Chapter 15

Gillnets: Design and Operation Strategies for Resource Conservation

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1.0 Introduction

Gillnet, a very simple passive fishing gear is widely separated in inland and marine waters world over. The optimized design, fabrication and operation of this gear in the most responsible way would make it suitable for harvesting the resources in a sustainable manner. The origin of Gillnet fishing cannot be traced with certainty. The earliest evidence came from herring drift nets of North Sea in the 11th and 12th centuries. The first major breakthrough in the technical development of gillnet fishery has been the material revolution in netting and the second has been the mechanization of hauling work by the introduction of net haulers. The net was made initially from vegetable fibres such as hemp, straw, sisal and cotton but in 1952, synthetic fibres was first tried for gillnets. The mechanization of propulsion and operation of the gear in gillnetting resulted in fishing ground becoming nearer, increase in the quantity of the net used and availability of labour power especially that of young men. By the 1950s these technological developments brought this fishing method to the forefront. It is also considered as a very selective gear as very few fishes are caught in gillnets whose length differs from the optimum by more than 20%. Conventionally gillnets are simple rectangular walls of netting kept erect in water by floats and sinkers. Other variations such as gillnets with vertical lines, frame lines and pockets are also seen in certain areas.

2.0 Capture process

A fish is actually caught in a gear by going through three distinct steps.

Fish comes or brought to the vicinity of the gear

⇩

Fish responds to the gear before coming into contact with it

⇩

Fish is caught in the gear

The first step depends on movement of the gear viz., drifting or fixed, and movement of the fish viz., swimming towards the gear or drifting passively with the current. Once this stage is successful and the fish is brought into the vicinity of the gear, at the 2nd step, there is a chance for the fish to escape by detecting the gear by sight, sensing the vibrations or smell. At the 3rd step, even when the fish is actually getting contact with the gear, it may not actually be caught and can escape. For example, in gillnets, if the fish is too small with reference to the mesh size, it will pass through and if it is too large it cannot enter the mesh and escapes.

When a fish approaches a gillnet, it tries to pass through the mesh. The mesh is selected in such a way that it is just large enough to allow the fish's head but not the rest of the body to pass through. When the fish cannot pass through, it senses the obstruction and tries to pull back. In its struggle to free itself, pressure exerted by the mesh at the opercular region of the fish opens the opercle and the twine of the mesh goes behind the opercle (Fig. 1.).

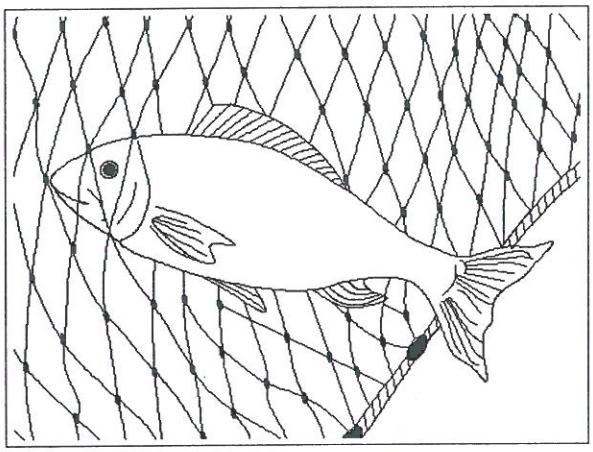

Fig.1. Gilling of fish in a mesh

This characteristic capturing is designated as 'gilling' and hence the gear 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 de-

pends on the construction of the net/looseness of the net, the body shape of the target fish and the current and tide condition. A fish encountering a loosely hung gillnet can easily become caught by entangling without actually getting gilled.

A fishing gear must have the dual function of catching fish and selecting the fish to be caught. Only in gillnet, the mesh of the net itself serves the dual function of fish catching in addition to selection. The mesh size, the material the net is made of, its thickness, colour and the hanging ratio of the nets perform these two functions.

3.0 Selectivity

Selectivity in gillnets mainly depends on the mesh size and mesh configuration, which in turn, is influenced by the hanging coefficient. Gillnet capture interpreted as a mechanical process depends only on the relative geometry of the mesh and the fish. Selectivity is represented by a curve fitted to points representing the percentage of fish either retained by the gear or escaping from it at each interval against the fish length. While the capture is mostly by gilling the selectivity can be represented by a normal curve or a bell shaped curve (Fig.2).

