Sustainable Gillnet Fishing

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The origin of gillnetting cannot be traced back exactly, but reports of its commercial existence dated back to 11th and 12th centuries. This fishing methodwithstood the technological and other transitional changes, the sector passed through such as introduction of bulk catching methods like purse seining and trawling. From a simple 20-30 m long piece of netting tied across a rivulet, it transformed to huge walls of netting running to 100 km and above in length and >50 m depth , with automated setting, hauling and catch removal.

Gillnet, a highly versatile gear, suitable for operation in the surface, column or bottom layers of the water column can target fishes as small as anchovies to big sized sharks and rays. The gear can be operated even without a craft or with a non-motorised, motorised or mechanized craft. This fishing method is having the simplest configuration and method of operation. The simplicity of its design, construction, operation and its low energy requirement make the gear very popular in all the sectors especially in the traditional sector. However, as the scale of operation increases, the fishing method becomes labour and capital intensive. Over the years, there has been a tendency to use nets of increasingly larger dimensions. An illegal drift gillnet of 130 km long with Antarctic toothfish from the Antarctic waters was reported (Gibson, 2009).

Typical gillnet

A typical gillnet is a wall of netting held in a vertical position in water by floats on the upper end (head rope/float line) and sinkers at the lower end (foot rope/sinker line). Structure of a typical net is depicted in Fig. 1.

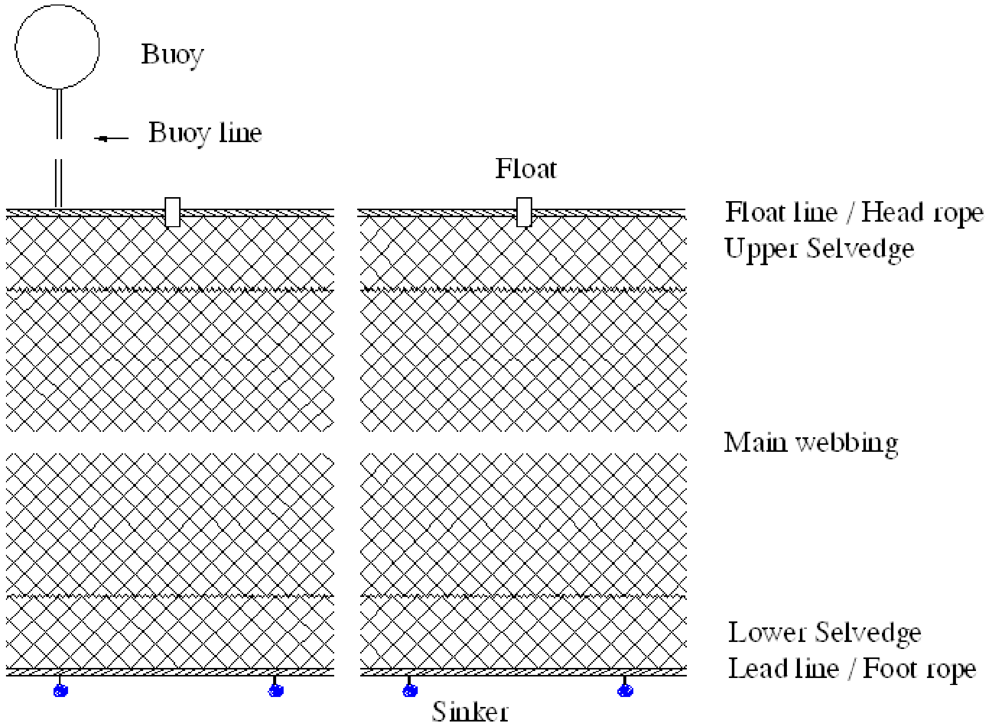

Fig.1. Structure of a typical gillnet

The net 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.1). 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. Plastic and expanded poly vinelydene (PVC) 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. Gavel lines or side ropes are attached to the side meshes of the netting. The required numbers of units are tied end to end depending on the size of the target species and area of operation.

