FACTORS TO BE TAKEN INTO ACCOUNT IN THE DECISION ON MINIMUM MESH SIZES AND THE MEASUREMENT OF MESH SIZE

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The size of mesh in fishing gear is one of the most common legal measures that can be taken to control the catch and thereby avoid catching juvenile individuals of the targeted species or of other species. A particular mesh size is usually chosen to allow smaller specimens of a species to escape but to retain the larger specimens. The size is generally commensurate with size of the fish after it has matured and allows a certain proportion of the population to grow to a size at which they can reproduce before being included in the catch. The choice of mesh size is fairly easy in a mono-species fishery as only one fish type has to be taken into account but becomes more complex when several species are present.

Legal mesh size is usually measured differently from the measure used when constructing the fishing gear or other calculations on the fishing gear. Generally legislation states the inside mesh size of the mesh when it is stretched, which means the legal mesh size is always smaller than the size given in the specifications of the net (see Figure 1).

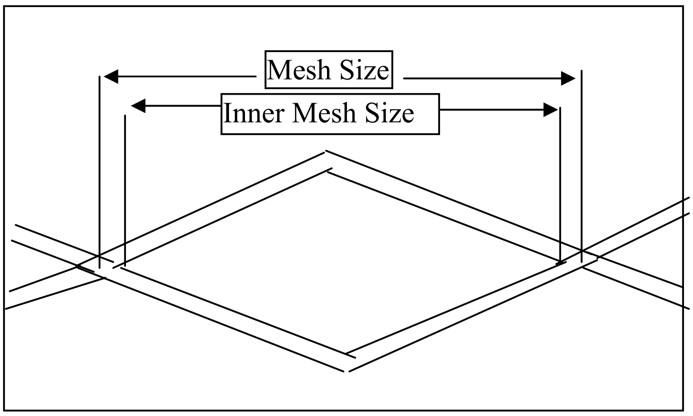

Figure 1. Difference between Mesh size and Inner Mesh Size

Although, the mesh of a fishing net is measured when it is stretched, when the net is used the mesh is usually in a diamond orientation. Theoretically netting covers the greatest area when the mesh is in the form of a square, with the internal angles at 90 degrees. However in mobile nets such as trawls and seines the mesh is usually stretched horizontally in the direction in which the net moves with the meshes having internal angles in the order of 60 and 120 degrees. This is because it is very difficult to provide enough vertical tension to counteract the tension used to pull the net through the water.

In stationary nets such as gill nets and trammel nets the direction of the mesh is with the diamond stretched vertically. This is because the shape of fish usually approaches such a shape. Note that the purposes of gill nets and trammel nets are to retain fish that are around the size of the mesh size, while fish smaller or larger than the mesh size escape. This means that gill nets and trammel nets have different selectivity curves. Trawls and seines on the other hand always have an S-shaped selectivity curve, where retention increases with the size of the fish (see below).

ENFORCEMENT OF LEGAL MESH SIZE

Fisheries management measures in many cases tend to be difficult to agree upon and most measures including those related to mesh size, tend to be a compromise as to what the optimum is thought to be. Some years ago, I was asked to carry out some research into the catches retained by various mesh sizes in the North Sea. I was a bit surprised because I had thought that this was being carried out continuously. In fact it had not been done for 30 years, despite new materials being introduced and more modern techniques adopted. Many hundreds of fishermen has been fined in the meantime for having mesh sizes which were slightly less than the legal mesh size. It is hardly surprising, given the differing opinions, even among scientists, as to what the minimum mesh size should be, that fishermen regard being fined for non-compliance with minimum mesh sizes as an occupational hazard rather than a criminal offence. Nevertheless, the law as it is stated has to be enforced and probably more importantly has to be seen to be enforced - that someone is doing something, despite the lack of evidence and even cynicism, on the effectiveness of conservation based on mesh sizes.

The most common instrument for the measure of mesh size is the standard gauge, which is calibrated with different mesh sizes and is pushed into the mesh. The depth to which the gauge enters the net measures the inner mesh size. There has been some criticism of the gauge because it is difficult to specify an exact pressure to put on the gauge. This led to research in the 1970s into how the measurement of mesh size should be made and various measurement devices with spring tension were proposed. However the European authorities have reverted to the simple wedge gauge with a weight of 5 kg attached so that a standard tension is exerted on the mesh. In finer nets undue pressure can force slippage in the knots so that the mesh size is made larger than it is. Slippage in the knots means that mesh sizes in the same net can vary, so it is normal for about ten or a dozen random measurements to be taken and averaged to avoid any possibility that an atypical small measurement leads to a prosecution.