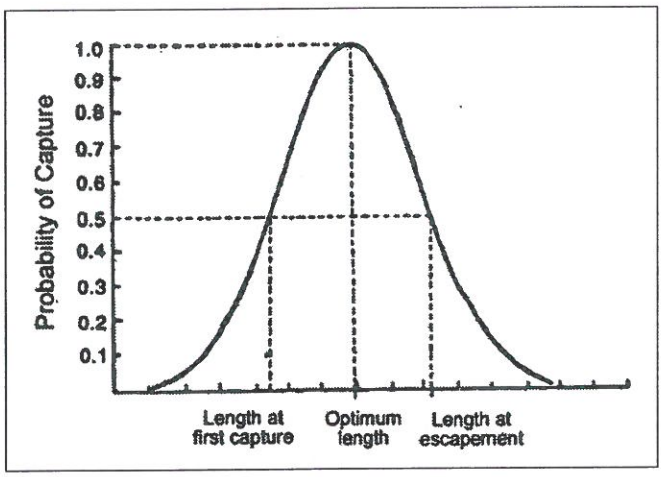

Fig. 2. Typical gillnet selection curve

Capture by gilling, wedging and tangling is dependent on the shape of the particular species of fish encountered. Hence, gillnets are size and species selective. Tangling may be less dependent on mesh size and more dependent on other factors. This type of selection cannot be described by a normal curve. The combined selectivity curve for gilling, wedging and tangling would become a unimodel curve skewed to the right hand side. When fish capture is concentrated at two or more positions on the body, the selection curve may have two or more modes.

4.0 Structure & Construction

Gillnets have either a single shot/unit of net or a number of units tied end to end to form a

full fleet of desired length. Each unit or shot is a rectangular wall of netting having a head rope on the upper part and a foot rope on the lower part. The net consists of a main netting with selvedge on the upper and lower portion, head rope, float line, foot rope, lead line, gavel line/side ropes, floats, sinkers, buoys and buoy lines (Fig. 3). The main netting is made of polyamide (PA) monofilament yarn/PA multifilament twine/polyethylene (PE) twisted monofilament of mesh size varying from 14 to 400 mm as per the target catch.

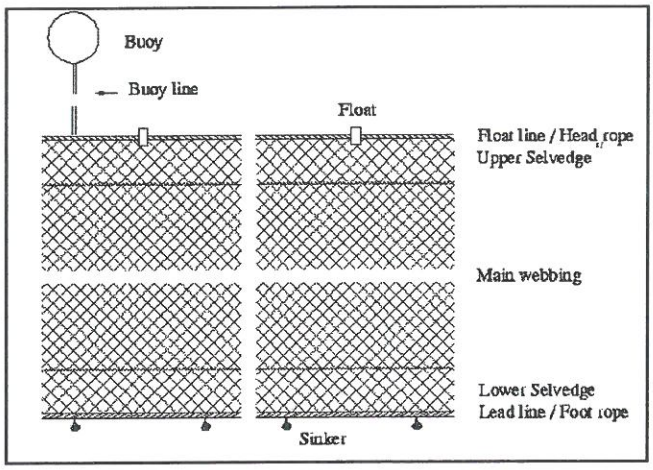

Fig.3. Structure of a simple gillnet

The number of meshes in depth depends on the swimming layer of the target fish and the area of fishing while the number of meshes in length depends on the size of the unit. The selvedge provides protection to the main webbing during handling and operation with a material generally thicker than that of the main webbing. The selvedge mesh size is either of the same size or bigger than that of main webbing. The stretched length of the selvedge is same as that of main webbing while the depth of the selvedge is as per the depth of the main webbing. Loop lines having double the breaking strength of the selvedge material are used to hung the selvedge meshes to the head rope. The netting is mounted to the ropes by a continuous hanging twine which is passed through the meshes and tied to the ropes using staples or loops. The netting is rigged to the float line according to a particular hanging ratio which determines the looseness of the netting and thereby the shape of the mesh as well as the hung depth of the mounted net. Usually the horizontal hanging coefficient employed for gillnets is 0.5. 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 through 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 main function of this is to protect the side meshes from wear and tear due to hauling. The length of the breast line must be 10 to 15% less than the depth of the main webbing in the stretched condition.

