellaneous gears – Traps, Grappling and wounding, stupefying methods and 3electrical fishing.

Factors affecting fishing gear design

Important factors which influence the design of fishing gears are (i) biology, behaviour and distribution of target species; (ii) fishing depth, current and visibility; (iii) sea bottom conditions; and (iv)other factors such as the scale of operations, size and engine power of fishing vessel, energy conservation objectives, selectivity and resource conservation objectives.

Design of fishing gear is greatly influenced by biological characteristics such as body size and shape, feeding habits and swimming speed; behavior in the vicinity of fishing gear and during capture process; spatial distribution and aggregation behavior of the target species. Body size and shape determine the mesh size required to enmesh and hold the fish in gill in nets and the mesh size to retain the target size groups of the species without gilling in the trawls, seines and traps. Body size is also related to the tensile strength requirements for the netting twine in gill nets and hook size and lines in hook and lines. Feeding habit of the target species is more important in passive fishing methods like hook and line and traps where the fish is attracted by the bait, and in the active fishing methods like troll line used for catching predatory fishes Consideration of the swimming speed of the target species is more important particularly in the active fishing methods like trawling, seining and trolling. Fishes are known to sustain a cruising speed of 3-4 body lengths per second for short duration. Catching efficiency is maximized when the vertical opening of the trawl mouth, vertical dimension in gill nets, and the catenary of the main line of the long line with branch of lines and hooks, coincide with the vertical range of the layer of maximum fish abundance. Hence knowledge of the vertical distribution of the target species could be used to optimize the horizontal and vertical dimensions of the netting panels in gill nets, main line catenary in long line and mouth configuration in trawls

Hydro-acoustic pressure increases approximately at the rate of one-unit atmospheric pressure (I bar) for every 10m depth. Buoyancy elements used in the deep sea fishing gear such as deep sea trawls, gill nets and bottom vertical lines have to be strong enough to withstand the high pressure at the fishing depth. Prevailing strong currents in the fishing grounds may restrict the choice of fishing gears to longlines and gillnets which are less affected by currents. Light levels at the fishing depth could influence the fishing success, as vision of fish is affected by light levels. In passive fishing gears such as gillnets, visibility of netting panel adversely affects fishing efficiency, visibility is again negatively indicated in hook and line operation while in light-assisted jigging-controlled light plays an important part.

Rough sea bottom conditions limit the operation of most of the fishing gears close to the ground except handlines, vertical longlines, bottom vertical longlines and traps. Trawling on rough bottom requires special rigging such as bobbin rig on rock hopper rig, improvements in trawl design to minimize gear damage or loss and selection of appropriate otter boards.

Design features of fishing gears will also be influenced by the scale of operations, size and engine power of fishing vessel, energy conservation objectives, selectivity and resource conservation objectives, catch volume requirements, operational and handling requirements of the gear, prevailing weather conditions, skill required for fabrication, maintenance and operation, material availability, local traditions and economic considerations.

Gear Based Technical Interventions – considerations

- The appropriate match between MMS (Minimum Mesh Size) and MLS (Minimum Legal Size) is a particular problem in multispecies fisheries
- The link between MLS, gear selectivity, and discarding rate is often poorly understood
- Stress-induced behavioral deficits increase the risk of predation in the hours or days after the encounter (Behavioral impairment of fish escaping trawls).
- Behavioral impairment not measured in the field and survival studies, which traditionally use enclosures to measure mortality, do not have predation risk

- Reflex action mortality predictors are often employed, but may not mimic the actual field conditions
- Need to go beyond well-known areas of research and to define possible behavioral ecology frameworks

The crucial questions that needs to be answered before implementation of any gear based technical measure:

- How large a change in gear/mesh size is possible?
- How long will it take to realize economic benefits and who will get them?
- How easily can the fishers manipulate selective properties of gear, legally and illegally?
- How to compensate for potential catch losses?
- How much does it cost to improve gear selectivity and who will pay?
- Are other measures, unrelated to gear, more efficient and more appropriate to improving stock status and future conditions?

Conclusion

Gear based technical devices can address juvenile bycatch to a great extent. The most practical method in juvenile exclusion in a multi species multi gear system like ours, is gear based modifications. Considering the devices and operation, we can see that the structure and size made them effective and easy to incorporate in the existing fishing gear. Most of the devices like fish eye and hooks have considerably less installation procedure. Since most of these devices, are based on interactions and escapement, mortality could be an issue. Devices that avoid direct contact such as aberration and funnelling are safe to operate whereas filtering type of excluding devices are harmful and increase mortality.

The best option would be to avoid the interaction by spatial / temporal closures based on prior knowledge. Which is in fact leads to socio economic adversity as the lean periods coincides with restricted fishing season. Alternative livelihood is yet a hurdle in the under developed and developing countries. Economic status of fisherfolk should be considered while implementing such restrictions. Studies to be taking up for accessing behavioural responses of fish, to avoid interaction of non-targets are novel approach yet taking pace gradually, could serve a better alternative option.

Close association with fishermen community will help significantly in the outcome of the studies carried out by research institutions. Monitoring the practices at sea is the bigger task hardly affordable by legislative bodies. Development of MCS systems in the sector will play a better role.