E-Training Manual | ADVANCES IN

FISHING GEAR MATERIALS

(under SCSP, ICAR-CIFT)

4 - 8 December 2023

ICAR - CENTRAL INSTITUTE OF FISHERIES TECHNOLOGY

Matsyapuri P.O Willingdon Island, Kochi- 682029, Kerala

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Published by:

The Director,
ICAR- Central Institute of Fisheries Technology
Cochin

Compiled and edited by:

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For citing the book:

Sandhya K. M., Manju Lekshmi N. (eds). (2023). Advances in fishing gear materials. ICAR- Central Institute of Fisheries Technology, Cochin, India. 72 pp.

Example for citing a chapter in the book:

Sandhya K.M. & Saly N. Thomas (2023). Fishing gear materials: classification, properties and advancements. In: Sandhya K. M., Manju Lekshmi N. **(**eds**).** (2023). Advances in fishing gear materials. ICAR- Central Institute of Fisheries Technology, Cochin, India, pp: 1-10.

Cover Design

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(ISO/IEC 17025: 2017 Accredited & ISO 9001: 2015 Certified)

Foreword

ICAR- Central Institute of Fisheries Technology, Cochin is a premier institute actively involved in research in the field of harvest and post-harvest technology of fish. It is with greatpleasure to introduce the comprehensive training manual evolved by the successful training programme on *Advances in Fishing Gear Materials* organized by Fishing Technology Divisionof ICAR- CIFT under Scheduled Caste Sub-Plan (SCSP) from 4-8 December 2023. The programme covered relevant topics by the experts with years of experience in the field of Fishing Technology. This manual is a compendium of 10 lectures covering various aspects of fishing gear materials, its latest developments, testing of materials and fishing gear protection.The compendium also discusses topics on energy saving in fishing gear operations and resource conservation. With the increasing complexity of the fishing industry, it is essential to equip with the latest knowledge and technological advancements in fishing gears and materials. I extend my appreciation to all the editors and authors, whose dedication and expertise have shaped this manual. I am confident that this manual is an asset for the students, researchers and other academicians to refer on advances in fishing gear materials.

(Dr. Gorge Ninan)
Director

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20/12/23

SL. NO	CONTENTS	PG. NO
1	**Fishing gear materials: classification, properties and advancements** Sandhya K. M and Saly N. Thomas	**1-10**
2	**Resource and energy conservation measures in fishing gears** M. P. Remesan	**11-17**
3	**Gillnet fishing: materials, impacts and mitigation measures** Sandhya K. M.	**18-27**
4	**Recent developments in trap fishing: design and materials** Prajith K. K.	**28-33**
5.	**Line fishing in India and advances in the materials** Renjith R.K.	**34-42**
6.	**Energy optimization in fishing systems through material substitution** Paras Nath Jha and Leela Edwin	**43-47**
7.	**Biofouling in fishing gears: assessment, impacts and prevention** Muhamed Ashraf P., Arun K. S. and Manju Lekshmi N.	**48-55**
8.	**Sea safety aspects in fishing operations** Baiju M.V.	**56-64**
9	**Bycatch issues in fishing gears** Madhu V. R.	**65-67**
10	**Fishing gear related micro plastics: impacts /assessment methods** Manju Lekshmi N.	**68-72**

Fishing gear materials: classification, properties & advancements

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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. Man-made fibres constitute natural polymers and synthetic polymer. 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.

***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.

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.

***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.

***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.

***Polyester* (PES):** The principal PES fibres are made from polymerization of terepthalic 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.

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.

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.

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.

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.

Basic terms in netting

Fibre: the basic material of netting, has length at least 100 times its diameter.

Netting yarn: is the standardized universal term for all textile material which is suitable for 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:or folded yarn is a netting yarn which is made of two or more single yarns or monofilaments.

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 International Organization for Standardization (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

Basic yarn types: Fibre is the basic material used for the fabrication of netting yarns. By twisting, braiding or plating, yarns are made into twine. For twine construction, there are two steps, first is the twisting together of two or more single yarns to form a strand/ply and the second step involves the twisting together of two or more strands to form a twine. The basic forms in which most synthetic fibres are produced are continuous filaments (multifilaments), staple fibres, monofilaments and split fibres. Continuous filaments are fibres of indefinite length. A quantity of continuous filaments is gathered up, with or without twist to form a filament yarn termed as multifilament. Staple fibres are discontinuous fibres, prepared by cutting filaments into short lengths usually 40-120 mm suitable for the yarn spinning fibres. Staple fibres are twisted to form a spun yarn. These have a rough surface due to the numerous loose ends of fibres sticking out from the twine. Monofilament is a single yarn strong enough to function alone as a yarn without having to undergo further processing. Unlike fine continuous filaments and staple fibres, this can be directly used as individual fibres for netting. Split fibres, developed from oriented plastic tapes (flat tape) which are stretched during manufacture at a very high draw ratio resulting in the tapes splitting longitudinally when twisted under tension.

Types of synthetic yarns for fishing

PA is available as multifilaments, staple and monofilaments yarn. PE is available as monofilaments (twisted) but not as staple fibres or as multifilaments while split fibres are not common. In the case of PP, fibres as multifilaments, split fibres and monofilaments for ropes are available. PES is available only as multifilament fibres and not as split fibres. The synthetic netting yarns used in Indian fishing sector are PA, PE and PP. PA and PE are the most commonly used fibres for netting while PP and PE are used for ropes. Of these, PA is mostly used in gillnets, line and purse seine sector while PE is used in the trawl net sector and to a less extent in deep-sea gillnet sector.

Nylon multifilament nettings are available as knotless and knotted while nylon monofilament nettings are available as knotted only. Nylon multifilament nettings are commonly used for the fabrication of various types of gillnets, ring seine, purse seine, cast net, Chinese nets, drift nets etc. Common specifications of nylon multifilament twine for fishing ranges from 210x1x2 to 210x12x3. The mesh size commonly required ranges from 8 mm to 450 mm for different fishing gear. It is more effective for fishing than polyester because of the better sinking speed and extensibility. Nylon monofilament is better for long lining and various types of gillnetting. The twine range for fishing purpose is from 0.10 to 0.50 mm dia and for long line fishing 1.5 to 3 mm.

HDPE twine is of two types; braided and twisted. Twisted twine is available normally in the range of 0.25 to 3.00 mm dia while braided twine is available in the range of 1.0 to 3.0 mm dia. HDPE netting is mainly used for fabrication of trawl nets.

Designation of yarn: Monofilament yarn is usually designated by diameter. Multifilament twisted twines are designated by runnage (length of twine against a standard weight) or by designation, viz., the yarn size, number of yarns in the strand, and number of strands in the twine.

Example: 200x4x6; indicates that the yarn size is 200 denier, 4 yarns in one strand and 6 such strands are twisted together to form the twine.

Yarn numbering system

For designation of the size of the yarn, a `yarn numbering system' is developed. The size of the yarn is given by yarn numbering system which is based on the length-weight relationship of the yarn. There are two types of yarn numbering systems, viz., direct and indirect.

1. ***Direct System:*** In this system, the weight of the yarn against a standard length is taken. For example the length of yarn is kept constant and the weight changes.

i. Denier

9000 m of yarn weighing 1 g is 1 denier

9000 m of yarn weighing 210 g is 210 denier

ii. Tex: This is the internationally accepted system of numbering for all textile yarns.

1000 m of yarn weighing 1 g is 1 tex.

1000 m of yarn weighing 20 g is 20 tex

2. ***Indirect system:*** Here the length of yarn for a standard weight gives the yarn number or the weight is kept constant and the length varies.

i. British Count (Ne)

840 yards weighing 1lb is 1 Ne

20x840 yards weighing 1 lb is 20 Ne

This is commonly used for cotton and synthetic staple yarns.

ii. Metric Count (Nm)

1000 m of yarn weighing 1 kg is 1 Nm

20x1000 m of yarn weighing 1 kg is 20 Nm.

In the direct system of numbering the more the yarn number, the thicker the yarn would be and in the indirect system the more the yarn number, the finer the yarn would be.

For conversion from one system to another, the following conversion formula is used.

$$Tex = \frac{590.5}{Ne} = \frac{1000}{Nm} = \frac{100000}{m/kg} = \frac{496055}{yds/lb} = 0.11 \text{ denier}$$

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.

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).

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

Table 1. Burning characteristics of synthetic fibres

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.

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.

Table 2. Identification of synthetic fibres by solubility test

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

+ = 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

Properties

As far as the fishing gear purpose is concerned, properties which are of importance are linear density, diameter, specific gravity, knot stability, breaking load, elongation, weathering resistance and abrasion resistance.

Diameter: The diameter of netting material is an important factor influencing the fishing gear performance. Thickness and rigidity of the material influences the resistance of fishing gear to water flow and hence the power required or the speed obtained in towing gears are depended on it. Thinner twines offer less resistance. Diameter of a material is dependent on the type of polymer, type of yarn, size of yarn, specification and construction. Diameter is expressed in mm and is measured using a travelling microscope or a micrometer.

Linear density: It is the mass per unit length of the material. The mass in g of 1000 m length of a material is expressed as R tex and mass of 9000 m of the material as R denier. While comparing different types of yarns, the Rtex values serve as a relative measure for the mass of netting. For the same kind of material, lower Rtex means thinner material and generally costs less while buying on a mass basis.

Specific Gravity:Specific gravity of most of the synthetic fibres is less than the natural fibres. Specific gravity influences the fishing gear as fibres with lesser specific gravity allows a greater length of netting for a given weight of yarn and helps in savings in handling and power. However, for a gear such as purse seine, material with very low specific gravity is not the suitable one as quick sinking of the net is a prime requisite to capture a shoal of fish.

Twist: The number of turns or twists imparted to a twine per unit length is important as it influences many properties especially the breaking strength, diameter, linear density, resistance to abrasion and general wear and tear of the twine. As the amount of twist increases the breaking strength also increases upto a critical degree of twist beyond which it would weaken the twine. The stability of a twine depends on the correct amount of twists per unit length. The twine has an inner/strand/primary twist and outer/secondary/twine twist. Balance between these two twists ie: primary twist for making strands from yarns and secondary twist to make twine from strands is important. Twines with a well balanced twist do not have a tendency to snarl.

Breaking strength and elongation: The breaking strength/load of a material denotes the ability of a material to withstand the strain. It depends on the type of polymer, type of yarn, degree of twist and thickness of the material. Tenacity is the breaking load in terms of yarn denier while tensile strength is the force in terms of unit area of cross section. The strength of fibre changes in the wet condition; in natural fibres the wet strength is higher while the reverse is true of synthetic fibres. Knotting also causes reduction in the breaking strength. This is dependent on the type of polymer, type of yarn and knot, twine construction and also on the degree of stretching. Breaking load is expressed in Newton (N).

Elongation is the increase in the length of a specimen during a tensile test and is expressed mostly in percentage of the nominal gauge length. Extensibility is the ability of a netting material to change its dimension under a tensile force. It involves a reversible and an irreversible elongation. Irreversible or permanent elongation is the part of the total increase in length which remains after the removal of the stress. Reversible or elastic elongation is the part of the total increase in length which is cancelled again, either immediately or after a long period of removal of stress.

Weathering Resistance: Even though all fibres, irrespective of natural or synthetic are prone to degradation on exposure to weathering, the problem is severe with synthetic fibres. The effect of weathering depends on the thickness of yarn, as thicker twines show better resistance. This is because the layers below are protected by the degraded outer layers and generally UV rays do not penetrate more than 1mm. By dyeing the weathering resistance can be improved. PVC has very high resistance against weathering, while PES has high and PA and PE, have medium resistance against weathering. Among different types of fibres, monofilament form is more resistant than multifilament and staple yarn.

Abrasion Resistance: The resistance of netting materials to abrasion, ie, abrasion with hard substances such as boat hull, sea bottom and net haulers, or abrasion between yarns/twines is important in determining the life of a net. The resistance to abrasion depends on the type of fibre, thickness and construction of the material. Polyamide has the maximum abrasion resistance, followed by PP, PES and PVC. The better abrasion resistance of PA is due to the inherent toughness, natural pliability, and its ability to undergo a high degree of flexing without breakdown. Among different types of materials, monofilament is better than multifilament, and between staple and multifilament, the latter is better. Abrasion can cause rupture of the material as also reduction of mesh size due to the internal abrasion caused by the friction of the fibres against each other.

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Resource and energy conservations measures in fishing gears

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Introduction

Due to various factors like climate change induced water quality issues, excess fishing capacity, over exploitation and IUU fishing, fishery resources are declining. Several species were disappeared in the fish landing during the past few decades, especially in the coastal waters. As a result, to make the fishery economically viable mechanised sectors started catching everything across the depth zones with high powered vessels and large sized fishing implements resulting in huge quantity of bycatch in the landings. Conservation of fishery resources is very important as the demand for fish for human consumption and fishmeal is increasing. To sustain the fish production in the present level resource conservation measures, need to be implemented urgently. Though the statistics is showing an increasing trend in the marine capture fish production, it may not be sustainable as IUU fishing is contributing significantly in the marine fish landings as reported by FAO and the bycatch and discards issue is continuing in the world fisheries.

Resource conservation measures

Excess fishing capacity leading to over fishing is a big challenge in world fisheries. Number of vessels, their size, engine power and fish hold size are much more than the actual requirement. Similarly, the dimensions of the fishing gears have been increased to several folds corresponding with the vessel size. Large sized vessel and gear and industrial fishing practices had negative impact on fishery resources, which are either touched or already crossed the maximum sustainable yield in many fisheries.

Ways to control and manage fishing capacity (FAO; 2001)

- Input control: moratorium for new vessels
- Output control-catch limit
- Fleet size regulation based on total allowable catch
- Regulated access based on licensing
- Buyback programs
- Gear and vessel restrictions
- Area and time (fishing ban) based restrictions on fishing- MPAs/ sanctuaries
- Followed by mesh regulation,
- minimum landing size,
- Ban on destructive fishing,
- Restructuring/diversification of fishing effort to under exploited areas

- Conversion of destructive fishing methods to selective fishing
- Regulation on gear dimensions
- Regulations on bycatch & discards

Mesh size regulation

Selectivity of fishing gears mostly depends on the mesh sizes and shapes. Small mesh size fishing gears usually catch variety of species including juveniles. Mesh shapes and sizes prescribed in the Fisheries Regulation Acts should be implemented properly. Endangered Threatened and Protected species are landed in trawls, gillnets, lines and purse seines. Appropriate bycatch reduction devices (BRDs) need to be implemented to conserve biodiversity. Minimum Legal Size fixed for the landings of commercially important species are another measure to control juvenile fishery.

Energy Efficiency of Trawl Systems

Trawling is the most energy intensive fishing method. Globally 50 billion litres of diesel is burnt by the fishing fleet annually. In India 1378.8 million litres of diesel was burnt in 2010 and released about 3.13 million tonnes of CO_2.To catch 1kg of fish trawling requires 0.8kg fuel, gillnetting 0.15kg, long lining 0.25kg and purse seining 0.07kg (Gulbradson, 1986). Drag is the most important factor responsible for fuel consumption of active gears like trawls. Estimated drag of commercial trawls in Kerala ranges from 1.37 to 48.94 kN

Factors affecting trawl drags are

- design of the vessel,
- engine power
- speed of propulsion
- type and size of fishing gear and accessories
- location of the ground
- skill and knowledge of the crew
- atmospheric and sea conditions.
- design of trawl net,rigging and operating conditions
- depth of operation, type and length of warp, etc.