The hung depth is determined by the vertical range of the swimming layer of the targeted

fish species. It generally ranges from 1 to 23 m. The required units of length 20 to 75 m are tied end to end depending on the target species and area of operation to make a fleet of length ranging from 300 to 2500 m. The commonly used materials for fabrication of nets are: (i) PA monofilament of 0.16 to 0.6 mm diameter; (ii) PA multifilament 210x1x2 to 210x12x3; (iii) HDPE twine of 0.5 to 2.5 mm diameter and (iv) polypropylene 810x1x2.

5.0 Classification & Gillnet types

Depending on the capture process, structure, method, area of operation and target catch, gillnets are classified into several groups (Fig.4).

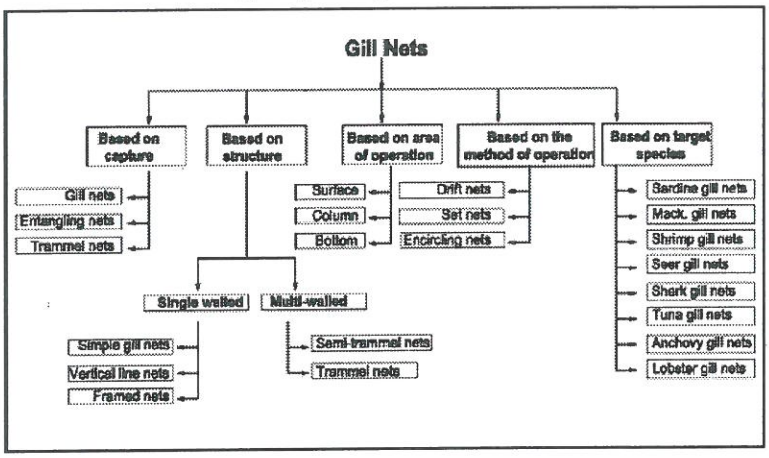

Fig. 4. Classification of gillnets

Simple gillnets are the simplest type of gillnets with a single wall of netting. Vertical gillnets are simple gillnets 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.

Trammel nets are triple walled nets having a loosely hung center/inner wall of small mesh netting which is bordered on each side by tightly hung outer walls of large open meshes. Fishes swimming through the outer meshes encounter the center 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. Trammel nets are mostly used in fresh water fishing and also for coastal shrimp fishing.

Depending on the mode of operation, there are drift nets (which drift freely or with one end attached to the craft), set nets (anchored or staked to the sea bed) and encircling nets (the fishes are surrounded and driven from the centre by noise or other means). There are surface, column and bottom gillnets depending 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.

Based on mode of operation, gillnets are divided into fixed/set, drift and encircling. The construction of gillnets also depends on the type of operation. Set/fixed gillnets usually have few floats but have heavily weighted foot rope which rests firmly on the sea bottom. Anchors, heavy sinker or stake/pole are attached to either end of the net with marker buoy at one or both the ends. Drift nets as a rule have large number of floats on the head rope/ float line while the number of sinkers will be less. In certain drift nets for large pelagics, the net will be devoid of foot rope and sinkers.

6.0 Design principles of Gillnets

The main principle of the gillnet designing is based on the mechanism of fish capture by the net. Since the fish is caught when it tries to swim through the meshes of the net, the size and shape of the mesh play a significant role in the catching power of gillnets. 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 of the net, (iv) visibility of the net, (v) softness of the material and the (vi) buoyancy and ballast given. The fishing height of the net has to be optimized according to the swimming layer of the targeted fish.

