

# **Gill Nets and their Operation**

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Gill net is a highly selective and passive gear accounting for 20% of all the fishing methods of the world. 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. It is a highly selective gear and the use of this gear in a responsible way ensures resource conservation. The gear is a vertical wall of netting, which is kept erect in water by means of floats and sinkers. The gear is mostly rectangular in shape whose upper end is mounted to a float line (head rope) and the lower end to a sinker line (foot rope).

The nets are operated in the surface, column or bottom layers of the water column in inland, coastal and deep sea. Gill nets are operated for the capture of different groups of fishes such as sardine, mackerel, prawn, hilsa, and larger varieties like tuna, shark, seer fish, and other large pelagics. When operated for such larger varieties in the deeper areas of the sea the nets extend to several kilometers.

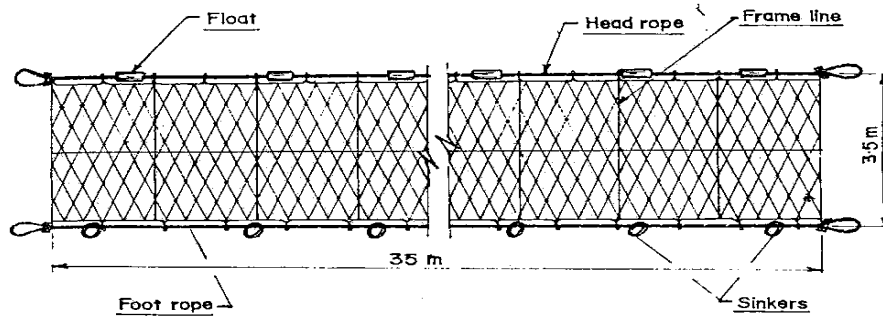
## **Mechanism of fish capture in gill nets**

The fact that separates gill nets from all other type of fishing is that in gill nets the 'mesh' of the net serves the dual function of 'selecting' the fish to be caught and catching it. The capture of fish in gill nets depends on the net construction, its dimensions, and the shape of the fish body. When a fish approaches a gill net, it tries to pass through the mesh. The meshes are just large enough to allow the fish's head but not the rest of the body to pass through it. When the fish tries to pull back, the pressure exerted by the mesh at the opercular region of the fish, opens the opercle and the twine of the mesh rolls and held behind the opercle. This characteristic capturing is designated as 'gilling'. The fish is also caught in gill nets 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.

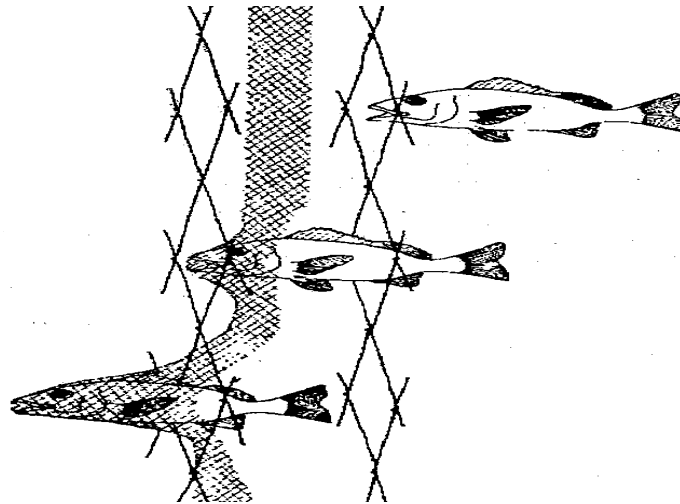
## **Type of nets**

Gill nets can be classified into different groups depending upon the type of construction, area of operation, fish targeted and method of operation. Simple gill nets, vertical line gill nets and frame nets are single walled nets while double and triple walled (trammel nets) nets 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.