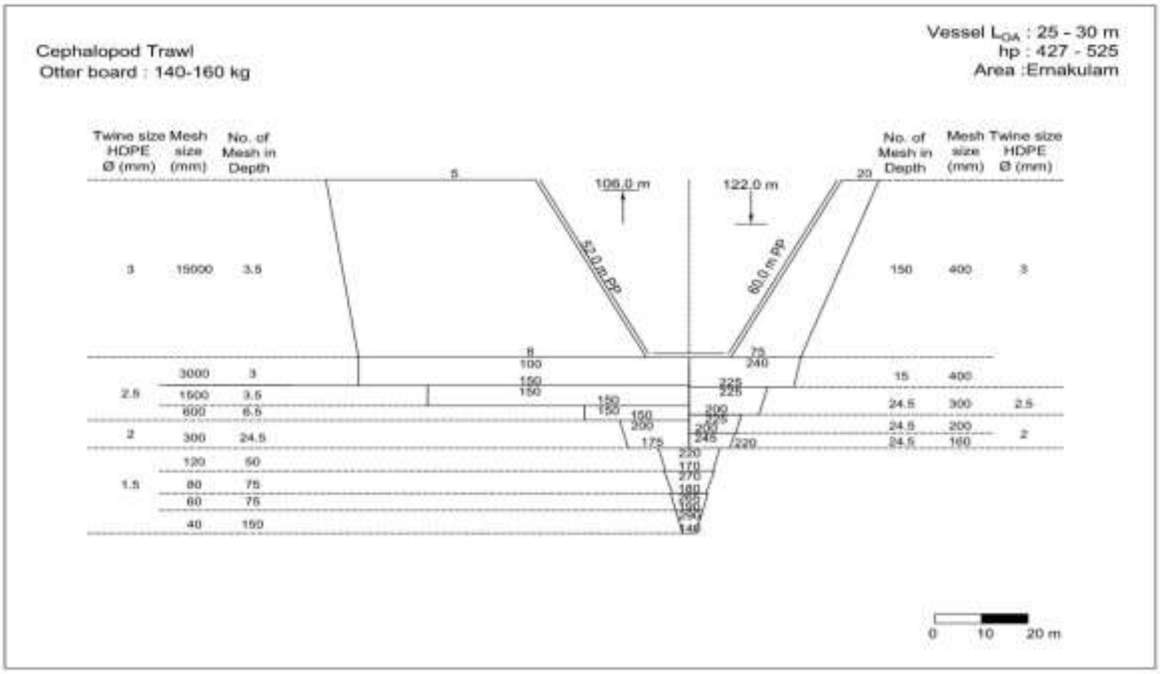
Factors to reduce trawl drag	**Reduction in drag (%)**
Operate multi-rig trawls	25-30
Use thinner twine for trawls	7.0
Use large meshes in the front	7.0
Use knotless netting	7.0
Use curved otter boards (OBs)	4.0
Use optimal angle of attack for OBs	4.0

Use slotted OBs	2.0

Low drag trawls developed at CIFT

Large mesh trawl

ICAR-CIFT introduced large mesh trawls in 1970s at Veraval in Gujarat for conservation of the resources and reduce the trawl drag for energy saving. The concept was well appreciated by the trawl operators in the country and fish trawls with mesh size up to 5000mm in the wing are common at present (Figure1) (Edwin, et al., 2014).



Design of a large mesh trawl from Cochin

UHMWPE trawls

Ultra-high molecular weight polyethylene (UHMWPE) twine is a strong material, which is being used for net making. A study by CIFT revealed that average fuel consumption of HDPE trawls was 31.86±1.25 l-h whereas it was 25.31±1.38 l-h for UHMWPE trawl. Results shows that material substitution, coupled with improvement in trawl design, appropriate gear accessories and towing speed can help significantly in reducing the drag and concurrent reduction in fuel use.

Particulars	**UHMWPE trawl**	**HDPE trawl**
Head rope length	24.0 m	24.0 m
Weight of netting	8.0 kg	14.48 kg
Twine size	1, 0.85, 0.75 mm	2, 1.5, 1.25 mm
Drag of the trawl	12.6 kN	14.83 kN
Fuel consumption	26 liter/h	30 liters/h
Cost for a net	Rs. 48,609.0	Rs.17,264.0

Expected life	2year	1year
Reduction in av. annual operational expenditure	7.5%	

Semi-pelagic trawl

Semi-pelagic trawl system was developed as an alternative to shrimp trawling and it reduce the trawling impact on benthic ecosystem as it is operated 1-1.5m above the sea bottom. High aspect ratio Suberkrub otter boards are used for better opening of the net. Shoes of these boards periodically only touch the bottom and front weights or depressors are used for vertical opening. The trawl system is selective, resource friendly and energy efficient

44 m Cut away top belly shrimp trawl

This trawl is without overhang and top belly is partially removed to reduce the drag without affecting the catch of shrimps. Better swimming fishes can swim up from the front of approaching trawl thereby bycatch quantity is also less. Due to less twine area energy efficiency of the trawl is improved.

27m Short body shrimp trawl

The length of the trawl body has been reduced by increasing the taper ratio to reduce drag. Vertical opening of the mouth has been reduced to eliminate bycatch by reducing number of floats in the head rope. The relatively better swimming ability of finfishes compared to shrimps help them to counter the short and lower vertical height of trawl and swim out of the net. Because of the larger horizontal spread of the trawl mouth, the effective sweep area is more, which is an important requirement for an efficient shrimp trawl.

Trawling for mesopelagics

Mesopelagic community consists of myctophids, salps, jellyfish, finfish, crustacean and cephalopods. Midwater trawl with a small mesh nylon net inner lining is required to retain the mesopelagics

Mesopelagic trawl operation and the net showing inner lining and catch

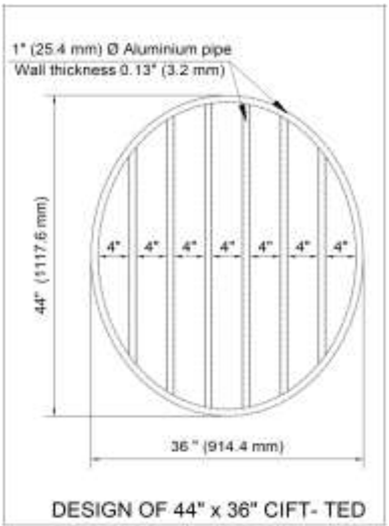
Gear accessories for resource and energy conservation

CIFT has popularised the v-form otter boards, which are stable and durable, and the performance, including trawl opening, was better. To reduce the drag of this otter board and conserve diesel CIFT has introduced the V-form double slotted bards (fig.8). Slots were made in the front part of body of otter boards to allow smooth flow of water through the boards to reduce drag and resultant fuel consumption. Compared to traditional v-form boards the slotted otter board showed reduction in diesel consumption about 2-3 l/h. About 30% of the trawlers have already adopted this technology.

1500mmx 900mm (110kg) V-form double slotted otter board

CIFT-TED

CIFT-TED was introduced to protect turtles from shrimp trawls and minimise fish catch loss. Trials revealed 100% exclusion of turtles with a catch loss of 0.19% for shrimp and 2.07% for non-shrimp components.

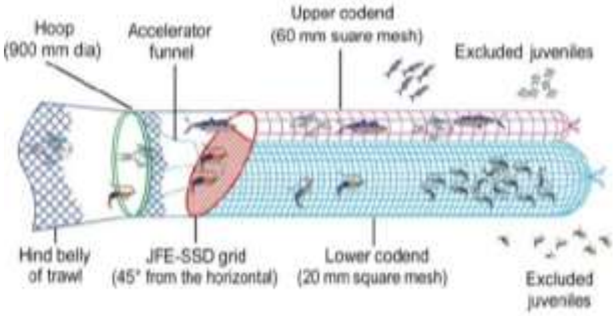


New grid of CIFT-TED

1200mmx1000mm Turtle Excluder Device

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

It is a bycatch reduction device with an in situ sorting mechanism, which replaces the conventional codend in a trawl. The device was designed to catch shrimps and commercially important fish species using a specially designed oval sorting grid with appropriate bar spacing and dual codends. Juvenile fishes are eliminated though the 60mm upper square mesh codend.



Juvenile Fish Excluder cum Shrimp Sorting Device

Square mesh codend with base panel

It was developed to improve the selectivity of square mesh codend by introducing a square mesh panel at the base of the codend. In the very first field trail of one hour trawling off Cochin using the new codend onboard CIFT research vessel RV. Matsyakumari-II about 150 kg juveniles of *Decapterus russelli* could be excluded through the base panel.

Square mesh codend with base panel

Jellyfish Excluder Device

It is a hard BRD with a metallic oval grid with vertical bars having 50mm bar spacing and an exit hole and flap cover like a TED.

Jellyfish Excluder Device

Bycatch reduction measures for long line fishing

Sea birds & turtles are hooked accidentally. Area, time, and depth to be more or less selective to certain spp. Use weights to ensure the lines sink quickly to avoid birds. Setting the lines during night reduce mortality of birds. Dying of bait, Bird scaring line, Underwater bait setting device are other options to reduce mortality of birds.

BRDs for bag net

Square mesh window fixed in stationary bag nets and bycatch from bag net

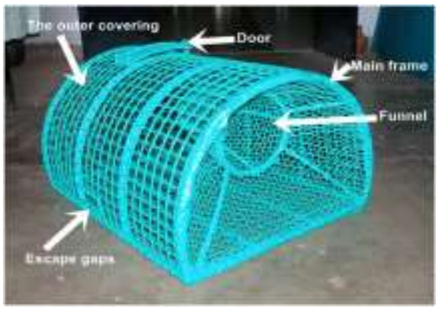
Rescue of dolphins in purse seines

Backdown procedure

The backdown occurs after most of the net is on board. At this point net retrieval is stopped, the net is tied to the vessel and the engine is put into reverse. This creates a water current that causes the remaining net to form a long channel in the water. The water current pulls the end of the channel underwater, with the corkline sinking a few meters, thereby providing an area for dolphins to escape (dolphins remain close to the surface while the tunas are lower in the net The **Medina Panel**, or dolphin safety panel, is a section of small-meshed webbing (net liner) at the apex of the net, which helps keep the dolphins from entanglement. It helps to increase resistance to the water flow and increase sinking of the corkline. DWN is operated in Kerala, India during March to May to protect ring seines from dolphin bite. While hauling DWN encircles the original net and prevents dolphins approaching the bunt with catch

CIFT-Collapsible fish trap for estuarine fishing

CIFT-Collapsible fish trap



CIFT lobster trap

Conclusion:

Responsible fishing gears and practices are promoted globally for resource and energy conservation, reducing the emission of greenhouse gases, minimizing the impacts of climate change and sustainable fisheries for food, employment and income for our survival. Let us together protect the natural resources.

Gillnet fishing: materials, impacts and mitigation measures

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Introduction

Gillnets, an efficient, selective type of passive fishing gear operated world wide both in inland and coastal waterbodies. Simplicity in design, construction, operation and low operating costs, the ability to operate from different vessel types make it a favourite choice among artisanal fishers . The gear is a vertical wall of netting, which is kept erect in water by means of floats and sinkers. Among the various fishing methods, it consumes between 0.15 and 0.25 kg fuels compared to trawl (0.8kg fuel/kg) to catch 1 kg of fish (Brandt, 1984, Gulbrandson, 1986). Gillnet is a highly selective gear compared to other gears. It can be operated in the surface, column or bottom layers of the water column in inland, coastal and deep seas. Gillnets of varying mesh sizes, target a variety of fishes such as sardine, mackerel, anchovies, tuna, shark, seer fish, prawns, lobsters etc. Gillnet operations contribute to more than 15% of total landings of India (Sathianandan, 2013). Currently in India, gillnets provide livelihoods for an estimated 0.86 million people in fisheries, and contribute significantly to fish catches, income and food security, as well as the local and national economy (Thomas *et al*., 2020)

Mechanism of capture in gillnets

Gilling is the basic mechanism of fish capture in gillnet where in the mesh size is selected in such a way that the fish can only partly penetrate the mesh and on sensing the obstruction it tries to pull back (Pinngue He, 2010). 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'. Fishes are also caught in gillnets by (1) snagging, when the fish is held tight by the twine of the mesh around its head, (2) wedging, when the fish is held tight around its body, and (3) 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 (Fig 1.).

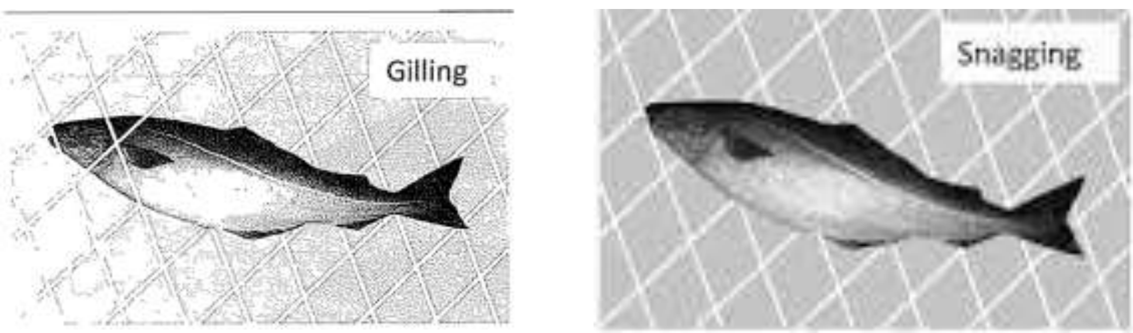


Fig 1: Mechanism of capture in gillnets (Source**:** Pingguo He. 2010.)

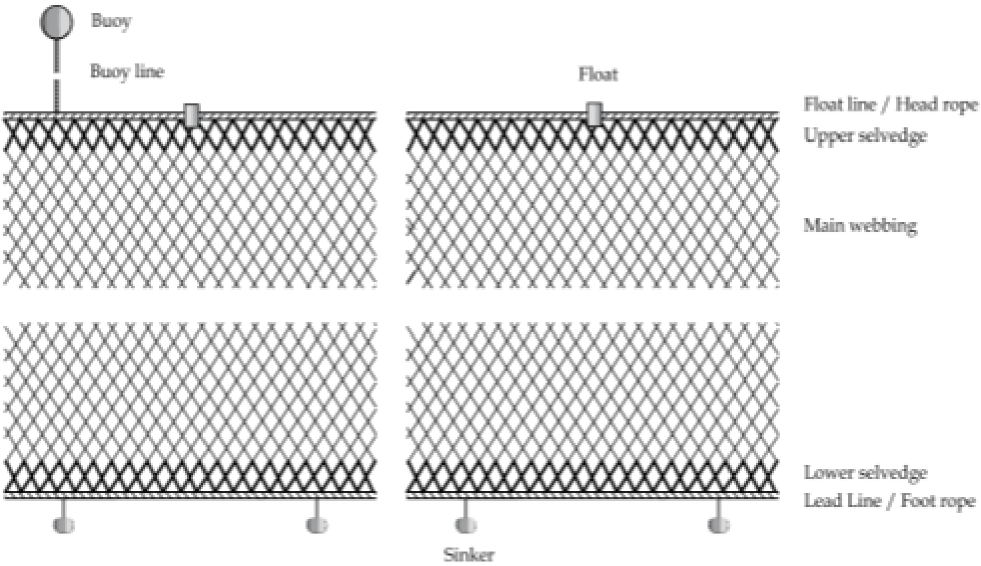
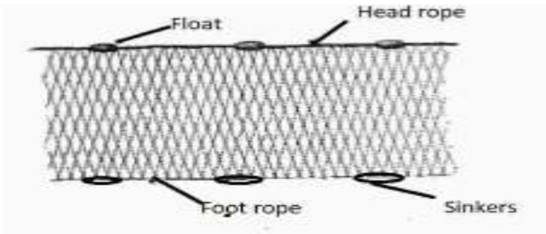


Fig 2: Typical design of gillnet (Source: Thomas., 2010)

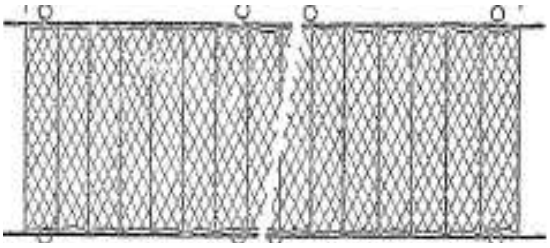
A typical simple gillnet consists of a main netting panel of specific dimensions, twine size and mesh size, selvedge (top and bottom), float line, lead line, gavel line/ side ropes, floats, sinkers, buoys and buoy lines depending on the target fishery (Fig.2). Selvedge, generally of thicker material than the main netting is provided along the edges to give protection to the main webbing during handling and operation. Floats are attached either directly to the head rope or to a separate float line, which runs along with the head rope. Sinkers are also attached likewise, either to the footrope or to a separate sinker line. Buoys attached through buoy lines to the head rope are for adjusting the floatation of the mounted net. The required numbers of units are tied end to end depending on the size of the target species and area of operation.

Types of gillnets

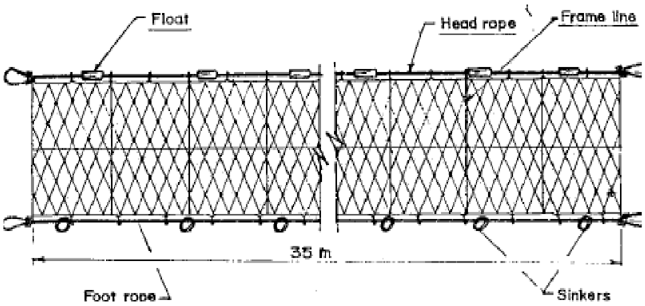
Gill nets can be classified into different groups depending upon the type of construction, area of operation, fish targeted and method of operation. Based on construction there are single walled and multiple walled gillnets. Simple gill nets,vertical line gill nets and frame nets are single walled nets (Fig 3) while trammel nets (double or triple walled) come under the multi walled nets. The vertical line nets are simple gill nets, which are divided into different sections by passing vertical lines from the head rope to the foot rope through the meshes of the webbing. Frame nets are single walled nets whose slackness is increased by attaching vertical and horizontal lines between the main lines dividing the main webbing to compartments of 1 to 1.5 sq.m.



