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Gill Netting

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1. INTRODUCTION

The introduction of fine synthetic materials, in the construction of fishing gear during the 1960s, marked the beginning of a radical change in the pattern of fishing in the coastal waters of England and Wales. The new materials were cheaper and easier to handle, lasted longer and required less maintenance than natural fibres like cotton and hemp, which had previously been used to make nets. In addition, nets made with synthetic twines generally caught more fish than nets of natural fibre used in comparable situations.

Most gill-net fisheries, for both migratory salmonids and marine species, have only developed in their present form as a result of the availability of the modern netting materials. The first effect of the new materials was to provide fishing opportunities that were not available to those using traditional gear. For example, gill nets could be set on rough ground, which had once been fished by long-lines but could not be fished by trawlers, and drifting gill nets could be used successfully in daylight, giving netsmen more freedom to choose the timing and duration of their fishing trips. The second effect was to attract new, often inexperienced or part-time, netsmen into the fisheries, and thus increase exploitation levels on certain stocks. In the licensed salmon fisheries, it has been possible to regulate the numbers of netsmen permitted to fish and the dimensions of their nets, but there are no restrictions on the quantity of gill nets that can be used for marine species around England and Wales, and it has been suggested that the resulting expansion in effort has led to local overfishing of some stocks.

Gill nets may be defined as fishing nets in which all, or a substantial part, of the catch is retained by becoming 'enmeshed', or wedged, in one or more meshes; the term 'gilling' refers to the way in which the fishes' gill covers (operculae) may act as barbs to prevent them from escaping. These types of gear are therefore distinguished from nets designed to 'enclose' or 'encircle' fish. Nets like trawls and seines can be made with very small meshes so that no fish become enmeshed, but most types of net are subject to minimum mesh size regulations which are intended to allow the smaller, usually immature, fish to escape. As a result, fish that are only a little too large to pass through the net tend to become enmeshed, whilst larger fish are contained within the net walls. With enmeshing nets, however, fish can be either too small or too large to be retained by the mesh; thus, for a particular mesh size, gill nets are more 'selective' for fish size than trawls or seines.

This leaflet describes the various types of nets that are used to enmesh fish and explains how they are made and how they work. Much of this information is based on experimental observations of salmon and the nets used to catch them, but the principles involved apply to all of the commercial fish species found around British coasts. A range of general fishery management problems, associated with the use of enmeshing nets, is also discussed.

2. SYNTHETIC NETTING MATERIALS

2.1 Background

Synthetic fibres, made from at least seven different groups of chemical polymers, are used in the construction of fishing gear. Trawls made from polyamide netting materials were first tested in the late 1940s, but synthetic nets were not in regular use until the cheaper polyethylene fibres (e.g. corlene) were developed in the early 1950s. Most modern gill nets used in the UK are made from polyamides, commonly called 'nylon' or known by other trade names. Such nets were introduced into the UK herring fisheries in the late 1950s and into the salmon fisheries in the early 1960s.

‘Netting yarn’ is the term used to describe textile materials which are suitable for the manufacture of fishing nets without the need for further processing (Klust, 1973). Synthetic fibres are produced in various forms, of which two, known as ‘multifilament’ and ‘monofilament’, give yarns suitable for various types of enmeshing nets.

2.2 Multifilament yarns

Continuous filaments are very fine fibres, normally less than 0.07 mm in diameter and of almost limitless length. ‘Multifilament’ netting yarns are made from large numbers of these filaments gathered together, with or without twisting. Most commonly, continuous filaments are twisted together to form quite fine ‘single yarns’, and several of these are in turn twisted together to make the netting yarn. Multifilament nets were the first to be introduced and are often still referred to as ‘nylon’ by fishermen, while some loosely twisted multifilament nets are sometimes called ‘single-throw’ (Figure 1).

An immense variety of multifilament yarns may be manufactured by altering characteristics such as those below:

- filament material (e.g. polyamide, polypropylene, etc.);
- filament thickness or denier (= weight in grams of 9000 m);
- number of filaments in each single yarn;
- degree of twist of the single yarn;
- number of single yarns in the netting yarn;
- degree of twist of the netting yarn; and
- direction of twist of the netting yarn relative to twist of the single yarn.