Catching mechanism

Depending on the species targeted as well as design and configuration of net, fishes are caught in gillnets by four types of catching mechanisms, viz., gilling, snagging, wedging and entangling. Gilling is the basic mechanism 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. 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'. The fish is also caught in gillnets by (i) snagging, when the fish is held tight by the twine of the mesh around its head; (ii) wedging, when the fish is held tight around its body; and (iii) 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. The mode of capture depends on looseness of the net and the body shape of the target fish.

Classification

The gillnet sector is classified into non-motorized, motorized and mechanized sub-sectors based on the vessel category in use. Gillnets are generally classified based on type of capture, structure, area of operation, method of operation and targeted species. Based on mesh size, Indian gillnets are classified into small mesh nets with 14 to 45 mm mesh size range and large mesh nets with 45 to 500 mm mesh size range.

Simple gillnets, vertical line gillnets and frame nets are single walled gillnets while trammel (triple walled) and semi trammel (double walled) nets come under multi walled nets. The vertical line nets - are simple gillnets, which are divided into different sections by passing vertical lines from the head rope to the footrope 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. Trammel nets are triple walled nets having a loosely hung centre wall of small mesh netting which is bordered on each side by tightly hung walls of large open meshes. Fishes swimming through the outer meshes encounter the centre netting and push their way through the opposite outer meshes getting trapped in the resulting pockets that are formed. The outer meshes on one side of the net must be a mirror image of the outer meshes on the opposite side.

Depending on the mode of operation, there are drift nets (which drift freely with both ends free or with one end attached to the vessel), set nets (anchored or stalked to the sea bed) and encircling nets (the fishes are surrounded and driven from the centre by noise or other means). Classification into surface, column and bottom gillnets is dependent on the depth of water column at which they are operated. 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 parameters

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 (Yamaha, 1994). 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.

Techniques of operation

Gillnet operation has been a relatively simple method compared to other fishing gears. Nets are set across the current and in the path of fish migration. The method of operation varies with fishing condition, depth and area of operation as also the species to be caught. Gillnets are operated mainly as drift, and also as set and encircling gear. In certain cases, the net is dragged with the help of two boats. The nets are held at the bottom, mid water or surface,depending on the target fish and depth of operation. The soaking time of the net varies from 1 to 6 h for drift nets and 12 to 24 h for set nets. In set gillnet, both ends of the gear are secured to the sea bottom by means of sinkers or anchors.

The nets are shot mostly from the side and sometimes from the stern of the vessel. The nets stored in the vessel with the float line and floats, buoy line and buoys to one side and sinker line and sinkers to the other side are thrown overboard to either side of the vessel to prevent tangling. Nets operated during night have lamps attached to a flagpole at the extreme end of the fleet and in between to keep track of the net.

Energy efficiency

In the background of alarming increase of fuel costs, gillnetting can be encouraged as an energy efficient gear. Gillnet fishing consumes only 0.15-0.25 kg of fuel per kg of fish caught, compared to trawling which consumes 0.8 kg (Gulbrandsen, 1986). The energy efficiency of gillnets in comparison to ring seine (mini purse seine) is confirmed in the Indian conditions also (Thomas, 2001; Edwin, 1997). Gillnets operated in coastal waters of Kerala, consumed 0.46 kg of fuel per kg of fish caught (Thomas, 2001). The revenue realized per rupee of fuel for ring seine during 1995-96 was Rs. 3.24 (Edwin, 1997) while the corresponding values for motorized gillnet and mechanized gillnet were Rs. 4.5 and Rs. 5.0 respectively (Thomas, 2001). Till recently, setting and hauling of gillnet has been done exclusively manual even in large mechanized gillnetters, mechanical energy for propulsion alone. From 2012 onwards, mechanized gillnetters deploying large volume of nets started using mechanical gillnet winches/haulers. Such measures ease out fishers' physical strain but add to fuel use.