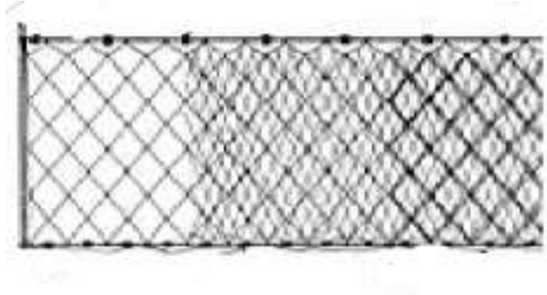
Simple gillnets



Vertical line gill nets



Framed gillnets



Trammel net

Figure 3: Types of gillnets based on construction (Source: Kuriyan. 1971**)**

Trammel nets are triple walled nets having a loosely hung center wall of small mesh netting which is bordered on each side by tightly hung walls of large open meshes. Fish swimming through the outer meshes encounter the center netting and push their way through the opposite outer meshes. Fish become trapped in the resulting pockets that are formed (Fig 4). The outer meshes on one side of the net must be a mirror image of the outer meshes on the opposite side. Semi trammel nets are same as that of trammel nets except that only one layer of outer webbing is present instead of two.

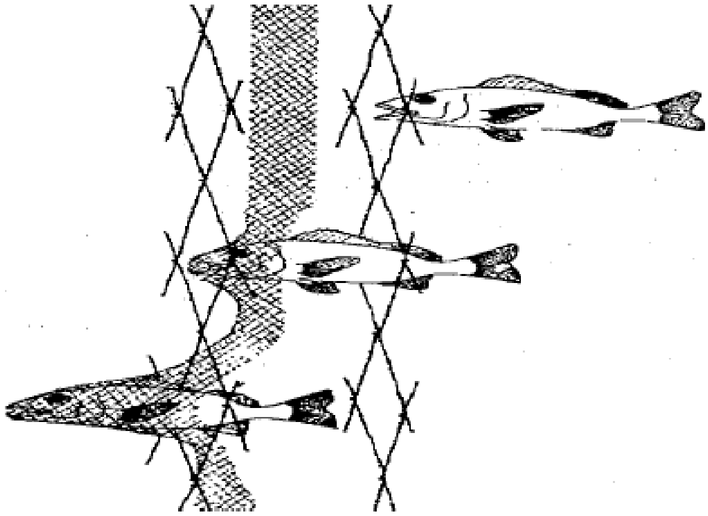
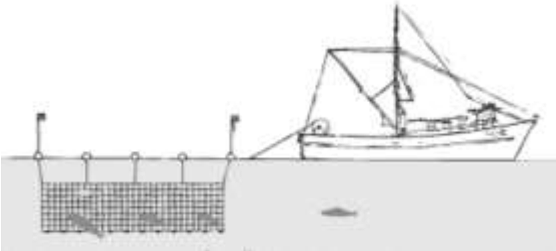
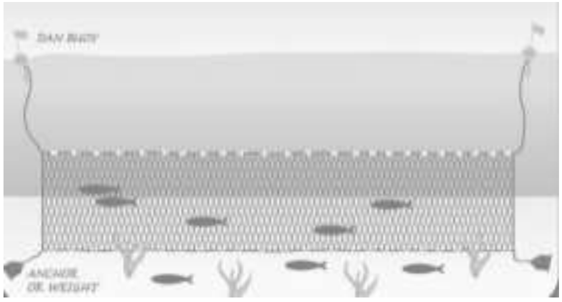


Figure 4 : Method of capture in trammel net (Source: Thomas., 2010)

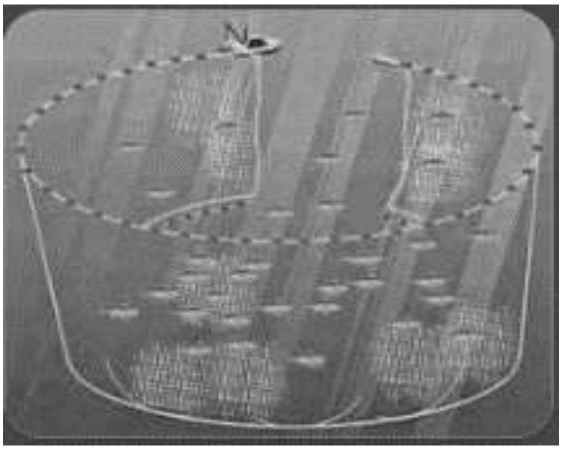
Depending on the method of operation there are 1) drift gill nets Drifting freely according to wind force or current and kept more or less vertically by floats on the headrope and sinkers on the foot rope. They may be attached at one end to the boat which is fishing them, or they may be left to drift free of the boat 2) Set gill nets which are set in water either surface subsurface or bottom and anchored or stalked to sea bed by means of anchors or stakes to prevent them from moving with water 3) Encircling gillnets where the fishes are surrounded and driven from the centre by noise and other means (Fig 5).



Drift gillnet



Set gillnet



Encircling gillnets

Figure 5: Types of gillnets based on operation

Based on area of operation, which is dependent on the depth of water column at which they are operated gillnets are classified as surface, column and bottom gillnets. Based on target species nets are also classified viz; nets for anchovy, lesser sardine, sardine, mackerel, prawn, mullet, crab, lobster, pomfret, hilsa, ghol, seer, tuna, shark, catfish, perch, snapper, rock cod etc.

Design aspects

The design of a gillnet depends on target species, its characteristic body shape, behaviour and swimming layer. The main parameters to be considered while designing a gillnet are: (i) size of mesh in relation to the size of the targeted fish, (ii) diameter of the twine in relation to mesh size, (iii) hanging coefficient (looseness of the net, (iv) visibility of the net, (v) softness of the material and the (vi) buoyancy and ballast given. The mesh size is the most critical factor as it selects the fish by body size or shape. Gillnet is the only gear in which the mesh itself serves the dual function of catching fish and selecting the fish to be caught. The mesh size, the material the net is made of, its thickness and colour and the hanging ratio of the nets perform these two functions. Any fish which is too small for the mesh size will be able to slip through the net and escape, while any fish that is too large on the other hand will not pass through and be able to escape the way it came (Thomas, 2010).

Material characteristics for gillnets

Diameter

The diameter or thickness of twine and its visibility determines the efficiency and strength of the net. The twine should be as thin and as soft as possible but at the same time sufficiently strong to withstand the struggle of the fish to escape. Thinner twine is less visible and reduces detectability by lateral line sense organs, but it cuts deeply into fish body to hold fish more strongly and have shorter life. Increase in the diameter increases the cost as well as durability of twine, where as the catchability decreases. Using transparent material could reduce the visibility. The firmness of fish body and extensibility of twine are also to be considered while choosing the twine. These conditions are fulfilled by synthetic twines especially monofilament. Thinner twines are recommended when fish concentration is less, and thicker twines when high concentrations exist. The ratio of twine diameter d, to mesh size a, is of decisive importance. The value of twine diameter should be proportional to mesh size. The ratio d/a should be between, 0.0025, for calm waters and low catches, and 0.01, for rough waters or bottom set. An average ratio is 0.005. Nets with 0.01 ratio have sufficient fishing efficiency and strength.

Visibility

Gill net should not remain as an impenetrable wall as the fish endeavors to move away from the net. An ideal net is one, which is invisible to the fish. Use of right colour and transparent monofilament material would reduce the visibility, so that it should contrast as little as possible with the surroundings. The measures to be adopted to decrease the visibility include the use of thinner twines, transparent monofilament and colouring the material to match the background. Depending on whether the net is to be used in shallow water or deep water, at night or in the day it is important to choose a colour that does not stand out from its surroundings. Studies by CIFT in the marine waters and reservoirs showed that there is species specificity with different colours. Yellow coloured nets, which were found to give maximum catching efficiency for pomfrets, are very popular in the Saurashtra coasts.

Softness of twine

The gill net should have the maximum possible softness and smallest swell. Solid objects reflect the waves pushed forward by a swimming fish more and the return swell is recorded by the lateral line sense organ of the fish. Therefore to reduce the swell, more slackening has to be effected and the twine should be made as fine as possible. Buoyancy and Weight There are two forces at work on the netting as it is suspended in water, a floating force and a sinking force. In order to keep a net suspended in a given position there must be a balance of the floating force created by the floats), the sinking force (created by the sinkers), the weight of the net itself and other ropes etc. In addition a number of other factors such as weight and pulling force of the fish caught in the net and the force of tide and current etc are also to be taken into account. The way a net hang in water is important in a gill net’s catching effectiveness. The desired hang may be a straight and vertical line or a loose curve along the sea floor depending on the type of fish to be caught. These factors must be taken into account when designing the floating and sinking force that will work on the net. There is no standard ratio for the buoyancy and weight given to a net since it depends mainly on the fishing conditions.

Float line and floats

Gill nets must have surplus buoyancy to keep up the total sinking power of the gear with fish entangled. Bottom set nets have lesser buoyancy than that of drift net. Even though there is no standard ratio for the buoyancy to be provided to a net, as a general rule, it will be equivalent to the weight of webbing in water plus 20 to 25% of the webbing used as sinkers or lead line. Additional buoyancy can be given according to the fishing conditions.

The float line used for mounting the webbing and attaching floats provides uniform buoyancy to the net. The diameter of the rope depends on the strain, which in turn is determined by the number of units, depth of operation, current etc. Ropes with small floats or other buoyant material braided as a core are also used as float line. The floats should be strong enough to withstand pressure. Small floats in large numbers gives necessary buoyancy to provide better shape to the net whereas larger ones avoid entangling of the floats with the meshes. The distance between floats should not be more than 75% of the depth of the net to prevent useful area of the net to sagging between adjacent floats. The materials used include wood, cork, aluminium, glass, plastic and poly vinyl chloride. These are available in different shapes and sizes.

Lead line and sinkers

While fishing for bottom fish, the net has to be ballasted more so that the net moves heavily hugging the bottom. The net has to be ballasted less if it is targeted to fish which live above the bottom. Fridman (1986) has worked out a formula and accordingly the weight of sinkers in water, Qs is greater than the forces of floatation. Qs = KBxQf, where the ballast coefficient KB, varies from 1.25 to 6, depending upon local conditions. Strong current, large fish and snaggy bottom require higher values, otherwise the values in the lower part of the range may be recommended. Heavy material like PVA and PES, can be used for gaining extra weight. A rope with braided or twisted in lead core will serve as sinkers. The rope termed as leaded rope ensures uniform distribution of weight along lead line. The sinkers are prepared out of iron, lead, rock clay, stones or concrete. These sinkers are mounted directly by strops or threaded to the rope.

Issues associated with gillnet fishing

Gillnets were considered as resource specific, eco-friendly having very low environmental impacts as the sea bed interaction is bare minimum in most circumstances. Besides, being a highly selective gear catching a narrow size range of fishes, it was considered as a very responsible fishing gear till two to three decades before. However, these attributes given to gillnets started losing by early 1990s due various issues associated with gillnets which are given below:

Incidental catch of juveniles and non target species

Selectivity of gillnets mainly depends on the mesh size and configuration, which in turn, is influenced by the hanging coefficient. Sainsbury (1996) suggested that for gilling the fish, hanging coefficient is usually between 0.5 and 0.66 with 0.6 being common. As the hanging co efficient decreases below 0.5, there are chances of entangling. These loosely hung drift gillnets entangle non-target species and juveniles of target species. Drift nets especially large mesh nets targeting large pelagics are hung very loosely which when allowed to drift with winds and currents ,entangle a wide range of living marine organisms such as birds, turtles and marine mammals. In the first global review of seabird bycatch in gillnets, it was estimated that 400,000 seabirds are killed in gillnet fisheries every year (Crawford, 2015).. Yousuf *et al.* 2009 estimated that 9000-10,000 cetaceans are killed by gillnets every year along the Indian coast. The incidental catch of marine turtles is associated with drift gillnets across the world and this happens in active gillnet as well as in lost gillnets. The problem is severe in India also and is more pronounced along the coasts of West Bengal, Orissa, Andhra Pradesh and Tamil Nadu.

Use of multi-mesh and non-optimum mesh size

The gillnets operated by commercial fishers often consist of a wider spectrum of mesh sizes, which may differ from the optimum. Optimum mesh sizes have been worked out for some of the commercially important fishes. Also, the fleet of these gillnets operated often consists of units of more than one mesh size attached end to end. This results in different species and different size groups of same species in the landings. Thus, in spite of the known selectivity of gillnet for a particular narrow size range of fishes, the use of different mesh sizes results in the landing of a wide size range of the species and size groups. There has been reports that in the coastal waters of India, juveniles and non-target species are landed using multi-mesh gillnets and gillnets with mesh sizes smaller than the optimum for a particular target species.

Increasing fishing effort

A major reason for many of the issues associated with gillnets is the steady increase in fishing effort viz.,increase in vessel size, engine power, volume of net deployed per operation , fishing time and soaking time all of which collectively add to the total fishing effort. Over the past 6 to 7 decades, there has been a substantial increase in the fishing effort in the gillnet sector. The intensification of fishing capacity through use of very large volume of nets extending to 100s of kilometres and rigging the nets loosely gave chances for catching juveniles and non-target organisms.

Loosely hung nets

Selectivity of gillnets mainly depends on the mesh size and configuration, which in turn, is influenced by the hanging coefficient. Sainsbury (1996) suggested that for gilling the fish, hanging coefficient is usually between 0.5 and 0.66 with 0.6 being common. For large mesh gillnets targeting pomfrets and mackerel, it is around 0.5 while that for seerfishes, tunas and sharks it is around 0.45 ranging between 0.41 and 0.65 (Thomas *et al* ., 2005). As the hanging coefficient decreases below 0.5, there are chances of entangling resulting in non-uniformity in the size class of fishes caught. Rigging of nets at a hanging coefficient of less than 0.5 is common. Drift nets especially large mesh nets targeting large pelagics are hung very loosely without even having foot rope and sinkers enabling easy entangling of large and fast swimming fishes

ALDFG and ghost fishing

Introduction of nylon monofilament material in early 1990s was a remarkable technological intervention adopted instantly by fishers. By late 1990s it became very popular and by early 2000 it almost replaced all gillnet types except large mesh nets targeting large pelagics. Monofilament nets last hardly for a season (2 – 6 months) and unlike nylon multifilament, it is difficult to mend monofilament netting. Once these nets or their parts are either abandoned, lost , or otherwise discarded (ALDFG) into the marine environment causes considerable threat to marine species (Ayaz *et al*., 2006) and also add to marine plastic pollution. ALDFG has detrimental impacts such as destruction of habitats, entangling with marine turtles, seabirds, dolphins, whales, seals etc, introduction of invasive species, hazards to navigation, adverse effects on tourism human health, and safety. As long as the gear configuration is intact, these lostnets continue to fish and leads to mortality of fish and other aquatic organisms including endangered species leading to *Ghost fishing*. The deployment of long nets and extensive use of monofilament gillnets by Indian fishers, pause high risks of gear loss and consequent ghost fishing in Indian waters. First study from India on ALDFG reported annual gillnet lost rate as 24.8% of the total gear per vessel per year (Thomas et al., 2020).

Mitigation measures

Optimum mesh size & Maximum allowable dimensions of gillnet

Many coastal states of India have come out with minimum mesh size regulation for gillnet fishery under the Marine Fishing Regulation Acts while Kerala has enacted it for seven gillnet types. The deployment of long nets and extensive use of monofilament gillnets by Indian fishers, pause high risks of gear loss and consequent ghost fishing in Indian waters. Monofilament nets last hardly for a season (2 – 6 months) and unlike nylon multifilament, it is difficult to mend monofilament netting. Once these nets or their parts are either abandoned, lost, or otherwise discarded (ALDFG) into the marine environment causes considerable threat to marine species and also add to marine plastic pollution. The uncontrolled increase in volume of gillnet, demands restriction as it may give more chances of entanglement and ghost fishing also. Though mesh size regulation is enacted by many maritime states, maximum allowable dimension (length and hung depth) of gillnets is not specified by any of the states. Kerala, for the first time in the country, amended the KMFRA Act and Rules in 2018, and brought out regulations on the dimensions of the gear for gillnets targeted for seven important commercial fishes. The maximum dimensions prescribed for small mesh gillnets are 2000 m length x 10 m hung depth and for large mesh gillnets are 5000 m length x 18 m hung depth (Thomas, 2019).

Minimum legal sizes of fishes

For the first time in the country, Kerala state has prescribed minimum legal size for 58 species of fish and shellfish to be landed. By following optimum mesh size, minimum size of fish to be landed by gillnets can be decided. Gillnets being highly size selective, strict adherence to optimum mesh size for specific fishery would help in reducing juvenile bycatch.

Biodegradable netting

As synthetic fibres are non- biodegradable, the environmental threats it causes due to ghost fishing is an important problem. Entanglement and subsequent mortality of non-target and endangered species due to derelict and lost gillnets can be lessened using easily degrading materials (e.g. thinner net twine diameter 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 (Gilman *et al.*, 2010). Carr *et al*. (1992) tested degradable plastic plates for attaching floats to the headrope of gillnet. Biodegradable gillnets made of polybutylene succinate (PBS) resin blended with polybutylene adipate-co-tere-phthalate (PBAT) resin have been widely studied (Bae *et al*., 2012).