2.3 Monofilament yarns

Monofilaments are single filaments which are normally more than 0.1 mm in diameter. Those thicker than about 0.4 mm are strong enough to function alone as netting yarns; nets with a mesh size of less

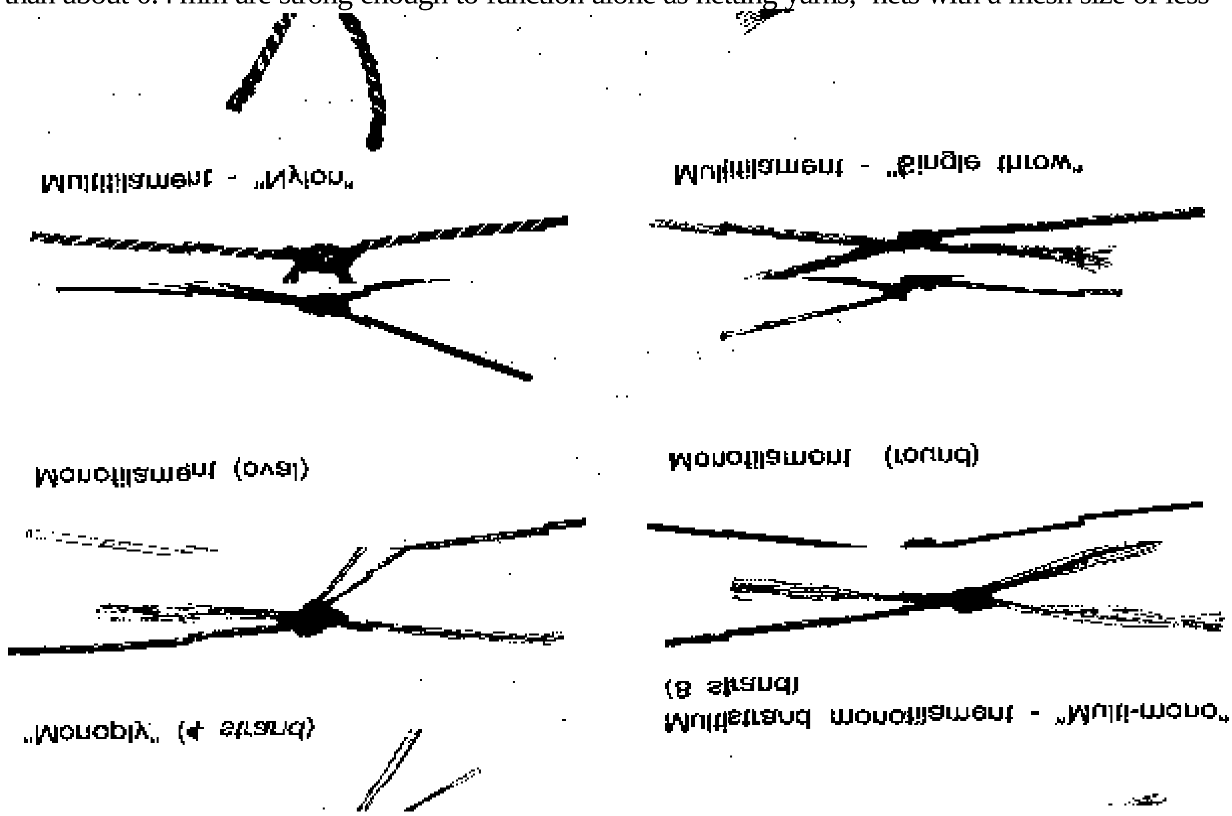


Figure 1. The various types of synthetic yarns used for gill nets

than 50 mm (knot to knot) are often made from 0.4 mm yarn, while 0.6 to 0.8 mm yarn is commonly used for larger-meshed nets. Netting yarns are also made by twisting a number of fine monofilaments together; these are usually referred to as 'mono-ply', when they are made with about three filaments and 'multistrand monofilament' or 'multi-mono' when larger numbers of thinner filaments are used (Figure 1). They are not normally regarded as 'multifilament' netting yarns, from which they can be distinguished on the basis of filament thickness or the number of filaments making up a yarn. In addition to the range of thickness, monofilaments are made round, oval or flattened in cross section.

2.4 Variability in synthetic yarns

Monofilament or multifilament yarns are used to make sheets of netting, which in turn are made up into various types of nets either by net manufacturers or by the fishermen themselves. The strength and durability of this synthetic netting may vary considerably, and the more commonly used monofilament nets, for example, show large differences in both the quality of the netting yarns and the construction of the netting, although there have been significant improvements over the past 20 years. Good-quality monofilament yarns are of consistent thickness, while the varying thickness of lower grade yarns tends to make them weaker and more elastic. The knots are the weak points in the construction of most nets and, particularly with monofilament yarns, they are liable to slip or come loose. Efforts have been made to reduce this weakness by using double or even treble knots and by treating them with heat or chemicals after tying. Many synthetic materials deteriorate in ultra-violet light and gill nets are therefore usually dyed to reduce the damaging effects of sunlight. Greens and blues are the colours most often chosen because, in water, they are also thought to reduce the visibility of the nets to the fish. Either the netting yarn or the completed nets may be dyed, and heating is required to fix the colour. These treatments are designed to improve the performance of the nets, but some processes can adversely affect the strength and elasticity of the net meshes.