Mesh size : Mesh size is the most important factor to be considered in the design of a Gillnet. It is proportional to the modal length (length of fish most frequently caught) of the fish caught. As the gear is size selective for a given mesh size, catch decreases on either side of the modal length of the fish. A net of a particular mesh size catches fish of a particular length most efficiently and has considerably reduced catching efficiency of smaller and larger fish. The equation of geometrical similarity is widely applied in practice. Fish of the same species but of varying age groups are to a certain extent geometrically similar. Similarly the meshes of different size are similar, provided the hanging coefficient is the same. If it is known that a gillnet with mesh size m1 catches a fish of length L1 best of all and the net with mesh size m2, catches fish of length L2 best of all, then according to geometrical similarity (Fig. 5),

$$L_2 / L_1 = m_2 / m_1$$

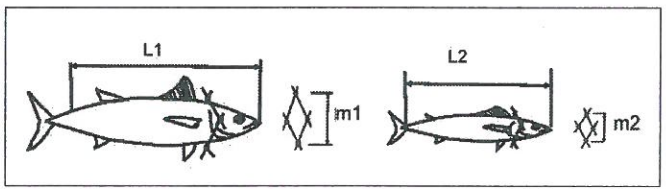

Fig. 5. Relationship between fish length and mesh size

Optimum mesh size for the target fish can be determined by selectivity experiments. According to Baranov (1914) the mesh size can be determined following the equation:

$$a = kl$$

where `a' is the size of mesh bar, `l' average length of fish for which the gear is designed,

and `k' a co-efficient specific for a given species determined empirically and can be found out by length or girth measurement.

Length measurement : The length frequency distribution of catch obtained in 2 gillnets, of different mesh bar a1 and a2, fished simultaneously may be prepared and the frequency curve corresponding to these can be drawn on a single graph (Fig. 6).

If 'lo' represent the length of fish, appearing in number in catches of both the nets, then the coefficient 'k' can be determined by the equation,

$$k = \frac{2a_1.a_2}{lo(a_1+a_2)}$$

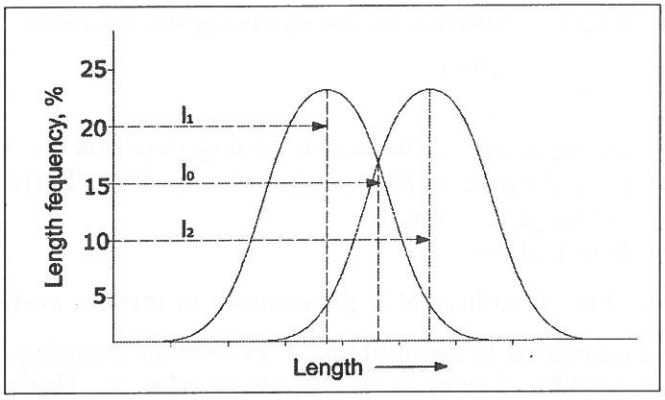

Fig. 6. Determination of lo, from the length frequency distribution of fish caught in two gillnets with differing mesh size

Girth measurement: The mesh size is also proportional to the girth of the fish. When a fish is gilled, its body gets crushed and due to its efforts to escape the twine of mesh stretches a little. Therefore the perimeter of a section of body of fish where it is 'S_1' always exceeds a little than the girth at gill covers S_2 .

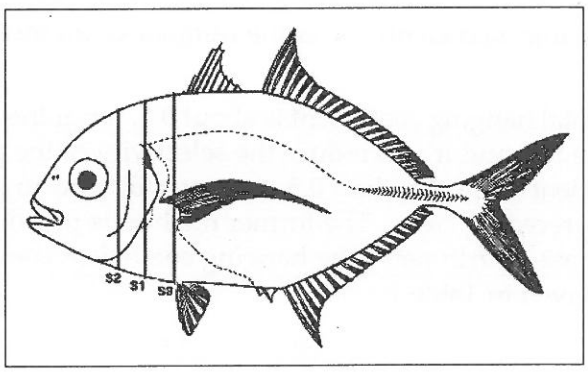

Fig. 7. Girth measurements

But the place of gilling S1 will be less than maximum girth S3 (Fig. 7).The relation between the mesh perimeter and area of cross section where it is caught can be represented as

n 1 = 4a / S1, where 'a' is the mesh bar

If the fish has to be caught firmly, S1 must be greater than S2 and less than S3. Taking into account this inequality the value of the perimeter S1 to the maximum girth of the fish S3 can be arbitrarily set as,

n 2 = S1 / S3

The relation of maximum girth of fish to its length can be represented as,

n 3 = S3 / l , where 'l' represents the fish length.