Measures to reduce interactions/entanglement of marine mammals and turtles in gillnets

Marine mammal/turtle entanglements in gillnets is a widely reported problem worldwide. Chances of entanglement are more in surface drift nets. Acoustic pingers and alarms are used to reduce marine mammal bycatch in gillnets and other fishing gears (Koschinski *et al*., 2006). Technical modifications in gillnets such as acoustically reflective nets or incorporating reflective components such as barium sulphate or metal compounds into the nets can help cetaceans to detect gillnet and avoid becoming entangled (Larsen *et al*., 2007). 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 (Wang *et al*., 2013). 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. Other technical measures include increasing net hanging ratio, using buoyless floatlines and/or reducing the number of floats (Gilman, 2010).

Conclusion

Gillnets have great scope in sustainable harvesting of resources, being a highly size selective gear. Enforcement of regulations by proper monitoring and surveillance is necessary for the continued harvesting of resources in a sustainable way. If proper care is taken to responsibly design and operate, gillnetting can continue to be a very sustainable fishing method.

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Recent developments in trap fishing: design and materials

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Introduction

Advancements in fishing technology, modernization and increased fleet size had detrimental impacts on the fish stocks and ecosystem which resulted in the over-exploitation of fishery resources. It is essential to ensure that the resources are utilized sustainably and responsibly through the adoption of national and international policies and programs. The main objective of responsible fishing is maximizing economic returns to the fishermen without affecting the long-term sustainability of the fishery resources and with minimum impact on the ecosystem. Technologies for responsible fishing are generally oriented towards the optimization of fishing fleet, implementation of closed fishing season to rejuvenate the depleted fish stocks, reduction of by-catch of non-target species, protected species and juveniles, minimise the environmental impact of fishing gear and their operation and minimizing the energy use per unit volume of fish landed, during fishing operation.

The concepts of ideal fishing gear ensure sustainable and responsible fisheries. Ideal fishing gear is a device which is 100% effective in catching target species with high selectivity. It captures targeted species over a particular size within its operating area while excluding all other non-targeted species. Also, it consumes less fuel for its operation. However, needless to say, this ideal is rarely met (Pravin et al., 2011) and there is no perfect fishing gear which can be said to be ideal for fishing. By examining characteristics like species-selectivity, size-selectivity, catch ability of target species, low interaction with environment, catch per unit of effort, fuel etc. Traps satisfy most of the characteristics required for an ideal fishing gear.

Pots and traps are gears which make the entry of the aquatic species easy and make the escapement difficult due to special designs. The parts of traps which prevent the escapement may be chambers, flaps, narrow paths, funnels etc. Enormous designs of pots and traps exist throughout the world. Based on the abiotic and biotic factors, pots and traps differ regionally in size, design, operation etc.

Pots and traps

According to Foos and Agricultural Organization, traps are large structures fixed to the shore. Pots are smaller, movable traps, enclosed baskets or boxes which are deployed from any craft. In India, the usage of “Pot” is not very common and the fish trapping devices are generally termed as “Traps”. Traps are generally operated in areas where other types of fishing gear cannot be operated due to uneven bottom or submerged obstacles. The advantages of trap fishing are

- Trap fishing is economic and low energy is required when compared to active fishing methods. They are highly fuel efficient both in terms of f returns and biomass per unit of fuel consumed (Wilimovsky and Alverson, 1971, Mohan Rajan, 1993).

- Organisms caught in the trap can be retrieved alive in an undamaged condition
- Traps can fish continuously day and night and require only periodical tending (Pravin et al., 2011)
- They can be left in the sea during unfavourable weather conditions and can be collected when favourable conditions set-in.
- Capital investment is relatively low and many traps show a high degree of selectivity.

Mechanism & Type of Fish Trapping

In India, based on the area of operation, pots and traps are classified mainly into pots and traps of the marine and inland sectors. The inland traps and pots are very common and popular throughout the country. Even though various marine fish traps are operated for livelihood subsistence, organized marine trap fishing exists only on the Southern coast of the country, especially in Tamil Nadu. Depending on the level of modernisation, traps are also classified into traditional traps and modern traps. Plunge baskets, box traps, filter traps, aproned filter traps screen barrier, bamboo screen barrier, net barrier, *Chemballi koodu, chevu*, Kalava traps, lobster traps, crab traps etc are some of the example for the traditional trapping systems (Remesan, 2006, Remesan and Ramachandran, 2008).

Targeted species

Most of the fishes, crustaceans and cephalopods can be caught with traps and pots. The catch rate of the trap fishing depends on the distribution and assemblage of the targeted species in the fishing ground also the behaviour of the fishes. In India,, shallow-water reef and estuarine fish and shellfish are commonly caught with traps and pots, Most pots and traps used in the tropics have been designed for fishing in reefs, rocky areas and on the rough bottom. The fish, cephalopods and crustaceans taken 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 (giant freshwater prawn) and a number of offshore shrimps. Various types of squid and octopus are also trapped in most tropical waters

Factors considered during the fabrication of fish traps.

The cost for material and the charge for fabrication of fishing traps should be made minimal, by using locally and easily available materials. The material used for the construction should be durable and should be able to withstand the physical stress of the fishing environment. If the traps are for marine use, the material used should be sturdy in sea water or it should be coated or treated with suitable anti corrosion agent. By using biodegradable materials, ghost fishing can be prevented in the event of losing the trap during operation. The design should be simple and easy to set and haul. The gear should be easy to carry in the vessel and should not have any complex structures, projections or attachments. The catch quantity can be improved by using more number of traps. For this stackability of the gear plays an important role. If the traps are of light weight and collapsible, more number of gear can be accommodated in boat or vessel. The design should be selected based on the biological characteristics of the targeted species like morphology, feeding and swimming behavior, niche etc.

Parts of a typical fishing trap

A typical fish trap consists of the following parts

Main frame skeleton (rib): frames are the main skeleton or ribs of trap. Usually strong materials prevent the traps and pots from losing their shape during fishing. Wood, bamboo or metal are the commonly used materials for the fabrication of main ribs,

The outer covering: This part may be with bamboo slits, synthetic meshes or metallic webbings. In traditional pots, coconut or palms leaves are used. The selection of material is mainly based on the traditional usage, cost and availability.

Funnel (entrance): funnel or entrance is the major part of a trap. These are the entrance to the trap. The number of funnel varies depending on the design of the trap. The entrance may be single or multiple. Studies show that more number of funnel increases the catching efficacy of the gear.

Door: Doors are referred to the catch collecting area**.** Some designs may be provided with, an area where the meshes can be opened and closed for collecting the catch

Escape gaps: An Escape vent ensures responsible fishing. These are the gates for the escapement of juveniles entering inside the gear (Fig 1). Escape gaps are common in lobster traps in many parts of the world, but not in India.

Bait area: normally bait will be provided in the trap to attract the fishes. Bait will be fixed in the main chamber of the trap with suitable bait bags or chambers. Small pelagic fishes, slaughter house waste and small animals are commonly used as bait for attracting the fishes. Even artificially formulated bait can be used in traps.

Ballast: In the area with higher tidal flow or current, suitable weights need to be provided in the traps to prevent losing of traps. Ballast are normally used in the traps constructed with light weight material. Ballast also helps to maintain the original posture of the traps during operation.

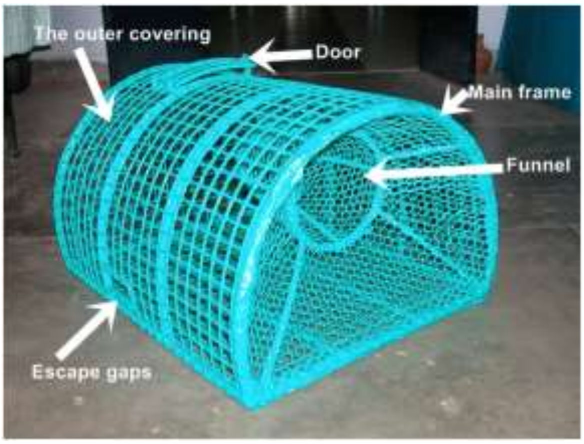

Fig 1. Modern lobster trap (ICAR-CIFT Design)

Operation of traps

Before operating traps, we should have some basic idea on the type of targeted fish, bait, post-harvest handling, storage of catch and market for the harvest. (Slack-Smit, 2001). Simple trapping and potting can be carried out from small boats or canoes or from large vessels. The efficiency of fishing with pots or traps can be improved by the use of equipment like power winches, haulers etc. Once the fishing grounds are fixed, traps can be setup at any time of a day.

Buoys or floats are normally attached to mark the location of the traps. There will be a buoy line attached to the traps/pots for the operation. Proper rigging is essential for the successful operation of the gear. The type and size of the buoy and the length of the buoy line varies based on the area of operation. Normally the length of float line is kept as one and half to twice the water depth of the fishing ground. The length of the line can be increased if the water current is higher at the fishing site. Bright coloured flags, radar, reflectors and even radio beacons are used in advanced trap designs for easy identification. Traps can be operated as single or in series (Slack-Smit, 2001).

Traps and pots can be operated with or without bait. In the case of habitat traps, there will not be provision for the bait attaching area. Funnel shape and positioning of the bait play important role in catch rate. Normally, centre of the traps is the ideal location for attaching the bait. The position of the bait can be optimised by fishers by continuous trial and error method. Depending upon the targeted species, waste from poultry slaughter house, fish and shrimp waste, molluscan meat, wheat flour mix etc can be used as bait. Quality of a good bait include effectiveness to attract targeted species, easy to attach in the gear, long lasting, local availability, low cost etc.

Soaking time also depends on the targeted species and its behaviour. It also depends on the species abundance at the fishing ground. Soaking time varies from few minutes to two to three days while 12- 24 hours is ideal soaking time. After suitable soaking time, traps can be hauled onboard. This can be done either by hand or by mechanical hauler. After collecting the catch, re-baiting can be done and traps can be deployed again in the same or different location.

Material used for trap fabrication

Almost four decades ago, fishing trips were fabricated using natural materials only. A study by Meenakumari and Mohan Rajan (1985) reported that lobster traps were made of different materials such as palm leaf stalks, (*Phoenix dactylifera*) splinters of bamboo (*Ochalandra travancorica*) and coconut (*Cocos nucifera*) leaf stalks. The study also tested the performance of wood (*Tetrameles nudiflora*) as a trap material and found that wood is not a preferred material for the construction of lobster traps. Mohan Rajan et al. (1988) developed an efficient trap for lobster fishing. The semi-cylindrical traps used were a modified version of an Australian pot with a frame of rectangular base and semi-circular ribs. These plastic-coated metal traps are more efficient than traditional traps. The life of the new traps was reported as 5-6 years.

The trap operated for spiny lobster in the southwest of India is known as 'Colachel traps', these traps are traditionally made of palmyra (*Borassus flabellifer*) leaf-stalks, which consist of three parts (floor, top, and sides). The different parts were generally tied together with natural fibres with biodegradable materials which have less durability and life in the sea. In this region, traps were typically consisting of a bamboo, wooden, or steel frame covered with chicken wire with a mesh size ranging from 2–5 cm (Meenakumari and Mohan Rajan, 1985). Colachel traps don't have much popularity in the other part of the country because the construction technique of these traps was known to only a few fishermen in this region (Mohan Rajan et al., 1988). A recent study along the Enayam coast of Tamil Nadu observes a full shift from the conventional biodegradable material to durable materials like Polyethylene, mild steel (MS) rods, etc (Beena mol et al., 2017).

Prabhu (1954) made a detailed investigation on the trap-based perch fishery of the Gulf of Mannar and Palk Bay. He recorded that the traps were made out of split branches of *Acacia planifrons*, thin bamboo strips, and midribs of palmyra leaves and operated in soft sandy (Gulf of Mannar) bottom and hard rocky (Palk Bay) bottom. Prior to the construction of traps, the materials are soaked in water to increase their strength and durability. Similarly, Varghese et al. (2008) also surveyed on materials used for the fabrication of traps. They recorded four types of natural materials such as Odai tree sticks, Eeecha tree sticks, Palmyrah roots, and Palmyrah leaves, and one synthetic material, Polypropylene, locally known as 'wire', which is usually used as a packing strap for cartons. The 'wire' is a recently introduced material for the construction of traps, which normally lasts for 5 years. The traps made of the Odai tree (*Acacia planifrons*) usually last for 1 year and those of the Eeecha tree last for about 2 months. After assessing the cost of construction and efficiency of fishing in terms of size and quantity, Kalaiarasan et al. (2014) reported the use of tree sticks of *Acacia planifrons*, roots of *Phoneic dactylifera* and leaves of *Borassus flabellifer* for the fabrication of traps. However, in recent years a noted a major change in the materials used for trap fabrication. Polyvinyl chloride (PVC) nylon garden fencing mesh is one of the recent materials used for trap construction. This material is preferred by fishermen because of its flexibility, lightweight, and durability.

Ghost fishing in the trap sector

Due to bad weather conditions, gear conflicts, the physical condition of the fishing ground, entangling of large marine animals etc., there will be a chance to lose or abandon the fishing gear during operation. These lost or discarded fishing gear which are no longer under a fisherman's control known as derelict fishing gear (DFG), can continue to trap and kill fish, crustaceans, marine mammals, sea turtles, and seabirds. The most common types of DFG to ghost fish are gillnets and pots/traps. Ghost fishing can impose a variety of harmful impacts, including the ability to kill target and non-target organisms, including endangered and protected species; causing damage to underwater habitats such as coral reefs and benthic fauna; and contributing to marine pollution (NOAA, 2015). To prevent ghost fishing in trap fisheries, the following steps can be adopted.

- Using proper ballast and anchoring mechanism
- Always operate traps in good weather conditions

- During unfavourable conditions, remove traps from the fishing ground
- Select a suitable site for the installation of traps
- Always provide an escape vent or escaping mechanism in the design.
- Use of biodegradable meshes in specific locations

Conclusion

Traps are highly energy efficient low-cost fishing gears with high size selectivity. Trapping allows some control over the species and sizes of the catch. The trap entrance, or funnel, can be regulated to control the size of fish that enter. Fresh and live catch ensure premium prices to the fishers. Once the traps are set, the fishers can operate other gear or engage in other works to increase their income. In the context of energy conservation and responsible fishing techniques, trap fishing in the artisanal sector needs to be promoted.

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Line fishing in India and advances in the materials

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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 challenge (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).

Gear materials and accessories

Longline fishing involves using a main fishing line that can stretch for miles and is equipped with smaller lines (called branch lines) carrying baited hooks. The materials used for longline fishing gear typically include:

1. **Mainline:** Usually made of monofilament or multifilament nylon. Monofilament lines are single-strand lines, while multifilament lines consist of multiple strands woven together.
2. **Branch lines:** These are attached to the mainline and are usually shorter lines with hooks and bait. They're also made from monofilament or multifilament nylon, similar to the mainline.
3. **Hooks:** Made of various materials, including stainless steel, carbon steel, or even non-metallic materials for specialized applications. These hooks are attached to the branch lines and come in different sizes and designs depending on the target species.

4. **Floats and weights:** Buoyant materials like styrofoam or plastic floats are used to keep the mainline afloat, while weights (often lead) help sink the branch lines to desired depths.
5. **Baits:** Natural or artificial baits are used to attract the target species to the hooks. Natural baits can include fish, squid, or shellfish, while artificial baits may be made of synthetic materials.
6. **Swivels and clips:** Swivels are used to prevent the lines from tangling, and clips are used for attaching hooks and weights to the lines.
7. **Markers and buoys:** Used to mark the positions of the longline for retrieval purposes. These are often brightly colored to make them easily visible.
8. **Reel and machinery:** For deploying and retrieving the longline, specialized reels or machinery are used, especially in commercial operations where longlines can be several miles long.

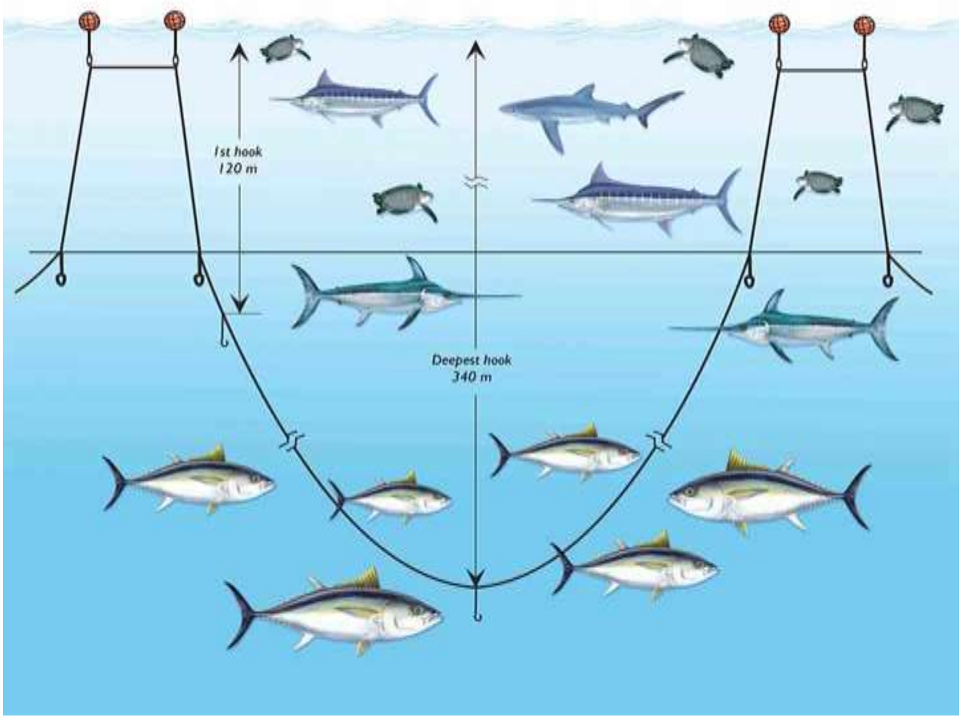
The choice of materials depends on factors such as the target species, fishing location, depth, and environmental considerations to minimize bycatch and ecological impact. Regulations often dictate the materials and fishing techniques used to ensure sustainability and minimize adverse effects on marine ecosystems.