Given the doubts on conventional mesh measures for conservation purposes and environmental concerns for the amount of discards from the fishing industry, various selectivity measures have been introduced into the industry. Square mesh panels have been introduced to allow the escape of unwanted catch, especially juvenile fish. The square mesh panel is mounted just ahead of the cod-end and is in most cases of a different colour from the surrounding net. In order to encourage the fishermen to use the square mesh escape panels, the legislation allows the use of a smaller mesh in the cod-end if a square mesh panel is used.

TURTLE EXCLUDER DEVICES (TEDS) AND BY-CATCH EXCLUDER DEVICES (BRDS)

The development of TEDs began in the Gulf of Mexico where concern was raised over the impact of shrimp trawling on the population of turtles. Turtles were being caught in the trawls and by the time the net was hauled they were drowned. Over a period of twenty years, continuous research has provided a partial answer to this problem. Grids fitted into the tunnel of the net divert any large object upwards out of the net, whereas the targeted shrimp are unable to swim upwards and pass through the grid eventually finishing up in the cod-end of the net. These rather simple explanations belie the amount of work and experimentation that has gone on to optimise the escapement of turtles and yet retain the efficiency of the net for the capture of shrimp. Furthermore it has been found that it is necessary to "fine tune" the fishing gear to different regions, different nets and different practices. For this reason the Fisheries Department of the USA has given a list of the different designs that they accept as suitable for legal purposes. The concern expressed by environmentalists for turtles in the Gulf of Mexico became international when American fishermen complained that their competitors in foreign countries were exporting shrimp to the USA and yet they did not have to use TEDs. Since that many countries, whose shrimp fisheries were dependent upon the American market have introduced TEDs.

During experiments on TEDs, it was noticed that in many cases small unwanted fish also escaped through the TED. This observation led development in another direction towards By Catch Reducing Devices (BRDs). These have the purpose of allowing unwanted catch to escape from the net. In some cases they consist of rigid grids and where these are considered inappropriate they can be flexible panels such as square mesh panels.

TYPE OF FISH AND MESH SELECTION

Mesh size regulation (and minimum landing sizes) are generally set for demersal fish, but very seldom for small pelagic fish. There are very good reasons for this. Firstly, demersal fish have a longer life cycle than the small pelagics and therefore the concept of escaping fish to be caught at a later time is not so important for small pelagics. Secondly small pelagic fish caught in mid water trawls (or seine nets) are generally all of the same size, at a much higher catch rate and in much higher quantities and the mesh size chosen is such as to avoid large numbers of fish becoming enmeshed in the net. Therefore, the mesh size is gear used to catch schooling small pelagics is much smaller than that estimated for gilling a similar sized fish.

CALCULATION OF APPROPRIATE MESH SIZE.

The mesh size in fishing gear is chosen for several reasons

f) To allow the filter of juvenile fish in demersal cod-ends

g) To gill fish in gill nets and allow larger and smaller fish to escape

h) To catch fish in trammel nets

i) To retain all catch and avoid enmeshing of fish in mid water trawls

There are two basic formulas to allow the calculation of the appropriate mesh sizes. The first is Fridman's formula, which relates the length of the fish to the mesh size of the net

mesh opening = (2/3) * (length of fish/ K)

where K= a shape coefficient
and where

	K = 5	for fish that are long and narrow
	K = 3.5	for an average shape fish
	K = 2.5	for flat, deep-bodied or wide fish

Once this factor has been calculated, experiments should be undertaken to check the selectivity of the net, particularly if legal minimum mesh sizes are to be considered. This formula has been calculated to enmesh the fish in the net (i.e. a gill net). For a demersal trawl the mesh size could be that calculated by the formula minus 10%. For a mid-water trawl the mesh size should by that calculated by the formula minus 20%. For trammel nets, the outer sheet (or lint) should be chosen so that the fish can pass through and the inner sheet so that the fish can be retained. In a trammel net there is usually a range of fish caught and the outer sheet of netting chosen so that it is three or four times the mesh size of the inner sheet.

Selectivity Curves
The mesh size selectivity for different fishing gears can be described graphically by plotting the percentage of fish of a given size that escape against the mesh size. These are shown in the following diagrams.