Then the coefficient 'k' can be determined by applying the formula,.

$$k = \frac{n\,1 n2\, n3}{4}$$

Hanging coefficient : The shape and looseness of netting depends on the coefficient of hanging. The hanging ratio is defined as the length of frame lines 'L' (head rope) or float line relative to the stretched length of netting.
Hanging coefficient, E = L/(N.m)

where, L the length of the float line, N is the number of meshes and m is the mesh size.

The hanging ratio is expressed in decimal and is known as `hanging coefficient'. The hanging ratio is also expressed by another term, hang-in or take up. This refers to the amount of excess webbing (loose netting) expressed as percentage of total length of webbing

$$H = \frac{\text{length of netting - length of rope}}{\text{length of netting}} \times 100$$

In order to design a net, it is important to know the hung depth of the netting after it is mounted to a rope. The theoretical hung depth, D can be worked out by applying the equation.

$$D = N.m.\sqrt{(1 - E^2)}$$

where 'E' is the hanging coefficient; 'N' is the number of meshes in depth and 'm' is the stretched mesh size.

Generally, the horizontal hanging coefficient is about 0.5, for gillnets. If it is less than 0.5, the net will tend to tangle fish and it will reduce the selectivity of the gear. On the other hand, if the hanging coefficient is greater than 0.5, the net will tend to gill the fish and be more selective than in the preceding case. The former method is practiced in the case of set nets and the latter in the case of drift nets. The hanging coefficient commonly given to different types of gillnets are given in Table 1.

Table 1. Common hanging coefficients for gillnets

Type of net	Coefficient of hanging	
	Horizontal (E 1)	Vertical (E 2)
Simple gillnet	0.5	0.87
Trammel net		
Inner layer	0.4 - 0.5	
Outer layer	0.7	
Frame net	0.5	0.5
Vertical line net	0.5	0.7

6.1 Material characteristics

The choice of proper material is very critical to the success of Gillnet fishing. The material 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. The firmness of fish body and extensibility of the material are also to be considered while choosing the material. These conditions are fulfilled by synthetic twines especially monofilaments.

Thickness: The thickness of material and its visibility determine the efficiency and strength of the net. Thinner material is less visible and being less rigid reduces detectability by lateral line sense organs, but it cuts deeply into fish body and has shorter life. Increase in the diameter increases the cost as well as durability of the material, where as the catchabilty decreases. Besides, thicker material especially multifilament twine has a tendency of rolling which would enable in the escape of fishes caught. Thinner twines are recommended when fish concentration is less, and thicker twines when high concentrations exist. The ratio of material 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 ratio 0.01 have sufficient fishing efficiency and strength.

Softness: The Gillnet should have the maximum possible softness and smallest swell. Solid objects strongly reflect the waves pushed forward by a swimming fish 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 material should be made as fine as possible.

Visibility: The efficiency of gillnets depends on the visibility of nets. 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 use of (i) thinner material, (ii) transparent monofilament and (iii) appropriate colour of netting. 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 in India have shown that yellow colour is appropriate for gillnets operated in Gobindsagar reservoir and yellow, green and grey colour is appropriate for Gillnets operated in Hirakud reservoir. Gillnets with yellow colour are reported to be efficient for catching hilsa (*Tenualosa toli* and *Tenualosa ilisha*) and Gillnets with white and yellow colour for pomfrets (*Pampus argenteus* and *Parastromateus niger*).

6.2 Buoyancy and Weight

In order to keep a net suspended in a given position there must be a balance of the floatation created by the floats, the sinking force created by the sinkers, the weight of the netting and ropes. 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 are also to be taken into account. Float line with integrated floatation and lead lines with lead core are also available which spread the buoyancy and ballast uniformly along the net. The buoyancy and weight given to a net depends mainly on the fishing conditions. In surface Gillnets, the buoyancy to ballast ratio is typically of the order of 2 and in bottom Gillnets it varies from 0.2 to 0.3 (Hameed and Boopendranath, 2000). In bottom nets the buoyancy is usually 3 to 6 times the weight of netting and lines under water and ballast is 3 to 6 times the buoyancy. The ratio of buoyancy and weight per unit length for surface drift net for sardine was 0.65 (Thomas, 2001).