Advances in 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.

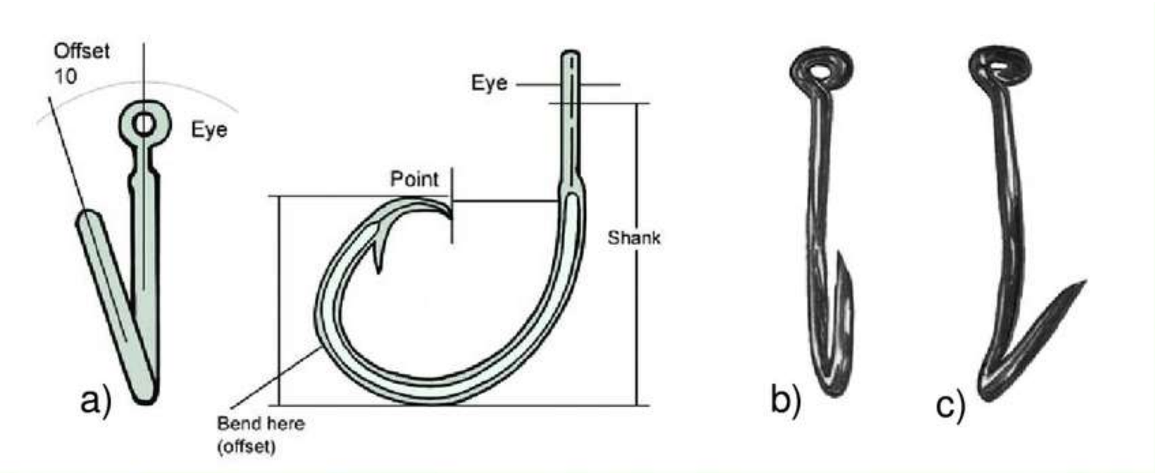
b. Set operational depth to deeper or shallow waters:



Swot,2006

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.

c. Use circle hook with offset:



FAO, 2009

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)

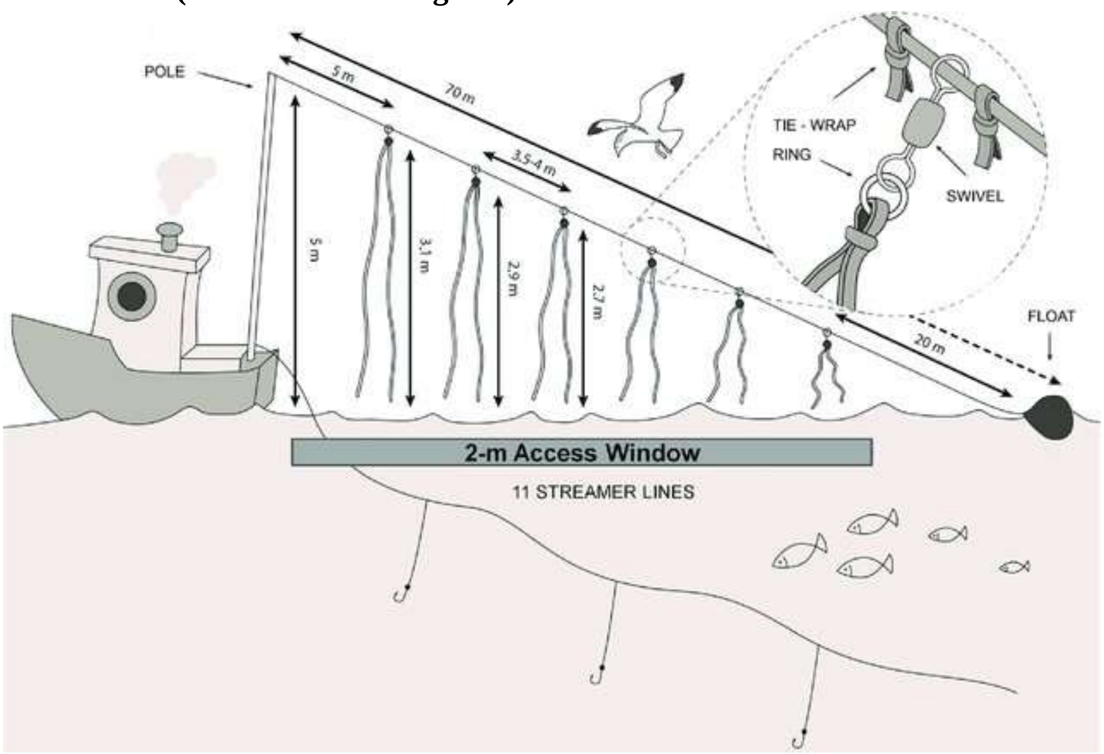
d. **Line weighting:** Weights are added to the branch line so hooks are quickly deployed to the target fishing depths. This reduces bycatch of seabirds by moving the baited hooks out of the diving range of seabirds. The effectiveness of line weighting depends on the distance between the weight and the 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):**



Vero & Jacob, 2018

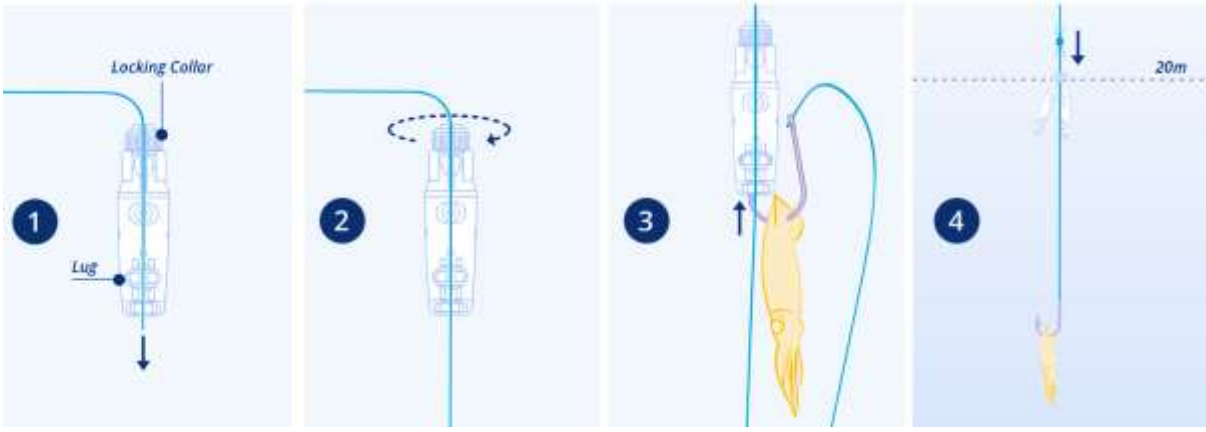
An extra line will be dropped behind the boat with streamers that is towed from a high point as the baited hooks are deployed (usually near the stern). An aerial segment with streamers suspended at regular intervals is formed as the vessel moves forward, creating drag on the streamer line. The mitigation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

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).

Conservation in long line by eco friendly materials

Developments in sustainable fishing practices have led to the exploration and use of biodegradable materials in longline fishing gear. Here are some materials being considered or already used:

1. **Biodegradable Fishing Lines:**

- **Biopolymers:** Polymers derived from natural sources like corn starch, sugarcane, or cellulose that decompose more readily compared to traditional synthetic materials. These are made from polymers derived from natural sources such as corn starch, sugarcane, or cellulose. These materials are engineered to degrade more quickly when exposed to environmental conditions.

- **Biodegradable monofilament:** Composed of biodegradable materials that break down over time, reducing the impact of lost or abandoned fishing gear in the oceans.

Composed of materials specifically formulated to break down over time, reducing their persistence in the marine environment. These lines are designed to maintain strength and functionality during their usable lifespan but degrade when no longer in use.

2. **Eco-friendly Hooks:**

- **Biodegradable or non-metallic hooks:** Made from materials that break down in marine environments, reducing the threat to marine life if lost.

3. **Eco-conscious Floats and Weights:**

- **Natural materials:** Floats and weights made from eco-friendly materials like cork, wood, or other biodegradable substances. Some fishing lines incorporate natural fibers that decompose more readily than synthetic materials. These fibers could include materials like cotton, hemp, or other plant-based fibers.

4. **Eco-friendly Bait:**

- **Natural or bio-based baits:** Substituting synthetic or non-biodegradable bait with natural alternatives or those derived from sustainable sources.

5. **Biodegradable Markers and Buoys:**

- **Bio-based or compostable materials:** Development is ongoing to create baits from bio-based materials that are biodegradable or more environmentally friendly than traditional synthetic baits. These might include plant-based or biodegradable polymers.Using buoys and markers made from materials that break down over time, reducing the presence of debris in the ocean.

Efforts to introduce biodegradable materials into longline fishing gear aim to minimize the long-term impact of fishing activities on marine ecosystems. However, it's essential to ensure that these materials maintain the necessary durability and functionality required for fishing operations while being environmentally friendly. The goal behind biodegradable fishing lines is to reduce the amount of abandoned or lost gear that contributes to ocean pollution. However, while these materials offer potential environmental benefits, their performance characteristics, durability, and suitability for different fishing conditions need to be thoroughly evaluated to ensure they meet the necessary standards for fishing operations.

Regulations and initiatives promoting sustainable fishing practices may encourage the adoption of these biodegradable materials, balancing the needs of the fishing industry with environmental conservation. As these technologies continue to evolve, research and development efforts are focused on creating biodegradable fishing lines that strike a balance between functionality, durability, and eco-friendliness, ultimately contributing to more sustainable fishing practices.

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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Energy optimization in fishing systems through material substitution

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Introduction:

Fishing is a process which totally depends on external energy. This process considered as one of the most energy-intensive food production systems globally. Commercial fishing operation mainly utilizes fossil fuels which results in emission of greenhouse gases. Broadly fishing has two processes; the first involves construction of fishing vessel, gear and other accessories and the second involves harvest process. The active cost of fishing is less understood and consequently receives less attention than the direct impact on fishery stock and marine ecosystem. Fishing boat is made up with different components and its construction is a complex process. Certain quantities of greenhouse gases (GHGs) are produced in the process of manufacture, transportation and utilization of these components, which can be converted in terms of equivalent CO_2. Similarly, in harvest process, several reoccurring inputs are required for every fishing operation, viz. fuel, lubricant, ice, fresh water etc. These inputs have their own carbon footprint value for construction/extraction/process, specially fuel contributes more than 95% out of all the components. Despite the fact that prevailing pre-harvest phase of marine capture fisheries lack general detail and standardization about LCA/carbon foot print studies; such studies and their findings can be useful in formulating constructional/operational recommendations to improve environmental performance of fisheries, under the context of ecosystem approach to fisheries along with future certification and different eco-labelling of fisheries. Studies related to pre-harvest, harvest and post-harvest fisheries LCA/carbon foot print analysis would be more appreciated by policy makers for regulation of fishing boat yards and other related fishing ventures.

Energy requirement in different fishing operations

Based on behavior and habitat, there are different methods of fish harvest and on the basis of their operation the quantum of fuel and energy requirement also varies. According to one study of globally large-scale industrial fishing sector consumed about 14-19 million t and small-scale fishing sector consumed about 1-2.5 million t of fuel oil. The production of fish per tonne of fuel was 2-5 t in the industrial sector and 10-20 t in the small-scale sector. As per the study by Parker et al., 2018, the world fishing fleet burned about 40 billion liters of fuel and emitted 179 million tonnes of CO_2 equivalent and other GHGs to the atmosphere. Overcapacity and irresponsible use of fossil fuel leads to increased level of fuel consumption in fishing contributing to climate change in the long run. India contributes 134 metric tonnes (2.7%) of CO_2 emission due to total marine capture fisheries, against 90 million metric tonnes (3.9% of global production) of fish production. The emissions due to fishing were not given importance as compared to other sectors for emission in India, however, the contribution of fisheries sector is negligible which roughly may be <1% to global GHG emission (Tyedmers, 2004). The other associated important environmental parameters by which health of environment, human and resource can be evaluated due to fishing process are; terrestrial acidification, formation of fine particulate matters, Water consumption, Ionizing radiation, ozone formation, human carcinogenic toxicity, fossil resource scarcity, mineral resource scarcity environment deterioration, human health, resource depletion and stratospheric ozone depletion etc. In energy context some of the important fishing methods are listed below:

Trawling: Trawling is one of the most energy intensive fishing methods. It consumed nearly 5 times more fuel compared to longlining and gillnetting (passive fishing methods) and over 11 times to purse seining for every kilogram of fish produced. For large trawlers, 90% fuel consumption accounts during active trawling operation. Percentage of fuel cost in the operational expenditure of trawlers may vary between 45% and 75%, depending on engine power and duration of voyage.

Gillnetting/longlining: Gillnetting and longlining are the passive type of fishing where the gross energy requirement is comparatively lower than trawling. These passive gears are either fixed or drifting in water column which do not require energy for operation process except hauling where it is done by mechanical means.

Purse seining: Purse seining is one of the most aggressive and efficient commercial fishing methods for capture of shoaling pelagic species (Ben-Yami, 1989; Ben-Yami and Anderson, 1985). It is a fishing technique which targets pelagic shoaling fishes. Before actual operation the shoal detection needs more fuel for fish scout, once shoal gets detected the encircling, capture and hauling process is follow-up. Purse seine operations are relatively energy efficient and greenhouse gas (GHG) emissions for small scale mechanized purse seine operations are low compared to trawling, gillnetting and lining operations.

Traps and pots: Traps or pots are gears in which fish are retained or enter voluntarily and will be hampered from escaping. They are designed in such a way that the entrance itself became a non-return device, allowing the fish to enter the trap but making it impossible to leave the catching chamber. It can be baited or non-baited. Generally passive fishing gears like gillnets and trammel nets, tangle nets, longlines, trap nets and pots, and other lift nets consuming very little power in fishing and in some cases no mechanical energy. Although travelling, setting and retrieval of gear may use some energy, target stocks are attracted by bait or are carried to the gear or encounter it by chance and are trapped. Tyedmers (2001) reviewed over an approximately 20-year period (early 1980s to late 1990s) and found about 330 L of fuel used to catch per t of catch in a crab trap.

Other fishing methods: There are several fish harvest practices which require more energy; light fishing is one of them. Fishing using lights has been practiced from historic times, a classic example is 200-year old Chinese dipnet, which use lights (earlier hurricane lamp and now CFL lamps) to attract fish to the net. Chinese dipnets are mostly animate energy based sustainable fishing operation. More than half of the purse-seine vessels, stick-held dipnet and squid jigging boats use artificial light. Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB), 2012, suggests that roughly global marine catches using lights is 1.09 million tonnes (1.6% of global catches) in 2010. Roughly 16% of the light fishing catches comprise of squids, and the remaining >80% are fish species (Mohamed, 2016).

Fuel and emission:

Fishing operation is an external energy-intensive operation which produces emissions mainly due to burning of fossil fuels (Parker et al., 2018). Other related activities which demand energy input, such as net fabrication, fishing gear operation, post-harvest activities etc. Fossil fuel is a dominant energy sources in different fishing methods such as long-lining, gillnetting, trawling, ring seining and purse seining. Mechanized and motorized fishing operations are dependent on fossil fuels which are non-renewable and releases high levels of carbon dioxide to the atmosphere contributing to greenhouse gases (GHGs) to the atmosphere. Due to increased level of fuel consumption in fishing operations, processing and storage of fish, emission of GHGs also increased which finally led to climate change adversely. The energy and material used in the fishing vessels can create negative environmental impacts, mainly due to the consumption of fuel, gear usage and loss, anti-fouling agents, paint and ice consumption. The use of energy is now increasingly important in comparative resource-use analysis, potential trade trends, and in carbon and related greenhouse gas (GHG) impacts in climate change mitigation (FAO, 2012).