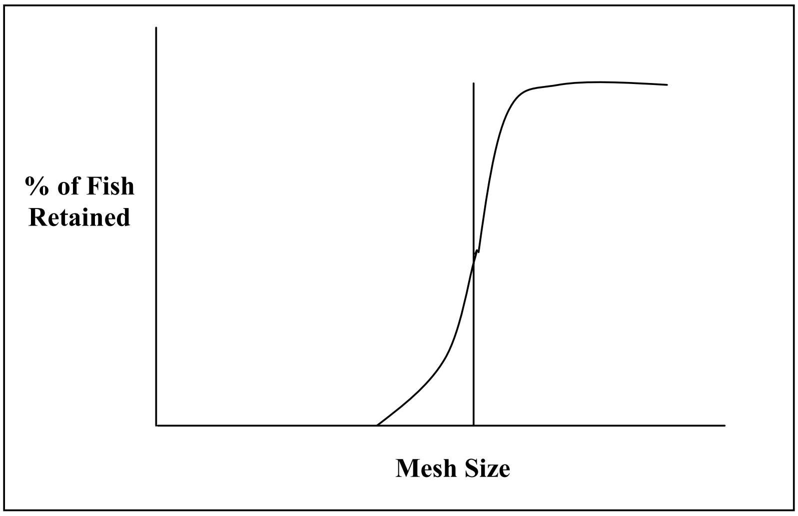

Figure 2. S-shaped selectivity curve of a cod-end

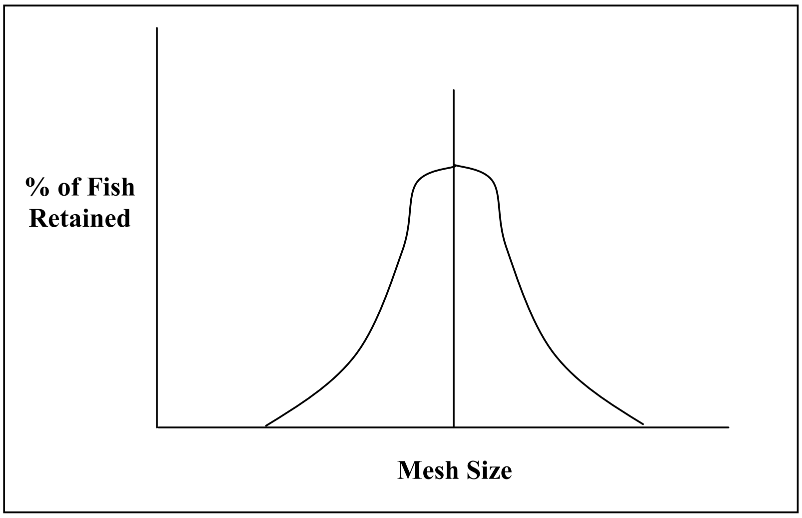

Figure 3. Bell-shaped selectivity curve of a gill net

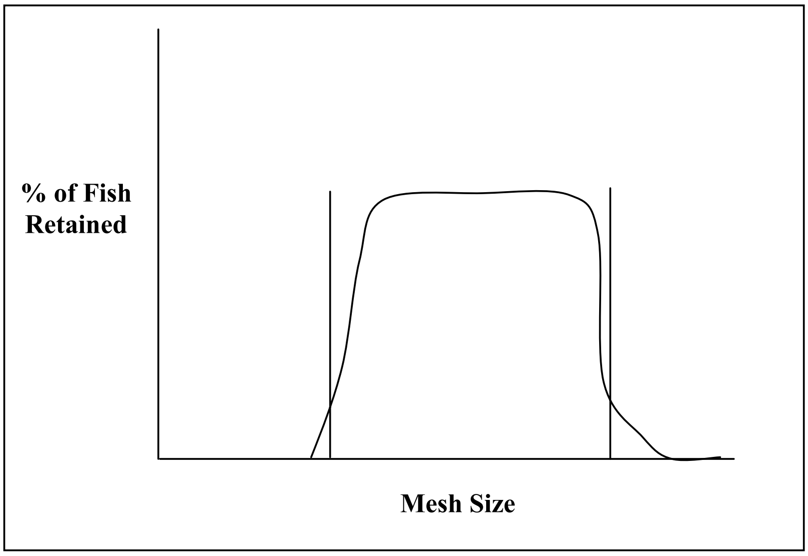

Figure 4. Selectivity curve of a trammel net

It has to be emphasised that these are very theoretical and simplified. The measurements and experiments have to be carried out for a number of different mesh sizes. A great difficulty arises when estimating the number of fish that escape from the gear and various measures have to be taken to give estimates of the number of fish that escape. This can be done by outer cod-ends or double cod-ends in trawls or by using a range of different sized mesh in gill nets or trammel nets during the experiments.