6.3 Float line and floats

Gillnets 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. According to Fridman (1986) for bottom gillnets,

Buoyancy requirement, Qf = KQ.Qn,

where 'Q'n is the weight of netting and mainline in water and
'KQ' is a coefficient between 3 and 6.

The buoyancy coefficient KQ should be greater in stronger currents and lower for calm waters. The float line used for mounting the netting 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 and current. 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, prevailing at the depth of operation. 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 sagging between adjacent floats. The floats are available in oval, disc, cylindrical, apple and irregular shape and in varying dimensions. The materials include wood, cork, aluminium, glass, plastic and poly vinyl chloride.

6.4 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.

Weight of sinkers in water, Qs = KB.Qf,

where 'KB' is the ballast coefficient which varies from 1.25 to 6, de pending upon local conditions; 'Q'f is the buoyancy used

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.

7.0 Operation

Method of operation and depth of operation of gillnets vary with the target catch, local conditions and operation range of the sector viz., motorized non-motorized or mechanized. Fixed /set nets will be set across the water flow fixed or anchored to the sea/river bottom. Set nets are more popular in rivers and streams.

Drift nets moves freely along with the water currents and one end of it will be tied to the boat while the other will be free with one marker buoy attached to it for identification. Gillnet operation has been relatively simple compared to operation of other fishing gear. 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 set, drift, and also as 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 vertical distribution of fish. 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 bottom by means of sinkers or anchors while in drift nets, one end is tied to the boat and the other end to a marker buoy and weights.

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 manually to either side of the vessel to prevent tangling. In the case of strong wind and current the net has to be shot in the same direction, and the net could be set across, if the current is weak. The boat has to go ahead, slowly while the net is paved out over the side that faces the wind. The net is positioned at the optimal fishing depth by adjusting the length of the buoy lines. Speed of the vessel is not a critical factor and as a general rule nets are not allowed to run out faster than the moving vessel, the speed of which during shooting could vary between 1 to 6 knots. One end of the net is tied to the vessel and the vessel drifted along with the nets. Nets operated during night have a lamp attached to a flagpole at the extreme end of the fleet to keep track of the net.

Hauling is generally done by the side of the vessel by pulling the float line or head rope; the nets are cleared out and stored in the shooting position. While hauling the anchor and the net are pulled over the front of the boat. With the advent of synthetic fibres and consequent increase in the length of fleet, gear operation is mechanised in recent years especially in the developed countries. This enables reduction of manpower requirement for handling gear. Two types of operation are in practice: nets set on stern and hauled over the side and nets set and hauled over stern.

7.1 Nets set on stern and hauled over the side

In this case the net is set over a transom roller and hauled up by a gurdy mounted to starboard just forward midship when ready to set the net, the first mounted to starboard anchor and buoy are placed overboard, followed by the free end of the net. The vessel then moves slowly along the setting course. When the net rolls over, the anchor and buoy are laid. The vessel may remain or leave to return for hauling. While hauling the vessel approaches the leeward end of the net, and retrieve the buoy and anchor together with the net. The net is guided to a gurdy by rail roller with end guiders. As the net is brought aboard, the gilled fish is shaken or taken out and net passes to stern side. An alternate means of hauling is by davit mounted power block so that the block extends outside the rail.

7.2 Nets set and hauled over stern

The gear is rolled out over stern, and is hauled from stern using a davit mounted or boom mounted power block. Drums are also used for hauling and shooting of Gillnet. While a drum holding the net is removed for repairs, another could be fitted into the vessel without interfering fishing. In order to minimise the labour involved, for removing large quantity of fish, shaking machines were developed. With the help of drums, the net with the gilled fish is pulled through the machine, thus shaking the fish out of the meshes.

Gillnetting is generally done on a daily basis in artisanal operations. Mechanised gillnetters undertake multiday operations of 14-21 days duration combining driftnet and long line operations.

7.3 Threats to resource conservation

Gillnetting though considered as a highly selective and responsible fishing method, of late, this gear has invited criticism due to the problem of ghost fishing associated with the lost gear, unwanted bycatch and low quality of fish caught in set nets.

Bycatch: Gillnets as such does not produce significant bycatch. However, drift nets operating for large pelagics are reported to generate bycatch in a substantial level. Sharks, dolphins, whales, turtles, sea birds, dugongs and other mammals are important species caught as bycatch in drift nets. Although long lines are the main gear contributing to sea bird by catch drift nets also contribute significantly.