The active cost of fishing is less understood and consequently receives less attention than the direct impact on fishery stock and marine ecosystem. During the last decade, the price of fuel and other energy sources was on a rising trend. In 2001, fuel was estimated to account for 21% of revenue from landed catch, whereas in 2008 this increased to about 50%. Fuel use varies usually with type of fishing and level of effort, but as one of the key cost components over which the fisheries sector has no direct control. Profitability and livelihoods are potentially highly sensitive to energy costs (FAO, 2015). The emissions from fisheries were not given importance as compared to other sectors, however, the contribution of fisheries sector is negligible which roughly may be <1% to global GHG emission. Later many studies, research publications and report highlighted its importance. During last 3-4 decades several factors played a pivotal role in increased emission viz. increment of fleet size and number (overcapacity), which resulted higher catch. The major direct and indirect energy inputs can be systematically analyzed using process analysis and input-output techniques. Mostly direct fuel inputs are used primarily for vessel propulsion. On an average direct fuel energy inputs account for between 75 and 90% of the total energy inputs, irrespective of the fishing gear used or the species targeted. Remaining 10 to 25% is generally dependents on vessel construction and maintenance, and the provision of labor, fishing gear, bait, and ice if used which depending on the character of the fishery and the scope of the analysis conducted. The secondary energy-consuming activities, which include on-board processing and storage is negligible compared to primary energy consumption in terms of fuel burned. Here squid jigging is an example in which relatively large proportion of fuel inputs are used for activities other than vessel propulsion. These include mainly batteries of high intensity lamps, automated jigging machines, and on-board storage facility etc. The energy requirement is met by diesel-fueled generators to attract, hook, and preserve the catch while fishing. On an average the non-propulsion energy demands account for 40% of the total fuel burned. Out of total indirect energy inputs, largest fraction account for building and maintaining the fishing vessels. This is mainly due to vessel's major components (hull, superstructure, decks, and fish holds) are fabricated basically from energy-intensive materials such as aluminum and steel as compared to wood or fiberglass.

As far as fishing craft and gear material is concerned, they play crucial role in energy consumption. The nature and texture of material for construction of craft and gear play a crucial role in drag/resistance offered while craft and gear are in operation. The resistance offered is directly proportional to energy requirement by the whole fishing system. ICAR-CIFT is instrumental in developing technologies by using material substitution which have reduced fuel consumption with less environmental burden. Fiberglass canoes and fiberglass sheathed canoes made of rubber wood introduced by ICAR-CIFT have become very popular because of its reduced resistance and fuel consumption. Aluminum boats designs by the institute is another milestone in this series. Aluminum is light weight material, which helps in smooth maneuvering and energy efficiency. ICAR-CIFT has made immense contribution towards the standardization of the netting, netting yarn and netting twine used for fishery purposes, which are mainly focused on reduced physical resistance with greater energy efficiency. These developments have led to an increase in the productivity of the fishing gear and increase in net profits of fishers due to low maintenance and long service life of the implements. Dyneme and platina are some of the material which can be substituted with conventional material in order to achieve energy optimization (Jha and Edwin, 2019).

Some measures for energy optimization:

Energy security and conservation have great significance on account of responsible fishing and also to meet the demand-supply gap of fossil fuel. During the tow, resistance of the vessel is insignificant compared to the resistance of the gear. The gear resistance therefore has a large effect up on overall fuel economy. Fuel cost can be over 50 percent of the total expenses on a fishing trip. Generally, fuel consumption due to floats, sweeps, warp, otter boards, foot rope and webbing are nearly 3%, 4%, 5%, 20%, 10% and 58% respectively. Some of the preventive measures can save fuel in trawling operation are use of knotless netting, thinner twine, large meshes, cambered otter boards, optimal angle of attack of otter boards, slotted otter boards, multi-rig trawling, pair trawling etc. The fuel consumption significantly increases at maximum speed of vessel, this is because of increase in wave breaking resistance. Facts established that reduction of 10-20% speed can lead to save fuel by 35 to 61% fuel. Application of proper vessel technology during construction of vessel is very important for energy optimised vessel. Operation at rated engine rpm helps in reduction in fuel consumption. Selection of right engine with proper periodic maintenance is required for effective energy optimisation. For energy optimisation, proper fleet management, resource conservation and fishery-based geo informatics system like PFZ etc are also very important.

Conclusion:

Different types of vessel and gear combinations are used for fishing to exploit various fish stocks. The important fishing practices are trawling, gillnetting, longlining, dol netting, purse seining etc. One major reason for the substantial increase in eq. CO_2 emission by construction process is the increase in number and efficiency of fishing boats otherwise called overcapacity, which need more inputs and equipment, results in more eq. CO_2 emission.

In modern fisheries the major direct and indirect energy inputs can be systematically analysed using process analysis and input-output techniques. Mostly direct fuel inputs are used primarily for vessel propulsion. On average direct fuel energy inputs account for between 75 and 90% of the total energy inputs, irrespective of the fishing gear used or the species targeted. Remaining 10 to 25% is generally depends vessel construction and maintenance, and the provision of labour, fishing gear, bait, and ice if used which depending on the character of the fishery and the scope of the analysis conducted. The secondary energy-consuming activities, which include on-board processing and storage is negligible compared to primary energy consumption in terms of fuel burned. Study of environmental burden is important in relative resource-use analysis and greenhouse gas (GHG) impacts in climate change mitigation (Gulbrandsen, 2012). It has got emphasis due to the high instability in fossil fuel cost which has potentially lasting impacts on the economic performance of various fishing systems. These impacts, its implications for fish harvest is markedly to fisheries sector, and are likely to have profound aftermaths for resource impacts and for food security across the globe.

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Biofouling in fishing gears & vessels: assessment, impacts & prevention

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Introduction

Accumulation of materials or particles and living organisms on a surface is called fouling. Fouling is categorized into three such as inorganic fouling, organic fouling and biofouling. Inorganic fouling is formed by the physical and chemical effects like heat, pressure, and friction or by natural process through which the minerals in the water stacked on the surface of the materials were immersed in the water. The materials that accumulate on the fishing inputs may be non-living, comprising detritus and organic or inorganic compounds, but it may also include organisms that may range in size from microscopic viruses to giant kelps, which can grow on to form complex multi-species, multi-dimensional communities. Biofouling as a process means biological fouling and is a general term used to describe both the micro-biological and macro-biological growths that occur on the exposed exterior of materials.

Marine biofouling has been a major problem for man since the ancient maritime explorations and initial human engagement with the ocean through artificial structures. The attachment, growth and colonization of aquatic fouling organisms on the exterior of fishery engineered structures likes vessel hull, fuel lines, propeller blades, wooden poles of stake net, concrete/ wooden poles of Chinese dip net, and nets & frames of aquaculture cages, etc. causes adverse effects in the fisheries and economy.

The ever-expanding global population has the quest for sustainable nutrition sources has intensified, triggering a heightened demand for food production. Capture and culture fishery together provide food security, but amidst this quest, aquaculture has emerged as a pivotal solution that offers both economic prosperity and enhanced food security. Cage culture has gained substantial popularity in mariculture as well as aquaculture. However, the persistent challenge of biofouling, particularly in cage aquaculture within marine and inland settings, poses a formidable hurdle to achieving efficient and sustainable production. The enduring development of the aquaculture industry is a key factor in the strategy to guarantee global nutritional safety. Nano technological interventions in cage aquaculture refer to the application of nano-technology to improve various aspects of cage-based aquaculture systems. Nowadays, different types of nano-technology-based systems have been employed to increase aquaculture production, efficiency and sustainability, and also for the prevention and control of biofoulers on the fishing gears, & fishing vessels. The assessment of biofouling on fishery inputs was essential for understanding the impacts of biofoulers and for implementing effective prevention methods.

Biofouling and fouling organisms

Biofouling is a multi-stage process and it develops sequentially from an initial condition layer of absorbed organic and inorganic matter in the aquatic environment. Biofouling is defined as the undesirable accumulation of living organisms on exposed artificial surfaces in the aquatic ecosystem by adhesion, growth and reproduction. When it occurs in the marine environment it is called marine biofouling. Marine biofouling accumulates on surfaces in five succeeding stages such as initial attachment, irreversible attachment, initial growth, final growth, and dispersion. Most aquatic fouling organisms prefer hard substratum for settlement. It was estimated that about 127,000 aquatic species depend on hard surfaces for living while 30,000depends on soft surfaces (*Gizer et.al,* 2023). However, a wide range of micro and macro-organisms can contribute to marine bio-fouling and approximately 5,000 species of marine biofouling organisms occur in the world, of which 2,000 species are recorded (Tseng andHuang, 1987). Marine biofouling can be divided into two main categories based on the size of organisms that accumulate and attach to the water contacted surfaces such as microfouling and macrofouling. Microscopic organisms like bacteria, viruses, protozoa, diatoms, fungi, and micro algae form micro fouling. Macro fouling organisms directly depend on microfoulers. Micro-fouling is essential for the settlement of more complex macrofouling organisms. Macrofouling organisms are further classified into two based on the body structure of the colonizing organisms namely soft and hard macro fouling organisms. Macro-algae, soft corals, anemones, tunicates, and sponges-like organisms with no solid/calcareous supporting structure are considered soft macrofouling organisms and organisms with hard supporting structures are hard macrofouling organisms such as barnacles, tubeworms, bivalves, and polychaetes which are difficult to remove once established. Some organisms bore more deep to the submerged and fouled materials such organisms are called borers. Organisms bore either for shelter or for food. The boring behavior of organisms directly destroys the submerged woods, rock, and other materials.

Processes behind biofouling

The processes of biofouling consist of five elementary processes such as transport, settlement, attachment, development, and growth of fouling organisms. All these elementary processes replace each other sequentially during surface colonization by foulers. The colonization processes consist of two models such as probabilistic model and succession model or classic model. Prior to colonization, film formation is the crucial step. Organic conditioning film formation is an important process in marine biofouling. Marine biofilm formation is a highly dynamic combination of chemical, physical, and biological processes that occurs within seconds of the initial interaction between exposed material and an aquatic ecosystem. Once a new surface, whether biotic or abiotic immersed in seawater can quickly adsorb organic matter that forms a nutrient-rich layer within a minute, in other words, it is described as the organic conditioning film. The formation of organic conditioning film is the result of a simple physical reaction, and it is comprised of colloidal organic matter and molecules such as polysaccharides, proteoglycan and proteins. Organic conditioning film formation is the first step of marine biofouling and that result in the development of a stickier surface and which makes the exposed surface more favorable for the attachment of bacteria. The attachment of bacteria to the conditioning film results from the metabolism of organisms, as a result, they adhere to the surface faster and lead to the development of bacterial colonization. The sequence of colonization consists of bacteria, diatoms, autotrophic flagellates, heterotrophic flagellates, amoebae, heliozoans and ciliates. This sequential colonization process is known as succession or microfouling and the resulting layer is termed as microfilm/biofilm/marine biofilm. Diatoms are considered the major contributor to the primary colonizer. The reversible adsorption and irreversible adhesion are the two distinct steps involved in the microorganism colonization. The reversible adsorption is governed mainly by physical effects such as Brownian motion, electrostatic interaction, gravity, water flow and Vander Waals forces. The irreversible adhesion occurs mainly through biochemical effects such as the secretion of extra cellular polymeric substances. Within the biofilm, bacteria can coordinate their adhesion, biofilm maturation, swarming, luminescence and toxin production through a process known as quorum sensing. Quorum sensing is a process that involves producing releasing, detecting, and responding to small hormone-like molecules termed auto inducers that are released into the environment by bacteria. Some bacteria and marine organisms like algae can respond to the quorum sensing signals of other bacteria. The development of a biofilm on a substratum changes the attractiveness of the substratum to invertebrate larvae and algal spores through physical modification of surfaces or by production and release of chemical compounds. In the next stage of marine biofouling, propagules of macroorganisms, larvae of invertebrates, and spores of macroalgae will settle on the surface. Two or three weeks later, these will finally evolve into a complex biological community. Microfouling is the first stage of succession of hard-substrate community and it is also considered the second step in marine biofouling. The colonization process is broadly described as a biological succession. The rod-shaped chemo-heterotrophic bacteria (e.g.*Pseudomonas*) are considered primary colonizers on the submerged surfaces. They appear on the conditioning film within 1 or 2h or earlier and may prepare the microconditions for the development of filamentous and stalked bacteria at the final stage of bacterial succession. Bacteria stimulate the fouling and development of diatoms. Succession may be based on the facilitation by early-species by creating conditions favorable for the late succession species. So the primary colonizers create conditions for secondary colonizers (spores of macroalgae, protozoa) this process continues until the development of tertiary colonizers. The first stage of macrofouling succession is by fast-growing and the second stage is by slow-growing organisms and succession ends with a short-term climax stage. This classic succession model over simplifies the colonization process implying stage to stage. The absence of a stage does not impede the occurrence of another stage and such colonization process follows a more dynamic and probabilistic model. In probabilistic model, some species like acorn barnacle and bryozoan's species may settle on the surfaces without the presence of a conditioning film and biofilm. The colonization process is dependent on the number and type of organisms and the attachment of organisms on substratum are independent of one another. The absence of a surface may result in the aggregation of foulants and form marine snow and it remains in the seawater. That entrapped the propagules of macroorganisms, larvae of invertebrates, and spores of macroalgae and it may gradually settle to a substratum that will allow the growth after attachment.

Biofouling assessment

The most commonly used assessment method for biofouling is Physical and biological assessment. The establishment of both physical and biological assessments forms the fundamental techniques in assessing biofouling problems

Physical assessment

This method focuses on detecting and analyzing any physical changes that take place due to the presence of biofouling growth and deposition on exposed surfaces. The first method uses a heat transfer monitoring (HTM) device for determining the thickness of micro fouling that is appeared as a thin layer of biofilm on the surface of the pipeline wall. Based on the concept of heat transfer measurement, the thickness of biofilm that acts as heat transfer resistance is measured by measuring the temperature difference between the heated section of fluid inside the pipeline and the reference temperature, in this case at ambient temperature. The apparatus consists of two thick-walled sections of copper cylinders, one section that acts as ambient temperature measurement and another section is a heated wall surrounded by a nichrome heater. The presence of biofilm is detected through changes of measured temperature difference.

Biological assessment

Scanning electron microscopy (SEM) is used to analyze biofouling growth and deposition profile on the contacted surface, providing crucial information of the type of organisms or materials involved, a rough estimation of biofilm thickness and the nature of its growth. Before this visual inspection, the accumulated biofouling sample on a set of attached coupons to the surface was extracted by scrapping manually or using a special tool to scrape any deposit on the surface of fishing inputs. These coupons were subjected to accumulate biofouling deposition over a period of time. It was done within six months up to one year before the samples were extracted. The extracted samples formed a biofilm layer comprised of entrapped diatoms and portions of differentiated algae and other organisms. Apart from determining the species present on extracted substrates, this technique evaluates the effectiveness of mechanical cleaning techniques by observing any residual that remains after the physical cleaning process. The availability of various biochemical assessments provides a comprehensive biological and chemical characterization of the extracted biofouling. There are a few biochemical assessments such as adenosine triphosphate (ATP) total organic carbon (TOC), carbohydrate analyses, chlorophyll contents, and total dissolved iron content, combustible organic matters. The various biochemical assessments provide quantitative measurement of biofouling. Several biofouling monitoring systems reported from other water treatment industries.

Impacts of biofouling

The adverse effect of marine fouling on vessel hulls still exists and it occurs on the vessel hull, propeller blades, fuel lines, etc. Macro-biofouling makes the vessel heavier and the hull rougher which leads to an increase in frictional resistance which results in a loss of the speed of the vessel which may decrease by 40% or more. The fuel consumption increases by about 40%. A layer of microbial slime of 1mm thickness can increase hull friction by 80% and cause a 15% loss in vessel speed. Frictional resistance increases with sufficient strong fouling of the hull by both micro and macro biofouling. While in some cases, the biofouling on the propeller blades is a more important cause of fuel waste. Biofouling indirectly influences the carbon footprint of vessels and greenhouse gases in the atmosphere, that is a 5 per cent increase in biofouling causes 17 percent increase in fuel consumption by ships which leads to 14 percent increase in greenhouse gases (CO2, NOx, and SO2) emission. On the other hand, heavy biofouling of fuel lines causes engine failure and a greater danger is observed by the fouling of heat exchangers. Biofouling accelerates the corrosion of metal walls. Docking frequency and other prevention methods such as antifouling coating are the widely used method for controlling biofouling. Up to200-400 tons of fouling biomass may be removed in one docking. Dry docking operation is more expensive and time-consuming moreover it generates a large number of toxic substances that are discharged into the ocean. While fouling on the poles of stake nets and Chinese dip net will reduces the service life of the both gears.

Submerged aquaculture cage nets are highly susceptible to biofouling especially during summer months due to favorable and nutrient-rich aquatic environments around the cages which attract micro and macro foulers, and also attract invasive species like Mytella strata. Biofouling in aquaculture cages develops either through a succession model or a probabilistic model. Biofouling in aquaculture cage nets causes several problems such as occlusion of mesh openings, thereby increasing weight and drag, deformation of cages due to the ensuing stress, reduction of volume, thereby decreased stocking density per area, anoxic condition due to disruption of dissolved oxygen flow, blocking of food waste diffusion, restriction of water exchange, increased hydrodynamic force, all of which makes an unfavorable environment for fish and which adversely impacted fish health. In addition, cnidarians' biofouling can be harmful to the fish; biofouling can facilitate and amplify the presence of pathogens by harboring viral, bacterial, and parasitic organisms that cause various diseases. This leads to economic loss and also makes that area not suitable for further aquaculture activities. Earlier the fouling in aquaculture cages was controlled by cleaning by means of brushing and scrubbing of cage nets. While for commercial farmers such cleaning and scrubbing on particular intervals were not practically possible because of more time consuming in addition to that high labor charge.