### Framed gill net



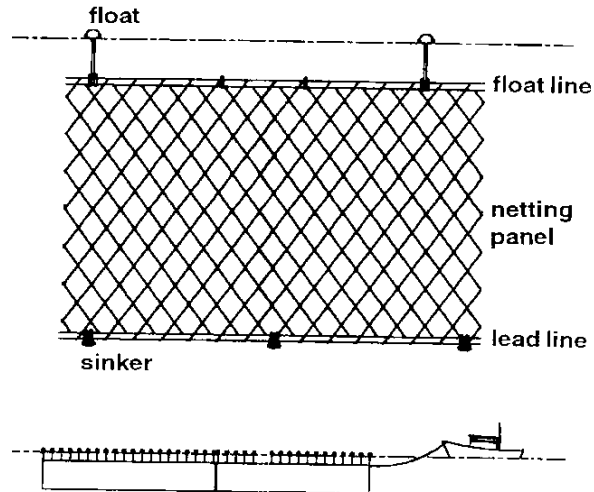
Trammel nets are triple walled nets having a loosely hung center wall of small mesh netting which is bordered on each side by tightly hung walls of large open meshes. Fish swimming through the outer meshes encounter the center netting and push their way through the opposite outer meshes. Fish become trapped in the resulting pockets that are formed. 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.



Depending on the method of operation there are drift gill nets (drifting freely or attached to a craft and floating), set gill nets (anchored or staked to sea bed) and encircling nets (the fishes are surrounded and driven from the centre by noise and other means). Depending on the area of operation there are surface, column and bottom gill nets.

### Structure of a typical gill net

A typical single walled gill net is a rectangular piece of netting essentially having the main netting, selvedge (top and bottom), float line/ head rope, sinker line/foot rope, gavel lines/side ropes/brush line, floats, sinkers and buoys and buoy line



Selvedge, generally of thicker material than the main netting gives protection to the main webbing during handling and operation. 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 and the hung depth of the mounted net. 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.

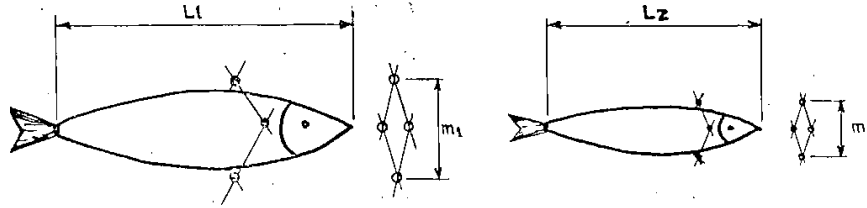
## Design Aspects

The main principle of the gill net 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 gill nets. The main parameters to be considered while designing a gill net are: (1) size of mesh in relation to the size of the targeted fish, (2) diameter of the twine in relation to mesh size, (3) hanging coefficient of the net, (4) visibility of the net, (5) softness of the material and the (6) buoyancy and ballast given. The optimum fishing height of the net in relation to the swimming layer of the fish is also important.

### *Mesh size*

Mesh size is the most important factor to be considered in the design of a gill net. 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 gill net with mesh size  $m_1$  catches a fish of length  $L_1$  best of all and the net with mesh size  $m_2$ , catches fish of length  $L_2$  best of all, then according to geometrical similarity

$L_2 / L_1 = m_2 / m_1$  using this, the length and mesh size can be predicted.



Optimum mesh size for the target fish can be determined by selectivity experiments. CIFT has recommended optimum mesh sizes for gill nets targeted at several commercially important resources (Table 1). According to Baranov the mesh size can be determined following the equation

$$a = kl$$

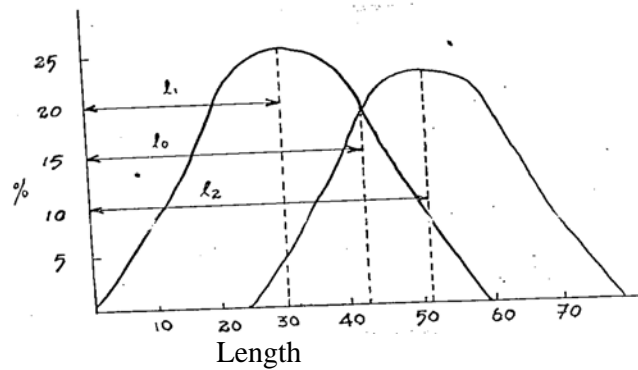
where 'a' is the size of mesh bar, 'l' average length of fish for which the gear is designed, and 'k' a co-efficient specific for a given species determined empirically and can be found out by, (i) length measurement and (ii) girth measurement.