Selectivity

Gillnets are typically size selective as the capture by gilling, wedging and entangling is dependent on the shape of the particular species of fish encountered. Gillnets generally have bell-shaped selection curves described by normal distribution (Fig. 2). Width of the curve represents the selection range and the height corresponds to optimum size of fish caught by the gear. In symmetrical curve, the ability to catch fish decreases equally on both sides. The left slope of selection curve represents smaller fish wedged in the meshes and the right slope represents larger fish mainly tangled by head parts.

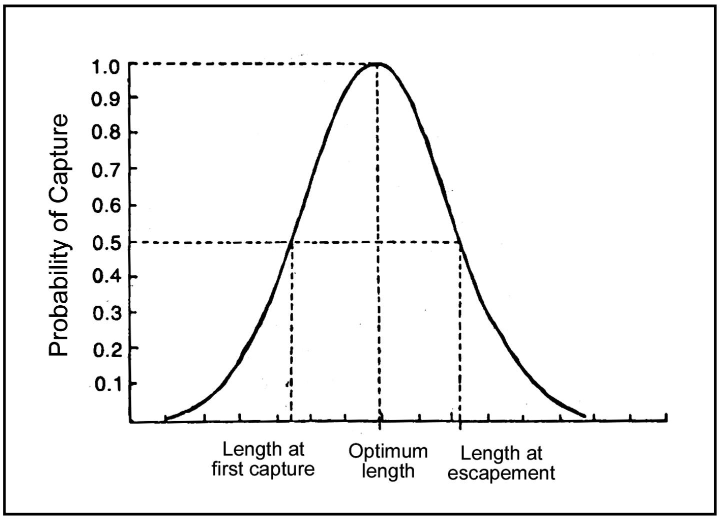

Fig. 2. Typical selectivity curve for gillnets

Gillnet selection curve becomes broader and more skewed to the right when many fishes are entangled and may approach the normal curve when most fishes are wedged/gilled. The mode of capture depends on form of body, gear material and hanging coefficient. Multi-model selectivity curves may be expected whenever capture is concentrated at body discontinuities such as maxillaries or spines. High selectivity of gillnets is a major advantage for sustainable harvesting of the resources.

Sustainability challenges

No fishing gear is perfect which does not have any impact on the environment. Among different gears, gillnets are considered as 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 to the large incidence of capture of marine mammals, turtles and sea birds in the high sea drift gillnets. Bycatch including juveniles, ALDFG and ghost fishing are the major problems associated with gillnets.

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 of non-target organisms including cetaceans and turtles getting entangled in the nets during fishing as well as through ghost fishing by lost nets. Consequently, use of drift gillnets at large-scale/industrial level in the western Pacific Ocean for tuna was discontinued after 1992. In the Northeast Atlantic, the use of driftnets was legal only until 2002 with the net length limited to not more than 2.5 km. However, driftnets continued to be widely used, in all coastal and small to medium-scale and large-scale fisheries worldwide. Major reasons adversely affecting sustainable gillnetting are increasing fishing effort, use of multi-mesh gillnets and mesh sizes below the optimum and use of loosely hung nets. Besides, the widespread use of very thin monofilament gillnets also is an area of concern. Major reasons associated with gillnet design and operation which adversely affect the sustainability of operation are discussed below.

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 by all the three gillnet categories viz., non-motorized, motorized and mechanized sub-sectors. In India, the length and depth of gill net increased from 150x3 m in 1950s to 18000x20 m at present. Currently, the mechanized gillnetters categorized as small (<12.0 m L_{OA}) medium (12.1-16 m L_{OA}) and large (16.1 -24.6 m L_{OA}) with 60, 120 and 193 hp engines respectively, are deploying large net fleets of 5 to 16 km long and 8 - 20 m deep (weighing upto 3 tonnes). In the non-motorized sector; and motorized sub-sectors also, the corresponding increase in net volume is alarming.