Strategies for biofouling prevention

Protection of technical and biological objects from biofouling includes a range of existing and emerging approaches. The protection can be based on physical and chemical factors or jointly. The process of biofouling occurs by both physical and chemical reactions. The protection can be easier by successful inhibition of the physical reactions which would constrain the later biochemical reactions. The different methods used for controlling biofouling include scrubbing off the fouling (docking), Autoclaving and plasma pulse technology, UV Radiations, use of remotely operated marine robotics for removal of biofilm and macrofouling from vessel hull, continuous bubble streams, high-frequency vibration, and biological control. The existing chemical, physical, and biological antifouling methods have not successfully tackled biofouling problems effectively and sustainably. Therefore, new surface technologies in combination with current methods should be developed by considering ecological effects.

Frequent visual inspections of cage nets can catch early signs of biofouling. Gently scrubbing or brushing the net surface can remove accumulated organisms before they become a problem.

In situ, net cleaning is one of the most common methods employed by farmers. This proactive approach prevents excessive buildup and maintains optimal water flow. Introducing natural predators like certain fish species and invertebrates into the cage ecosystem can help control biofouling organisms. These natural grazers feed on unwanted growth, reducing the need for manual cleaning. This method encourages a balanced ecosystem within the cage. Periodically moving aquaculture cages to new locations can disrupt the settlement of biofouling organisms. This method prevents attachment and growth on cage surfaces, reducing the overall impact of biofouling. Applying non-toxic anti-fouling coatings to cage nets can deter the attachment of biofouling organisms. These coatings create a slippery surface or release compounds that discourage settlement, making it easier to clean the cages when necessary. Using UV light systems can inhibit the growth of biofouling organisms on cage surfaces. UV treatment disrupts their reproductive cycles and prevents excessive accumulation. This method is environmentally friendly and helps maintain clean cages. Simple mechanical devices, such as rotating brushes or water jets, can be installed on cages to continuously clean the net surfaces. These devices help prevent biofouling build up and ensure consistent water flow.

The existing In-situ cleaning, rotational movement, and biological control methods have not successfully tackled biofouling problems effectively and sustainably. Therefore, new surface technologies in combination with current methods like the use of nano-engineered particles should be developed by considering ecological effects. Nanotechnology has enormous potential to provide innovative improvements to aquaculture systems to reduce costs, increase efficiency and reduce our impact on the environment. The non-polar nature of polyethylene aquaculture cage net causes difficulties in antifouling strategies over. For minimizing this problem in antifouling coating CIFT introduced copper oxide (CuO) nanoparticles coating over the modified surface of polyethylene by using polyaniline. The small size and high surface activity of nanoparticles rendered them a potential material that can use in cage nets. Nano copper oxide has the efficiency to avoid incrustation of microorganisms and hence prevent biofilm formation. The nano CuO-treated cage net exhibited excellent biofouling resistance in the marine environment and the percentage of occlusion of the mesh by foulers was 56.77% more efficient than the untreated cage net. Nano-materials improve the durability and strength of cage materials by improving the adhesiveness and rheological parameters such as viscosity, elasticity, mechanical strength and plasticity that increases the resistance to corrosion and wear and tear in harsh aquatic environment. In addition, Nano-material coating reduces the maneuverability and cost of cleaning cage frames and cage nets. The continuously flowing water may carry the leached nano-particles so the probability of accumulation of nano-particles (CuO) on cultured species in the cage is very less. While, nano metal oxide–polymer composites as it exhibits hydrophilicity, large surface area, and high toxicity towards microorganisms all these properties make it an suitable option for managing biofouling in cages.

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Sea safety aspects in fishing operations

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Fishing is considered as the most dangerous profession in the world. The reasons are the following:

1. Fishing is to be done in the open sea
2. Sea conditions can change at any time
3. Fishing boat has a lot of limitations
4. Fishing done from open area on the deck
5. Space available on the deck is limited

Principles to be followed for the design and construction of marine vehicles like Ship, Tug, Barge, Pax Vessels, Boats, etc are the following:

- Design according to rules and safety requirements-
- Prepare all drawings to meet the requirements of the owner in compliance with rules
- Choose a proper yard for construction
- Use only marine grade raw materials and workmanship
- Use all available methods to estimate main engine power and propulsion details
- Painting, anodes, corrosion prevention steps
- As fitted drawings with all modifications
- Inclining experiment / Trim & Stability booklet and sea trials

The boat design involves the following steps.

1. Choose suitable construction material, raw materials, welding rod, resin, glass
2. Prepare the initial design
3. Analyse the preliminary stability
4. Prepare detailed Structural Design and General Arrangement plan
5. Identify the deck equipment, winch and a comfortable deck layout
6. Design a cold storage for fish
7. Choose proper engine power to minimise the fuel consumption
8. Propulsion and steering arrangements
9. Select deck winch, marine paints
10. Bill of materials, construction schedule
11. Conducting trials and stability tests

The shortages in the existing commercial fishing boats are:

- No toilet facilities onboard: (risky at sea) as well as at harbour
- No galley (kitchen): Comfortable and safe cooking facilities are not available
- Berth for crew: Presently there is no proper berth available onboard.

- Less hygienic storage conditions on the boat

Commercial deep sea fishing is very important because

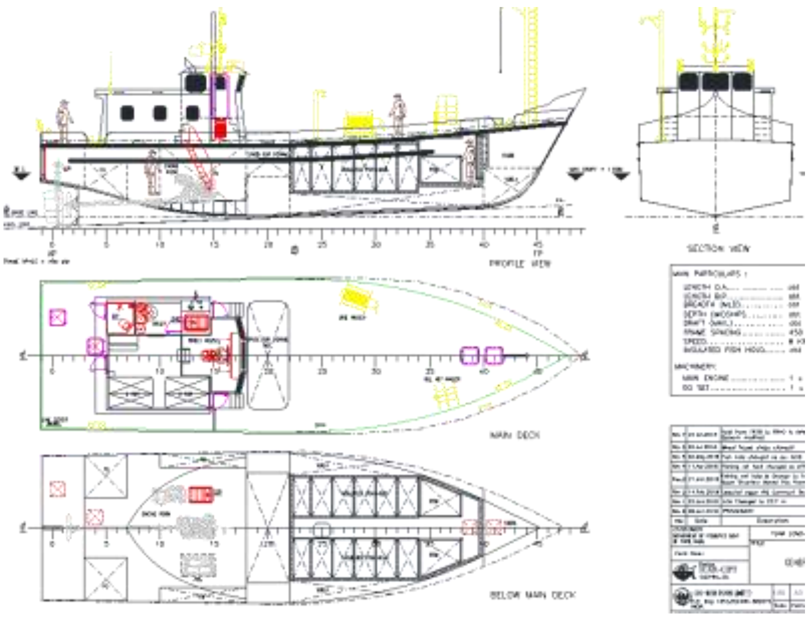
- It is a selective fishing method.
- Less damage to near shore bottom
- Help to improve stock
- More export possibilities
- Helps traditional fishermen to fish nearshore area.
- Juveniles will not be caught
- Longer and expensive fishing trip
- Expensive boat and gear system

The deep sea commercial fishing methods are:

- Trawling
- Long lining
- Gill netting
- Purse seining/ring seining
- Squid jigging
- Dolnetting

Comparison of approved and non approved design and construction of deep sea fishing vessels are:

Approved design and construction below.



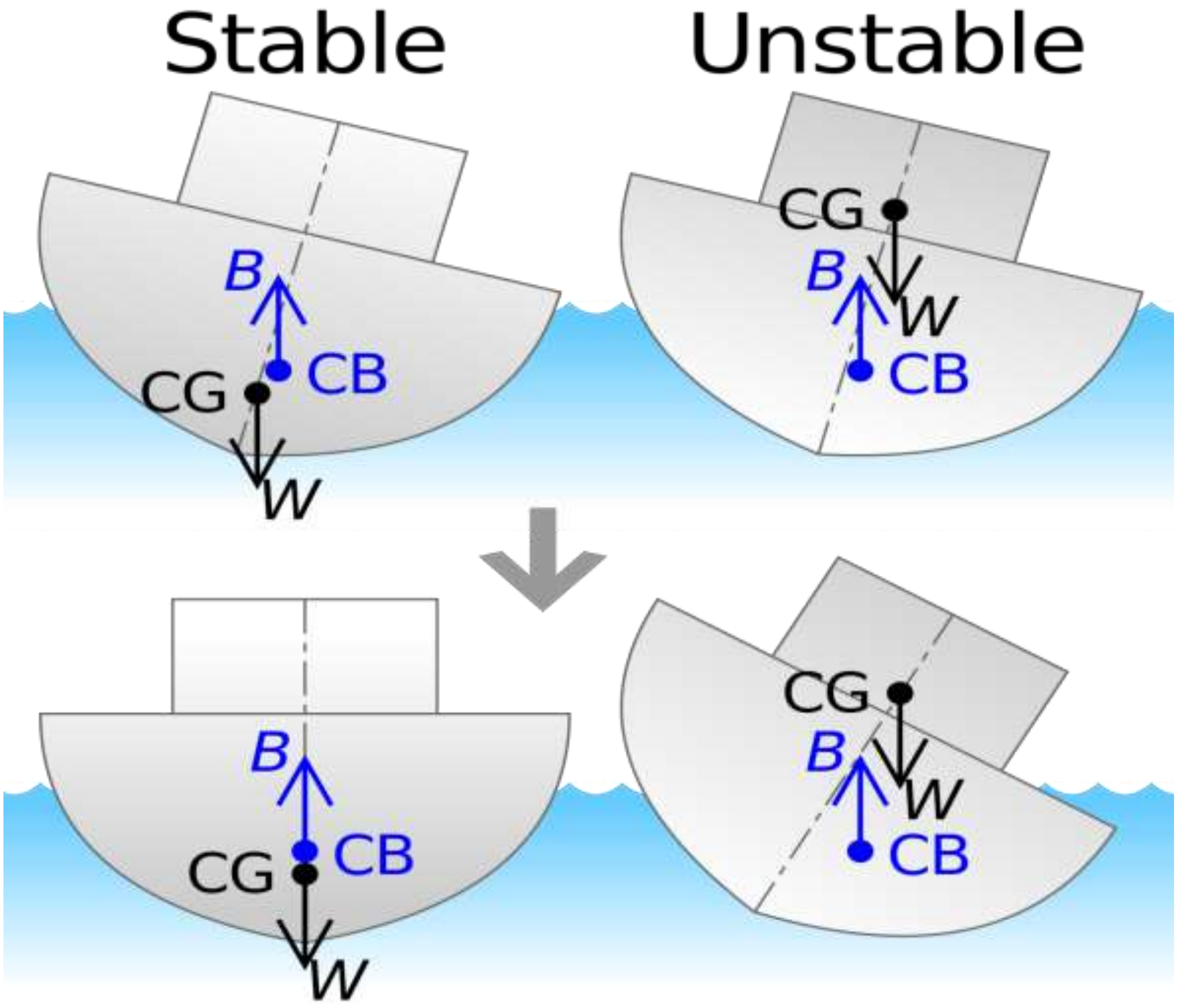
The non approved boat constructed is like below:

The wheel house cum accommodation is very congested and not safe for navigation. The bulwark height is low and not safe for sea fishing. The quality of boat building materials used are lower and corrodes faster leads to leak. Berth, toilet and cooking facilities are not provided.

Factors affecting stability of fishing vessels are: Material of construction

- Depth and breadth of vessel
- Weight carried onboard
- Distribution of weight onboard
- Design of vessel
- Construction of vessel
- Operation of vessel

The stability of a vessel can be explained by the below figure.



A stable ship or boat has the center of gravity below the center of buoyancy. The unstable boat will have the cog below the cob.Legally defined, a seaworthy ship is one that is fit for any normal perils of the sea, including the fitness of the vessel itself as well as any equipment on it and the skills and health of its crew. Fishing activities are carried out onboard the vessels at sea. To work comfortably onboard, the fishing vessel should be seaworthy. The rolling, pitching motions to be very low. For all marine vehicles including boats, stability certificate is mandatory. This is to ensure the safety of the vessel with crew / passenger onboard and the cargo/ fish it is carrying. The registration will be given only after obtaining a Trim and Stability booklet approved by the Classification society/ MMD.

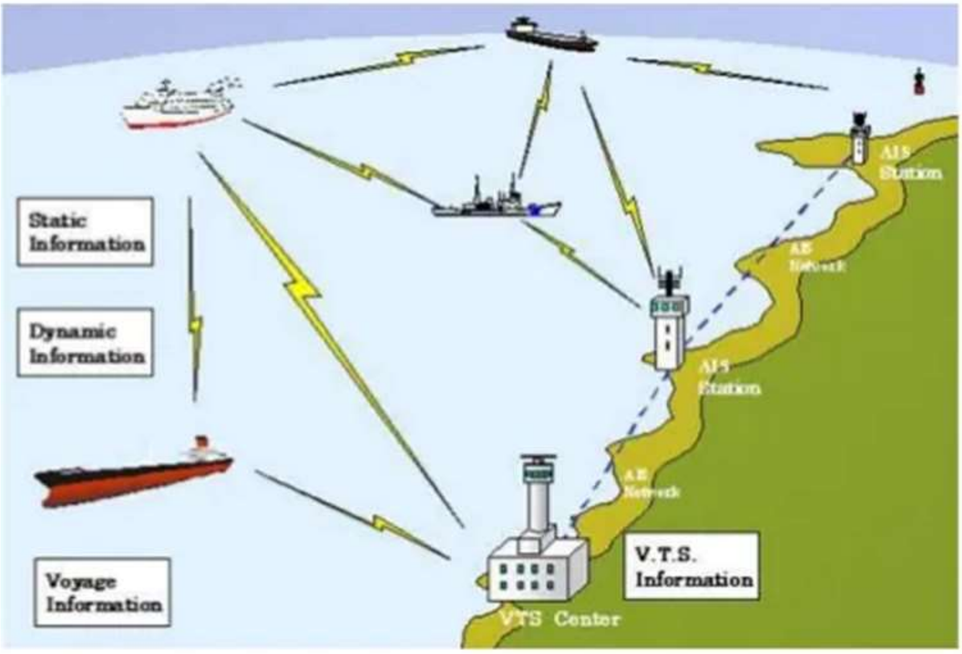
Stability can be ensured by:

1) Conducting an inclining experiment and

2) Preparing stability booklet

Sea safety equipments are:

1. **AIS (Automatic Identification System)**



This can track all the vessels surrounded on this vessel with the position, speed and course

2. **MF/HF radio station** is a high tech equipment, designed for receiving and transmitting messages between vessels in the medium and high frequency range. It usually consists of a transceiver, a control block, and an antenna.For any vessel crossing oceans and seas as well as for those working offshore, an MF/HF radio is an indispensable section of equipment, it ensures long-distance radio communication. MF/HF radio is an important part of GMDSS, that's why most of the vessels are obliged to install it in accordance to international safety regulations.

This requires license from Ministry of Communications

3. **Life buoy**

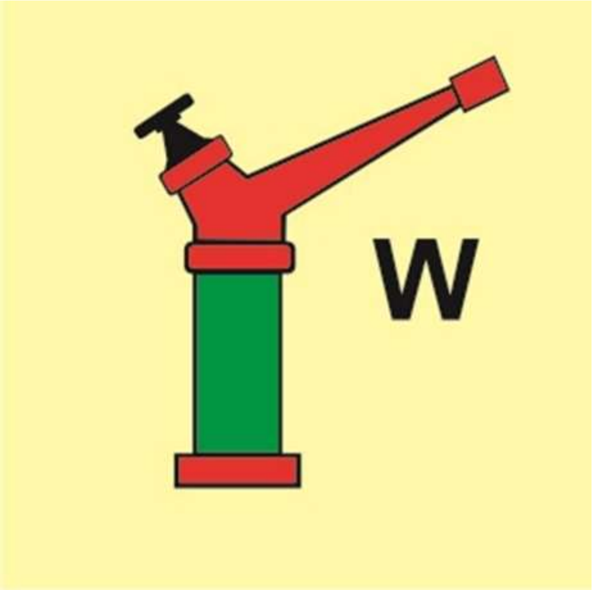
Lifebuoy shall:

- Have an outer diameter of not more than 800 mm and an inner diameter of not less than 400 mm; to be constructed of inherently buoyant material;
- It shall not depend upon rushes, cork shavings or granulated cork, any other loose granulated material or any air compartment which depends on inflation for buoyancy;
- Be capable of supporting not less than 14.5 kg of iron in fresh water for a period of 24 hours;
- Have a mass of not less than 2.5 kg;
- Not sustain burning or continue melting after being totally enveloped in a fire for a period of 2 seconds;
- Be constructed to withstand a drop into the water from the height at which it is stowed above the waterline in the lightest.