**Length measurement**

The length frequency distribution of catch obtained in 2 gill nets, of different mesh bar  $a_1$  and  $a_2$ , fished simultaneously may be prepared and the frequency curve corresponding to these can be drawn on a single graph.

If 'l<sub>0</sub>' represent the length of fish, appearing in number in catches of both the nets, then the coefficient 'k' can be determined by the equation.

$$k = \frac{2a_1a_2}{l_0(a_1 + a_2)}$$



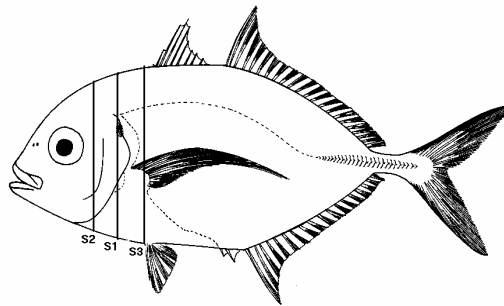
**Fig. 1 Determination of l<sub>0</sub>**

**Table 1 Optimum mesh sizes suggested by CIFT for gill nets**

Species/group of fishes	Common name	Optimum mesh size (mm)	Common mesh sizes (mm)
<i>Sardinella longiceps</i>	Oil sardine	33.4	30-38
<i>Rastrelliger kanagurta</i>	Mackerel	50	38-52
<i>Scomberomorous commersoni</i>	Seer	152	90-140
<i>S. guttatus</i>	Spotted seer	104	90-140
<i>Pampus argenteus</i>	Silver Pomfret	126	110-130
<i>Hilsa toli</i>	Chinese herring	102	
<i>Penaeus indicus</i>	Indian white prawn	38	32-52
Freshwater fishes	-	-	100-180
Tuna	-	-	70-140
Shark	-	-	120 - 500

### 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<sub>1</sub>' always exceeds a little than the girth at gill covers S<sub>2</sub>



**Fig. 2 Girth measurements**

But the place of gilling S<sub>1</sub> will be less than maximum girth S<sub>3</sub>. The relation between the mesh perimeter and area of cross section where it is caught can be represented as

$$n_1 = 4a / S_1$$

where 'a' is the mesh bar and this will be different for different species of fish. Obviously if the fish has to be caught firmly, S<sub>1</sub> must be greater than S<sub>2</sub> and less than S<sub>3</sub>. Taking into account this inequality we can arbitrarily set the value of the perimeter S<sub>1</sub> to the maximum girth of the fish S<sub>3</sub>, as

$$n_2 = S_1 / S_3$$

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

$$n_3 = S_3 / l$$

Which is found by simply measuring the fish length, l. Then the coefficient 'k' can be determined by applying the formulae.

$$k = \frac{n_1 n_2 n_3}{4}$$

### ***Coefficient of hanging***

The shape and looseness of webbing depends on the coefficient of hanging. From the point of view of geometry, the mesh of fishing net is rhomboid with properties attributed to it. The hanging ratio is defined as the length of frame lines 'L' (head rope) or float line relative to the stretched length of netting 'LO' with N as the number of meshes and Lm, as the mesh size.

$$E = L/LO = L/(NLm)$$

Where, E is the hanging coefficient, L the length of head rope/float line, LO length of stretched webbing. This can be obtained if mesh size Lm and its number, N are known.

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

$$H = \frac{\text{Length of webbing (L)} - \text{length of rope}}{\text{Length of webbing}} \times 100$$

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

$$D = NLm \sqrt{1 - E^2}$$

Where E, is the hanging coefficient, N, the number of meshes in depth and Lm mesh size (stretched).