In addition to the effects of exposure to sunlight, the physical properties of synthetic nets can also change gradually with use. In particular, abrasion of the nets removes the shine from the material, and the accumulation of dirt in the knots and on the roughened surface of the yarn makes the netting more visible in the water.

3. THE CONSTRUCTION OF GILL NETS

3.1 Net dimensions

The mesh size can be described by several different measurements (Figure 2).

- 'Knot to knot' and 'bar length' (b) refer to the length of yarn between two adjacent knots (sometimes measured between knot centres).
- 'Stretched mesh' (s) is the distance between two knots on diagonally opposing sides of a (four-sided) mesh when they are pulled apart, usually with a set force.
- 'Mesh circumference' and 'round four sides', as the terms imply, give the full distance round each mesh.

Thus, 'stretched mesh' is approximately equal to 2 x 'knot to knot', and 'mesh circumference' is approximately equal to 4 x 'knot to knot'.

Mesh size regulations for trawls and other towed nets are usually specified as stretched mesh measurements, and the various restrictions in European waters are set down in Council Regulation [EEC] No. 3094/86 (European Community, 1986), which does not apply to enmeshing nets. The Salmon and

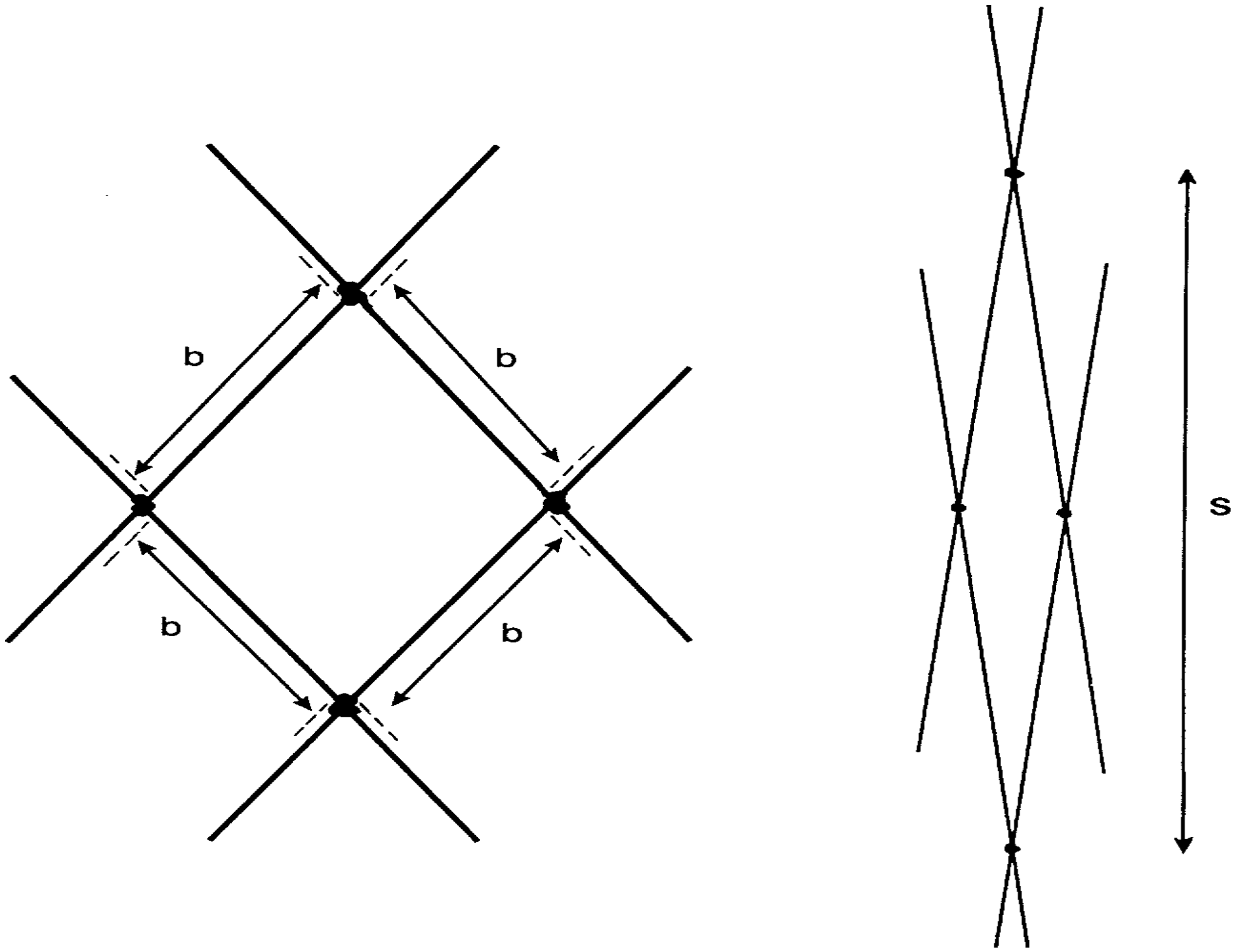


Figure 2. Mesh size measurements

Freshwater Fisheries Act 1975 (Great Britain – Parliament, 1975), however, refers to measurement of 'knot to knot' and 'round four sides'. As a result, byelaws passed under this Act use the same terms, although they are not precisely defined and there is no procedure set down for measuring them. With monofilament nets in particular, the question of whether 'knot-to-knot' includes the width of one knot can make a significant difference to the measurement. It would therefore be helpful for future regulations to specify the appropriate procedure for measurement of stretched meshes, as in Statutory Instrument 1284, 1989 (Great Britain – Parliament, 1989).

All mesh sizes referred to in this report are given as stretched mesh measurements in metric units. A chart for converting metric units to imperial units is given in Section 9 (see Figure 11).
The net length is the length of the piece of sheet netting when the ends are pulled so as to collapse the meshes and form a 'rope'. Sheets of netting are commonly 100 or 200 m long and, when made-up, nets are usually one-third to two-thirds of these lengths. The depth of the sheet netting is the number of full meshes from the top of the net to the bottom.

The construction of many enmeshing nets simply involves attaching a headrope with floats along the top of the sheet of netting and a weighted footrope along the bottom. The floats may be spaced up to 6 m apart along the headrope, and the weights may be tied to (or incorporated into) the footrope, the latter being known as a 'leadline'. When the netting is attached to the headrope it is said to be 'set in' by a certain proportion. This proportion, which is termed the hanging coefficient (E), equals the length of the fishing net when made up divided by the length of the original sheet of netting. In this leaflet, E is expressed as a decimal but it may also be shown as a percentage or a fraction (e.g. E = 0.67 is equivalent