The Multi Species Problem

The paradox of the choice of mesh size can be illustrated by using the North Sea demersal fishery as an example. Four main round fish species make up the major part of the catch, see Table 1

Table 1. Minimum sizes of four demersal species in the North Sea

Species	**Minimum landing size (total length incm)**
Cod	35
Haddock	30
Saithe	30
Whiting	27

The minimum landing size is roughly the size at maturity, so if a mesh size is chosen that is to catch all whiting above mature size it will result in immature cod, saithe and haddock stocks being caught. Conversely if the mesh size is chosen so that cod are caught at maturity the saithe, haddock and whiting stocks will be underfished. An interesting twist was proposed some years ago where it was pointed out that if the larger mesh size was chosen then the larger whiting stock which was under exploited could be feeding on the young cod, thereby negating the positive influence of the larger mesh size.

One could argue that with knowledge of what the landings of the various species were or the MSY, an optimum solution could be reached whereby the optimal catch in terms of quantity or value could be calculated. Unfortunately, different countries land different quantities of each species as is shown in Table 2. A further complication arises because these percentages have changed with time.

Table 2. Landings by country of four demersal species

Country	Norway	Denmark	UK	Minimum size
Cod	321,631	69,025	77,182	35
Haddock	79,031	5,786	83,436	30
Saithe	194,131	3,973	12,261	30
Whiting	166	114	27,243	27

The result is that different countries advocate different minimum mesh sizes, from the UK with 80 mm mesh size to Norway advocating 120 mm mesh size. The result is that in the southern North Sea a smaller mesh size is used than in the northern section of the North Sea, where most of the Norwegian vessels are fishing. Note that in the simple example given, there are only the four main species with the main countries, but in fact about twenty species and all the other northern EU countries are involved. The situation becomes much more complicated in tropical countries where there is a far greater number of species.

Efficiency of Filtering

Studies have shown that the filtering effect of the net is reduced when there are large quantities of fish in the cod-end or when large quantities of fish are entering into the net at the same time. This is easy to explain as the fish get jammed up against the mesh and therefore the filtering effect is reduced. Pelagic fish are normally caught at higher catch rates than demersal fish so this effect is more often seen in mid water trawls.

Survival

The filtering action of the meshes in mobile gears is aimed at allowing the smaller fish to escape and to grow and eventually be caught at a later date. However, many fish are damaged in escaping and die. The effect is the same as if they had been retained and landed. For this reason there has been numerous experiments in recent years to measure the survival rate of fish after they have passed through a cod-end mesh. The results have shown that demersal fish have a high rate of survival, whereas pelagic fish have a low rate of survival after passing through the mesh. This is thought to be due to the demersal fish being more resistant to skin damage, whereas the scales on pelagic fish are easily rubbed off. Research has even been carried out into the psychological stress that fish experience when passing through the mesh to try and explain the differences.

Fishermen's tricks

Mesh size regulations have been in existence **for hundreds of years** and not surprisingly fishermen have found ways of decreasing the effectiveness of mesh selectivity when they want to catch fish around the minimum mesh size. It should be noted, however, that when the minimum landing size and the selectivity of the mesh size are in close correlation, there is little incentive for the fishermen to reduce the selectivity because it will involve more work in discarding under sized catch.

The first method is by tying a light string around the cod-end that restricts the cod-end from expanding in a lateral direction. Hence the diamond shape of the mesh is also restricted and smaller fish are retained. If the cod-end fills up or when the cod-end is lifted on board, the light string is broken so that all evidence of the measure undertaken to avoid selection disappears.

Another way of keeping the mesh sizes closed in a lateral direction is to insert a heavy weight in the cod-end. On larger vessels a tractor tyre is used because it does not damage the cod-end. The tension exerted by the object at the bottom of the cod-end keeps a much higher tension in the direction of towing, therefore again the lateral opening of the mesh is reduced.

Another method is to use very heavy stiff twine in the cod-end, so that it is not so flexible and requires far more tension to open the meshes, however this can be legislated against by specifying maximum twine diameters that can be used in the cod-end. Chafers (an outer cod-end with the objective of reducing abrasion on the inner cod-end) can also be used to reduce the opening of the meshes as one layer overlaps the other. This is counteracted by legislation of the chafer mesh size.

CONCLUSION

Mesh size selectivity has had a long and involved history and it can be stated that the effectiveness of mesh size on selectivity is quite demonstrable by experiment. What is at question is the effectiveness of mesh size on the sustainability of the resource particularly where several species are involved. This aspect of mesh selectivity needs far more research even in countries where minimum mesh sizes have been accepted for more than a hundred years.