4. **Life jacket**

5. **Infatable life raft**

6. **Fire Controlling Appliances**
   - CO_2 Extinguisher
   - Foam type
   - AFFF
   - DCP



7. Lights, Shapes and Sound signals

Orange Signal Flag

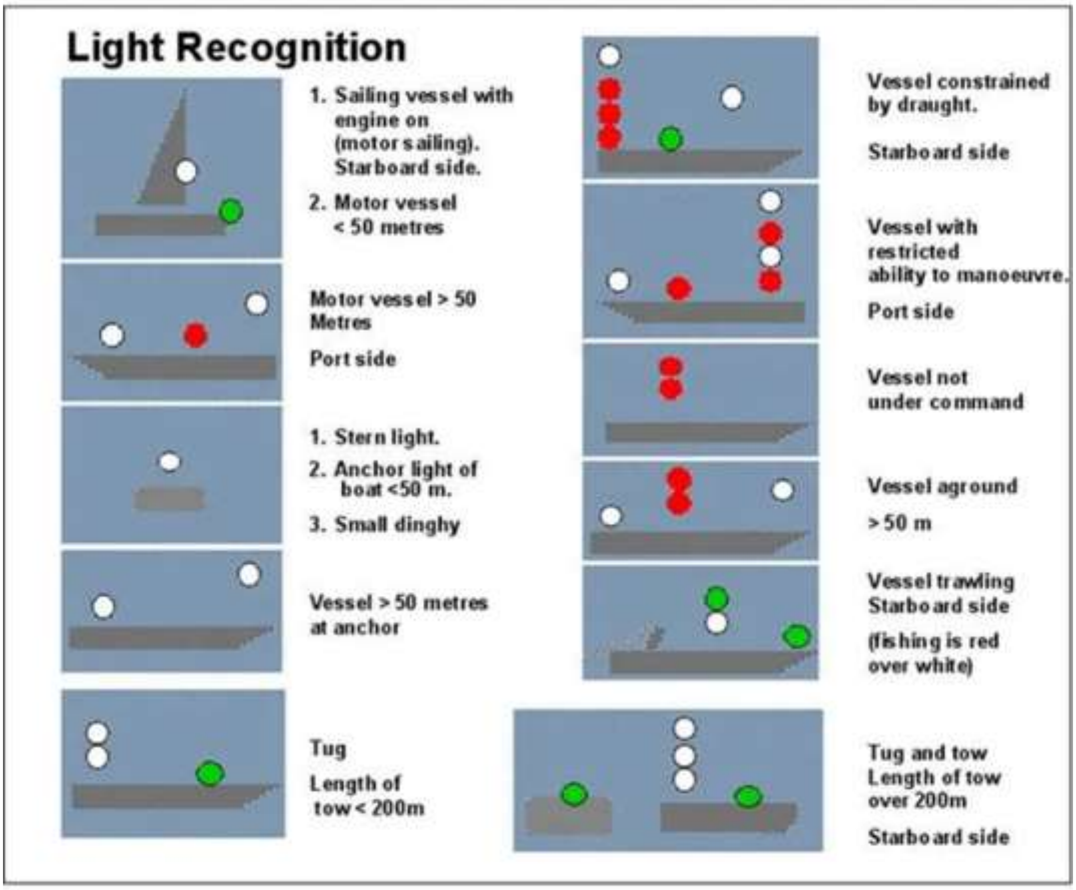
SOS: The universally known SOS as per the Morse Code which basically is the most widely known way to communicate distress. Such a signal sent by radiotelephony or any other method such as sounding it on the ship's whistle is a non pyrotechnic means of signaling

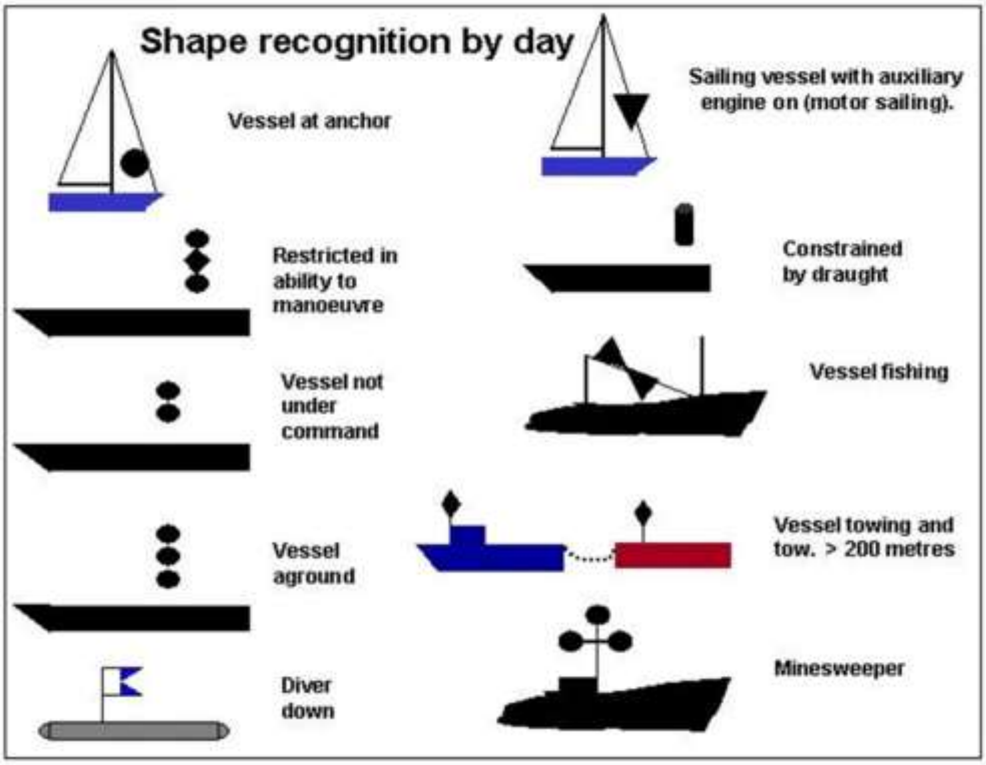
Radio Signals: As part of the GMDSS, radio signaling is a method of communicating distress at sea. A distress alert may be sent by the Digital Selective Calling methods transmitted on the VHF channel 70 or the following MF/HF frequencies

When the word "Mayday" is communicated verbally via radiotelephony, it indicates distress.

Signals transmitted by the Emergency Position Indicating Radio Beacon (EPIRB) indicate distress.

Signals transmitted by the Search and Rescue Radar Transponder (SART) also indicate distress.


Light Recognition
1. Sailing vessel with engine on (motor sailing). Starboard side.
2. Motor vessel < 50 metres
Motor vessel > 50 Metres
Port side
1. Stern light.
2. Anchor light of boat <50 m.
3. Small dinghy
Vessel > 50 metres at anchor
Tug
Length of tow < 200m
Vessel constrained by draught.
Starboard side
Vessel with restricted ability to manoeuvre.
Port side
Vessel not under command
Vessel aground
> 50 m
Vessel trawling
Starboard side
(fishing is red over white)
Tug and tow
Length of tow over 200m
Starboard side


Shape recognition by day
Vessel at anchor
Sailing vessel with auxiliary engine on (motor sailing).
Restricted in ability to manoeuvre
Constrained by draught
Vessel not under command
Vessel fishing
Vessel aground
Vessel towing and tow. > 200 metres
Diver down
Minesweeper

Bycatch issues in fishing gears

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Introduction

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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Fishing gear related micro plastics: impacts /assessment methods

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Introduction

UNEP defined "Marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds; or accidentally lost, including material lost at sea in bad weather". Marine litter is a pressing global concern, with plastics constitutes over 80% of all litter. Plastics encompass a wide range of synthetic or partially synthetic materials that use polymers as their main building blocks with intrinsic flexibility makes it possible to shape solid things with a variety of shapes by molding, extruding, or pressing. This property, along with numerous of other qualities including light weight, durability, adaptability, and cost-effective manufacture, has driven their widespread acceptance. Chemicals made from fossil fuels, particularly natural gas and petroleum, are a major component in modern plastic manufacture. However, recent advancements in industrial methodologies have introduced alternatives manufactured from renewable resources, including derivatives sourced natural materials.

Plastics have become an integral part of modern life and are used in various industries, including packaging, construction, electronics, automotive, healthcare, fishing and more. The production of plastic experienced a remarkable surge, escalating from 2 million tons in 1950 toan astonishing 200 million tons by the year 2020. Notably, 40% of the global plastic output finds application in packaging purposes. Most of the packaging purposes use single-use plastics. Single-use plastics do pose significant environmental challenges and have been widely recognized as a major contributor to plastic pollution. Single-use plastics are described as plastic products that are intended to be used just once before being discarded. Due to their affordability, toughness, and adaptability, these polymers are frequently utilised for convenience and packaging. Plastic straws, water bottles, plastic bags, plastic cutlery, and other food packaging materials are all examples of single-use plastics.

In the marine litter, approximately 35% plastic waste materials are denser than seawater which results the sinking of these materials to the seafloor and infiltrating the depths of our oceans. The remaining 65% remains buoyant on the ocean's surface, capable of traversingextensive distances through wind-driven currents. Plastic production and consumption persist at current levels, projections from the UNEP suggest that by 2050, the oceans will contain more plastic (in terms of weight, measured in thousands of tonnes) than fish. Furthermore, UNEP estimates that approximately 99% of seabirds have ingested plastic, underscoring the widespread and concerning impact of plastic pollution on wildlife and marine life.

FRP is maintenance-free and has many benefits over typical wood materials. Its sleek finish and light weight help the fishermen to navigate quickly. Earlier FRP was used as a sheathing materialfor fishing vessels constructed with plywood and wood. But presently many of fishing vesselsare constructed with FRP as the primary material. The life span of sheathed vessels is only a life of less than 10 years while boats constructed only with FRP having a life more than 30 years.

As the numbers of boats are increasing disposal became an issue for the ELB (End of Life Boats)FRP fishing boats. Due to lack of recyclability, it became a burden to the owners when it comes to an end of its service life. Because there is no simple way to dispose of plastic ELBs and existing options are quite expensive, it may seem tempting to get rid of the problem by dumping them some place in nature or in the sea. Abandoned or derelict vessels (ADVs) are a sort of maritime debris that are aground, broken apart, submerged, exhibit no signs of maintenance or usage, or are generally deteriorated. Abandoned boats are commonly observed on the foreshores,intertidal flats and reefs, throughout the coast. There is currently no financially viable solutionfor recycling FRP materials used in the hull of ships and boats that are manufactured with thermoset resins. Such composite hull components cannot be formed by melting, rolling, thermalforming, or molding into other usable physical forms. In 2016, London convention and protocol discussed and identified abandoned FRP boats is an environmental threat and to be regulated.

Environmental Interactions of Plastics

a) Weathering Of Plastics: Formation of Micro and Nano Plastics

Weathering is a process that entails the transformation of plastic materials when subjected to various environmental factors, including sunlight, temperature fluctuations, and mechanical forces. This prolonged exposure leads to the gradual breakdown of larger plastic items into smaller fragments. Based on size, these breakdown fragments are classified into Mega (>100mm),Macro (21-100 mm),Meso (5-20 mm) and Micro (<5 mm) plastics and nanoplastics (1 to 1000 nm). Nano & microplastics, produced through weathering, encompass a wide range of sizes and are more prone to ingestion by various organisms, potentially entering the food chain and accumulating up the ecological hierarchy. The adverse effects extend to human health as microplastics and associated contaminants can infiltrate the food chain through seafood consumption. The IUCN (International Union for Conservation of Nature) has documented that South Asia, including India, is discharging 274,000 metric tonnes of primary microplastics into the ocean. On a global scale, the yearly average release of primary microplastics into the ocean isestimated to be 1.5 million metric tonnes. Notably, research conducted by IIT Mumbai has revealed the presence of microplastics even in sea salt sourced from Indian waters.

Microplastic can further undergo weathering to form nano plastics. Nanoplastics refer to extremely small plastic particles that have dimensions in the nanometer range, typically ranging from 1 to 1000 nanometers in size. These particles are even smaller than microplastics and are a

subset of the broader category of plastic pollution. Because of their tiny size, nanoplastics have unique properties and behaviors that differentiate them from larger plastic particles. They have a higher surface area relative to their volume, which can lead to increased interactions with other substances in the environment, including chemicals and pollutants. This characteristic makes nanoplastics potentially more chemically reactive and capable of adsorbing or carrying pollutants from the surrounding environment.

They may spread out quickly in a variety of habitats, including soil, water, and the air thanks to their tiny size. Nanoplastics may take on a variety of shapes, from spherical to asymmetrical, which impacts how they interact with the environment and living things. They demonstrate higher mobility and bioavailability due to their large surface area compared to volume, which might cause them to enter the food chain and have an impact on diverse creatures. Their potential toxicity, ecological effects, and function as carriers of pollutants are still being studied. Regulations and more research are essential to address the possible dangers of nanoplastics and reduce their prevalence in the environment since they are a growing problem.

a. Leaching Of Plastics

Leaching refers to the release of chemical additives present in plastics into the surroundings, often triggered by interactions with water or other solvents. Plastic products, including single-use items and larger plastic structures, often contain various chemical additives to enhance their properties, such as flexibility, flame resistance, or color stability. These additives can include plasticizers, stabilizers, flame retardants, and pigments. When plastic items degrade or interact with their environment, either through weathering, mechanical stress, or exposure to different temperatures, these additives can gradually leach out into the surrounding environment.

In aquatic environments, leaching can occur when plastic items like bottles, packaging, or microplastics come into contact with water. As water interacts with the plastic surface, it can dissolve and carry away the additives, potentially releasing them into the water. This process can lead to the contamination of water bodies with these chemical compounds, raising concerns about their impact on aquatic life and ecosystems.Leaching can also be relevant in the context of landfill sites where plastic waste is disposed of. Rainwater or other liquids can percolate through landfills, causing the leaching of chemicals from the decomposing plastics and potentially contaminating groundwater.

Plastics may survive for decades or even centuries because of their strength and resistance to degradation. This persistence can lead to various ecological and environmental issues includes

Impacts on Flora and fauna

Animals can mistake plastic items for food or become entangled in plastic debris. Ingesting plastics can lead to choking, internal injuries, and even death. This is a significant concern for marine life, birds, and other animals.

Ecotoxicity

Plastics can contain additives and chemicals that are toxic to both wildlife and humans. These toxins can leach into the environment, posing a threat to aquatic ecosystems and the organisms living in them.

Habitat Degradation

Accumulations of plastic waste can alter natural habitats, disrupt ecosystems, and damage fragileenvironments like coral reefs and coastal areas.

Aesthetic Impacts

Plastic pollution can tarnish the beauty of landscapes and water bodies, affecting tourism and recreational activities. Cleanup efforts also incur significant costs.

Social And Livelihood Impacts

Plastic pollution raises the issue by encroaching upon the spaces traditionally used for fish landing and various related activities. As plastic waste accumulates along coastlines, beaches,and water bodies, it diminishes the available area for fishing operations, processing, and other essential tasks. This not only disrupts the livelihoods of fishing communities but also hampersthe overall efficiency of the fisheries industry.

Mitigation Initiatives for Fishing Plastics

Addressing environmental concerns related to fishing gear and boat disposal requires a different approach. These include the implementation of stringent gear regulations, marking for easy tracking and identification, to enhance responsible fishing practices. Encouraging the adoption of biodegradable materials for fishing material construction contributes to reducing environmental impacts. Additionally, the proper disposal of fishing materials including end-of-life Fiberglass Reinforced Plastic (FRP) fishing boats necessitates the establishment of clear guidelines. Ensuring the construction of FRP fishing boats adheres to set standards is essential for long-term sustainability. Creating awareness within the fishing community can be achieved through seminars, symposiums, and field demonstrations. Incentive-based programs for litter collection by fishers, as well as promoting recycling options, provide practical ways to combat pollution. Initiatives like the "SuchitwaSagaram", a Kerala government project which aimed for the eradication of plastics from the sea, further contribute to effective waste management in coastal areas, collectively driving the pursuit of a more environmentally conscious fishing industry.

The 6Rs represent a set of principles aimed at promoting sustainable and responsible consumption and waste management in the case of plastics. Each "R" stands for a different action that individuals and communities can take to minimize their environmental impact.

Rethink: Reevaluating our consumption habits and considering the environmental and social consequences of our choices.

Refuse: The "refuse" principle encourages saying no to products or items that are unnecessary or harmful to the environment. This can include refusing single-use plastics, excessive packaging, and other items that contribute to waste.

Reduce*:* This principle promotes the idea of consuming less and minimizing our overall consumption. By using resources more efficiently and avoiding overconsumption, we can reduce our ecological footprint.

Reuse: Reusing involves finding ways to use items again instead of throwing them away after a single use. This can include using durable containers, repairing and repurposing items, and participating in activities like thrift shopping.

Recycle: Recycling involves the proper sorting and processing of materials to create new products from old ones.

Repair: Repairing items instead of discarding them helps extend their lifespan and reduces the demand for new products. This contributes to a more circular economy where items are used for as long as possible before being recycled or disposed of.

It's important to note that addressing plastic pollution requires global cooperation and individual actions to reduce plastic consumption and improve waste management practices.

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