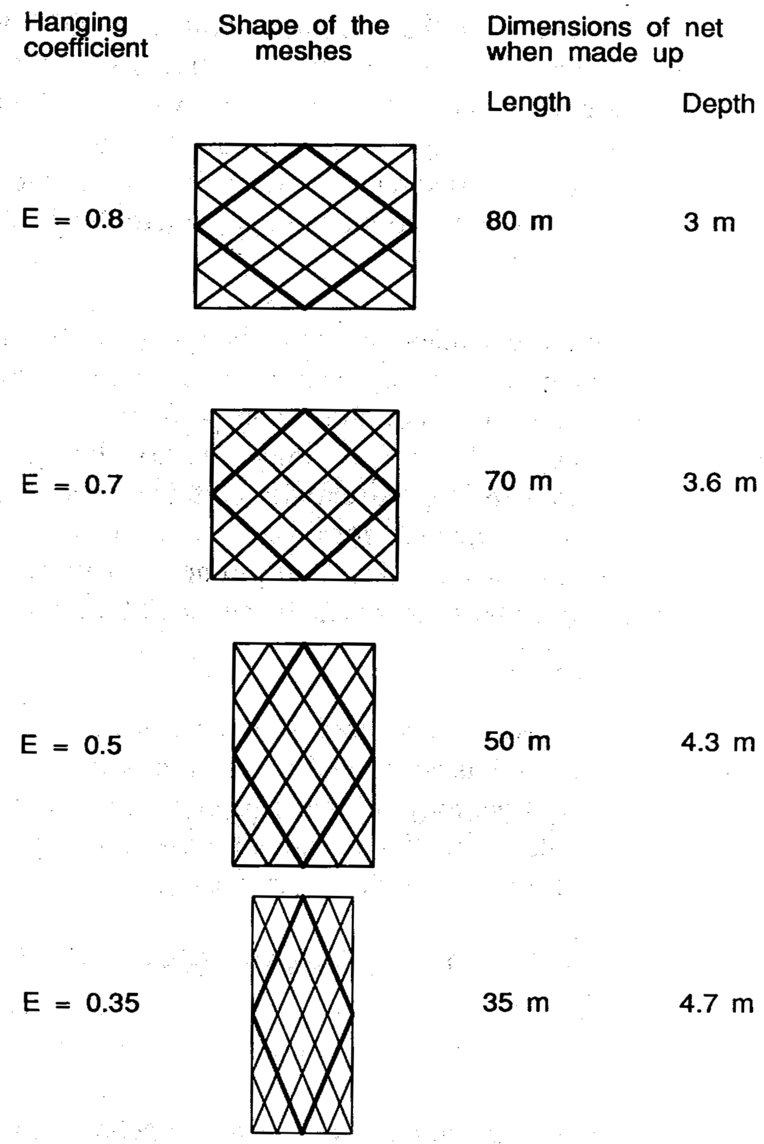


Figure 3. The relationship between the hanging coefficient (E), the shape of the meshes and the length and depth of a gill net made from a sheet of netting 100 m long, 50 meshes deep and with a stretched mesh size of 100 mm

to E=67% or E=2/3). Figure 3 shows how the hanging coefficient determines the length and depth of the final net and the shape of the meshes in the water.

3.2 Types of gill net

The way in which gill nets are constructed and operated varies from area to area, depending on the main target species and local conditions. In general, fixed nets employ a heavily weighted footrope and have few floats on the headrope, so that the bottom of the net rests firmly on the sea bed and the net forms a loose, upright wall. Each end of the net is attached to an anchor,

weight or stake to prevent the net moving with the current, and one or both ends are marked with a buoy. Drift nets, on the other hand, are allowed to move freely with the water currents, and therefore have more floats on the headrope and a very lightly weighted footrope, so that they hang down loosely from the surface. In the case of drift nets used to catch bass, herring or cod (for example), the headrope is often suspended some distance below the surface on rope strops attached to buoys. Such nets can be fished close to the sea bed, where this is clear of obstructions.

Both drift nets and fixed gill nets are usually made up with a hanging coefficient (see above) of about two-thirds (E = 0.6-0.7), which approximately maximises the area of the netting by making each mesh roughly square. If the nets are set on the headrope with a large amount of slack netting (E = 0.3-0.4), fish are more likely to become entangled without being properly enmeshed. Such nets, often termed tangle nets, are particularly suitable for species such as rays, turbot and monkfish, although they are widely used for other fish because, for a given mesh size, they will catch a larger size range of fish than conventional gill nets. Drift nets are often made with hanging coefficients of 0.5-0.6, in order to increase the chance of the fish becoming entangled as well as enmeshed.