Capture of Juveniles: Operation of multimesh gillnets viz., a fleet of net having units of different mesh sizes would result in harvesting of all size class of fishes including juveniles. When different mesh sizes are simultaneously used in a gillnet, it behaves like a trawl and

the selectivity advantage is lost. The problem is more severe in tropical countries where multi species fishery exists.

Illegal Fishing: Taking undersized fish, fishing in closed water, taking more than the allowed quota and fishing during seasonal closure come under Illegal Illegal, unreported and unregulated (IUU). In this context drift nets also contribute to IUU fishing. Drift gillnetters of many countries fish in the international waters or the high seas violating the drift net fishing laws.

Wasteful fishing: The drift nets when operated on large scale cause wasting of marine life by way of unintentionally catching commercially unusable species. Though they are released after getting caught in the nets, due to the damage and injury caused to the catch they would not survive and is surely a waste.

Ghost fishing: Lost gillnets continue to gill and entangle fish and other marine organisms leading to unwanted mortality as gillnet material is non-biodegradable. This process known as ghost fishing is a negative characteristic of modern gillnets.

Adding to Marine Debris: Drift nets often measuring to kilometers are very easy to loose or cut accidently and become trash adding the marine debris. Thus the drift gillnets pose severe environmental, social and economic threat to the ecosystem.

8.0 Design and operation based Mitigation strategies

The ill effects of gillnets resulting in capture of juveniles, over capitalization, ghost fishing, wastage of resources and incidental mortality of protected and endangered species of marine mammals and turtles necessitate appropriate mitigation measures.

The measures can be based on interventions at the design and construction level and at the operation levels.

8.1 Design and construction related approaches

- Optimization of gillnet dimensions: Very large drift gillnets measuring more than hundred kilometer length and 50 m depth should be strictly avoided. As per the UN (Willington Convention defined drift gill nets of more than 2.5 km as large scale and Un General Assembly imposed a global moratorium on all large scale pelagic drift net fishing on the high seas from December1992
- Optimization of mesh size: Optimized mesh size for the target catch should be selected at the design stage. Mesh size regulation in commercial gillnet fisheries is proposed to reduce bycatch discard rates and to ensure minimum size limit for fishes caught and landed. Imposing minimum mesh size for gillnet does not meet with the same opposition that go with other measures such as limited entry or closed season.
- Choice of netting material: Netting material of sufficient thickness and strength is to be selected. Selection of very thin and fine material, especially PA monofilament yarn is to be avoided. Promoting use of multifilament netting material instead of

monofilament can reduce marine debris as the very fine PA monofilament netting is replaced frequently due to the difficulty in mending.

- Optimization of hanging ratio: Hanging ratio which would aid maximum mesh opening and avoid too much looseness is to be selected at the design stage so that entangling of the nets and bycatch can be avoided.
- Use of biodegradable materials in rigging and construction: Use of biodegradable natural fibre twines or biodegradable polymers or time release elements to connect the netting to floats would minimize ghost fishing by lost gillnets. Once the floats are separated due to the breakdown of these links, the gillnets lose their fishing ability.

8.2 Operation related measures

- Choice of fishing area: The fishing area is important from the point of view of avoidance of protected area, rough and rocky fishing grounds where there are chances of net being damaged.
- Choice of fishing depth: In rough and rocky fishing grounds, the depth of operation should be restricted to surface and column layers to avoid damage to the net.
- Choice of fishing time and season: Fishing time and season also are to be selected in such a way that nets are not operated during breeding season of the target catch and during very very rough weather.
- Use of scaring devices and acoustic deterrents: Incidental catch of mammals can be prevented by making the gillnets detectable by marine mammals having echolocation abilities, using acoustic pingers and specially treated netting. Use of netting treated with barium sulphate which makes the nets acoustically reflective and stiffer has been reported to reduce the incidental catch of marine mammals and birds in gillnets.

The design, construction and operation of the gillnets if carried out in a responsible way, this gear can be recommended as a simple, energy efficient and cost-effective fishing gear which can be operated in the inland (river and reservoir) and in marine waters for sustainable harvesting of fishery resources.

9.0 Further reading

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