Use of multi-mesh and non-optimum mesh size

A wider spectrum of mesh sizes is used in the commercial fisheries, which may differ from the optimum. Optimum mesh sizes have been worked out for some of the commercially important fishes (Table 1). However, the fleet of gillnets operated in commercial fisheries 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.

Table 1. Optimum and commonly used gillnet mesh sizes in commercial fisheries

Gillnet type	Targeted fish	Commonly used mesh sizes in commercial fisheries (mm)	Optimum mesh size (mm)
Sardine net	Indian oil sardine (*Sardinella longiceps*)	30, 32, 33, 36, 38, 40	33.4
Mackerel net	Indian mackerel (*Rastrelliger kanagurta*)	38, 40, 50, 52	50
Seer drift net	Narrow-barred Spanish mackerel (*Scomberomorus commerson*)	70, 90, 100, 110, 120, 140, 170	152
Seer drift net	Indo-Pacific king mackerel (*Scomberomorus guttatus*)	65, 70, 90, 100	104
Pomfret net	Silver pomfret (*Pampus argenteus*)	110, 116, 120, 130	126
Prawn net	*Fenneropenaeus indicus*	32, 34, 36, 38, 48, 50, 52	38
Tuna drift net	Frigate tuna (*Auxis thazard*)	60, 65, 70, 90, 100, 115	84
Tuna drift net	Kawakawa (*Euthynnus affinis*)	60, 65, 70, 90, 100, 115	104.2
Sardine net	Goldstripe sardinella (*Sardinella gibbosa)*	25, 26, 28, 30, 32	29.6
Sardine net	Spotted sardinella *Ambligaster sirm*	25, 26, 28, 30, 32	30.5

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.

Monofilament gillnets

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. Unlike multifilament nets, monofilament nets mostly follow a `use and throw' style as it is difficult to mend the nets, which is not a healthy practice. Monofilament nets last hardly for a season (2 – 6 months) and unless properly discarded, these nets will end up in ocean adding to plastic pollution, ALDFG and ghost fishing.

Bycatch problem

Loosely hung drift gillnets entangle non-target species and juveniles of target species. Specialized gillnets for oceanic fishing when allowed to drift with wind and currents, gill, entangle and enmesh a wide range of living marine organisms such as birds, turtles and marine mammals threatening the large marine ecosystem.

Juveniles

Practices such as using multi-mesh gillnets, nets with mesh size smaller than the optimum and not adhering to resource specific gillnets lead to juvenile landings. Review of the size composition of species from gillnet landings in various locations of India showed that the bulk of the landings comprised of juveniles. In multi species fishery, complete avoidance of juvenile landings is not practical, but sasonal use of resource specific gillnets can limit juvenile catch to a great extent.

ALDFG

Abandoned, lost and discarded gear (ALDFG) is the internationally recognized name for derelict fishing gear (DFG). UNEP defines ALDFG as the "multitude of nets, lines, traps, and other commercial or recreational fishing equipment that has been lost, abandoned or otherwise discarded in the marine environment". 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 and safety of life at sea and adverse effects on tourism, human health and safety.

Gear loss due to abandonment, accidental loss and purposeful discard is a serious problem getting attention world over in the past few decades. Gillnets and traps are considered more susceptible to losses. Uses of very large volume of nets, rough weather, entanglement with bottom obstructions, purposeful discard etc are reasons for gear loss. ALDFG drifts with wind and waves and entangle aquatic animals and finally ends up on the ocean floor and on coral reefs destroying the ecosystem and also adds to marine debris. As per the FAO estimates, the average loss of gillnets and traps per year is 10%. ALDFG contributes around 10% of global marine litter by volume and an estimated 6.4 million tonnes of marine debris are added to global seas annually (UNEP, 2005a). The pioneering study by ICAR-CIFT in 2017-18 on ALDFG in Indian waters relating to gillnets and trammel nets has brought to light the seriousness of the issue in the country demanding immediate attention. Restriction on use of very large volume of nets, use of quality material and avoidance of operation in very rough weather and in areas with bottom obstructions could reduce loss of gillnets. Fishers are be encouraged to use materials with standard quality specification as the use of low quality and old/damaged netting give more chances for gear loss. Beides, absence of disposal facilities at the harbor and landing centres, for damaged net is also a problem faced by fishers.