Generally the horizontal hanging coefficient is about 0.5, for gill nets. And if it is smaller than 0.5, the net will tend to tangle fish and will capture a variety of species. 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 of drift nets. The hanging coefficient commonly given to different types of gill nets are given in Table 2

**Table 2 Common values of hanging coefficient for gill nets**

Type of net	Coefficient of hanging	
	Horizontal (E <sub>1</sub> )	Vertical (E <sub>2</sub> )
Simple gill net	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

### ***Twine Characteristics***

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 (Table 3). Yellow coloured nets, which were found to give maximum catching efficiency for pomfrets, are very popular in the Saurashtra coasts.

**Table 3 Colour of gill nets most suited for different fishery**

Targeted group/area	Colour
Pomfret	Yellow, white
Prawn ( <i>Penaeus indicus</i> )	Green, orange, red
Hilsa	Yellow, white
Govind sagar reservoir	Yellow
Hirakud reservoir	Yellow, grey, green
Saurashtra coast	Yellow, white

### ***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. According to Fridman (1986) the buoyancy requirement of a bottom net is

$$Q_f = KQ \times Q_n$$

where  $Q_n$  is the weight in water of netting and mainline and  $KQ$  is a coefficient between 3 and 6. The buoyancy coefficient  $KQ$  should be greater in stronger currents and lower for calm waters because more floatation produce large vertical forces on the netting.



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,  $Q_s$  is greater than the forces of floatation.

$$Q_s = KB \times Q_f,$$

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.

## **Techniques of operation**

Gill net operation has been a relatively simple method compared to operation of other fishing gear. Nets were 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. Gill nets are operated mainly as bottom set, or surface net, drift net, 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 behaviour of 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 gill net, both ends of the gears are secured to bottom by means of sinkers or anchors. In drift nets one end is tied to the boat and the other end with 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.

### ***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.

### ***Nets set and hauled over stern***

The gear is rolled out over stern, but is hauled from stern using a davit mounted or boom mounted power block. Drums are also used for hauling and shooting of gill net. 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.

## **Issues and Concerns**

Gillnet which a hundred years ago was considered as environmentally safe, has in the latter part of the 20<sup>th</sup> century aroused much controversy. In the 1980s and 90s drift nets have been criticized as both wasteful and unselective as trawlers were before. Some of the issues on which criticisms are made are the following.

### ***Capture of non-target species and juveniles***

Low loosely hung nets capture by entangling leading to mortality of non-target species and juveniles of even target species. Specialized gill nets for oceanic fishing which when allowed to drift with winds and currents gill, entangle and enmesh a wide range of living marine organisms such as birds, turtles and marine mammals. Thus they pose threat to the oceanic pelagic ecosystem, which is relatively species poor.

The fishing fleet in a tropical inshore (coastal) gill net fishing system often consists of more than one category (mesh size) of gill nets attached end to end. This results in the

occurrence of different size groups of a species in the catch from a landing centre. Thus, in spite of the known selectivity of the gill net for a particular narrow size range of fishes, the use of different mesh sizes results in a wide size range. Even though the mesh sizes for several commercially important resources have been optimized, a multitude of mesh sizes are being used simultaneously (Table 1).

### ***Ghost fishing***

The resistance of synthetic material to decay and the deployment of large amounts of netting in some fisheries have led to the problem of 'ghost fishing'. Segments of netting, which are lost accidentally during fishing or deliberately discarded, may continue to fish for an indefinite period of time or at least capable of entangling birds, turtles and marine mammals near the surface.

### ***Dropout***

A form of wastage in drift net fisheries comes in the form of 'dropout' of fish during hauling. A proportion of fish caught in the nets will fall from the net before being hauled onboard and a further proportion will escape from the net injured. This has led to the allegation that drift net fisheries are wasting resources.

### ***Low quality of fishes caught***

Fishes, which are caught in drift and set gill nets, are often left in the water for several hours prior to retrieval on deck and a relatively high proportion of the catch is spoiled and has to be discarded.

Most of these issues are concerned with large-scale drift net fisheries or industrial high sea fisheries. UN (Wellington Convention) has defined large-scale drift net fisheries as only those using nets of more than 2.5 km or only those fisheries conducted outside the EEZs. If operated responsibly gill net fishing is a selective and energy efficient fishing system suitable for the conservation of the resources.