Ghost fishing

Nets, lines, and traps that become ALDFG, continue to catch, entangle and harm marine animals without human control and is termed as ghost fishing. Gillnets, trammel nets and traps have relatively high ghost fishing potential. Gillnets are more likely to become ALDFG and do ghost fishing resulting in unaccounted mortality of fish and other aquatic organisms including endangered species. As long as the gear configuration is intact, the gear continues to fish. Gillnets are reported to have 3 to 9 months ghost fishing capacity. There are no authentic reports on ghost fishing from Indian waters.

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. Use of biodegradable materials in rigging floats on the nets would reduce ghost fishing ability of lost nets.

Marine turtles

The incidental catch of marine turtles is associated with drift gillnets across the world. 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. Fishing ban in areas of intense nesting of turtles during the nesting period is widely used to prevent turtle bycatch. Net illumination with light-emitting diodes (LEDs) placed on float line is suggested as an effective conservation tool to reduce marine turtle bycatch in gillnet fishery (Ortiz et al., 2016).

Marine mammals

Marine mammal entanglement in gillnets is a widely reported problem worldwide. Chances of entanglement are more in surface drift nets. In India, there is no reliable data on the number of mammals caught incidentally in drift gillnets during fishing or after becoming ALDFG. Reduction in height of the net, use of aquatic pingers, increasing the reflectivity of net by treating with barium sulphate (Ba SO_4), use of stiff ropes, biodegradable/weak seams and setting the net just below the surface are mitigation measures to reduce mammal interaction.

Sea birds

Sea birds are occasionally caught in surface driftgillnets. Entangling of sea birds in derelict nets is also widely reported. However, reports on bird mortality from gillnets are almost nil from India (FAO, 2017).

Management measures

Fishing gear regulation

The uncontrolled increase in volume of gillnet, demands restriction. 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 KMFR 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.

Implementation of mesh size regulation in commercial gillnet fisheries would help to a large extent in sustainable harvesting of resources. 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 (Table 2).

Table 2. Mesh size regulations pertaining to gillnets, in different maritime states

State/UT	Minimum mesh size prescribed for gillnets
Gujarat	150 mm
Maharashtra	Not prescribed
Goa	24 mm for fish gillnets and 20 mm for prawn gillnets

Karnataka	Not prescribed
Kerala	Prescribed for 7 gillnet types (minimum is 33 mm for sardine gillnets)
Tamil Nadu	25 mm
Andhra Pradesh	15 mm
Orissa	Not prescribed
West Bengal	25 mm
Andaman and Nicobar Islands	25 mm
Lakshadweep Islands	50 mm

Source: Shenoy and Biradar (2005); Govt of Kerala (2018)

Minimum legal size of fish

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.

Conclusion

Gillnets have great scope in sustainable harvesting of resources, being a highly size selective gear. In the context of energy intensive fishing operations ecoming un–economical, being a low energy gear, importance of gillnet cannot be undermined. However, the uncontrolled expansion in the volume of gear, use of mesh sizes less than the optimum, wide spread use of very thin nylon monofilament gillnets etc make this gear a threat to the environment and the resources. Fishers are to be made aware of the ways to avoid losing of gillnets and on the negative impacts of ALDFG and ghost fishing. Besides, proper disposal facilities for damaged net is also to be made available by authorities. 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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