The trammel net is another type of gear which is classed as an enmeshing net. This is also based on a loosely hung gill net (the 'lint') but it has additional walls of very large meshed 'armouring' hung on one or both sides. Fish may still become enmeshed in the lint, the mesh size of which is chosen to catch particular 'target' species, but those too large to be properly held may be trapped in a pocket of netting forced through the armouring.

4. PHASES OF FISH CAPTURE BY FIXED AND DRIFTING NETS

4.1 Background

There are three distinct phases in the way in which a net operates, each of which may influence the numbers of fish caught. The first phase relates to the way in which the fish come or are brought into the vicinity of the gear. This depends on whether the gear is anchored or moving and whether the fish are swimming actively or drifting passively with the current. The second phase of capture relates to the way in which fish respond to the gear before they come into contact with it; fish may detect the gear by sight or smell or they may sense vibrations through the water, and they will behave accordingly. Finally, even if a fish comes into contact with the gear, it may still escape capture. The third phase relates to how fish are held and behave in the net. Most nets are selective because they are able to retain fish only in a limited range of sizes, but the construction of a net and the type of yarn will also influence its ability to catch fish.

4.2 Relative motions of fish, water and nets

4.2.1 Drift nets

In theory, drift nets remain virtually stationary relative to the water and fish must actively swim towards them to be vulnerable. In the simplest situation, a net can be pictured spread across the fishes' path (Figure 4). The time during which the net is fishing and the swimming speed and direction that the fish take through the water will determine how many fish encounter the net.
In fact, fish may approach the net from any direction and at different depths, and their behaviour may be influenced by the tidal streams. In addition, tidal currents are complex, particularly close to the shore, and large areas of water tend not to move uniformly. Although this means that the net rarely lies straight for any length of time, it also results in some fish being moved passively towards the net. This effect can be exploited by experienced netsmen to aid the capture of fish. Drifting nets are sometimes also used as 'ring nets' to encircle fish, such as, for example, shoals of bass or mullet, thereby increasing the chances that the fish will come into contact with the net.

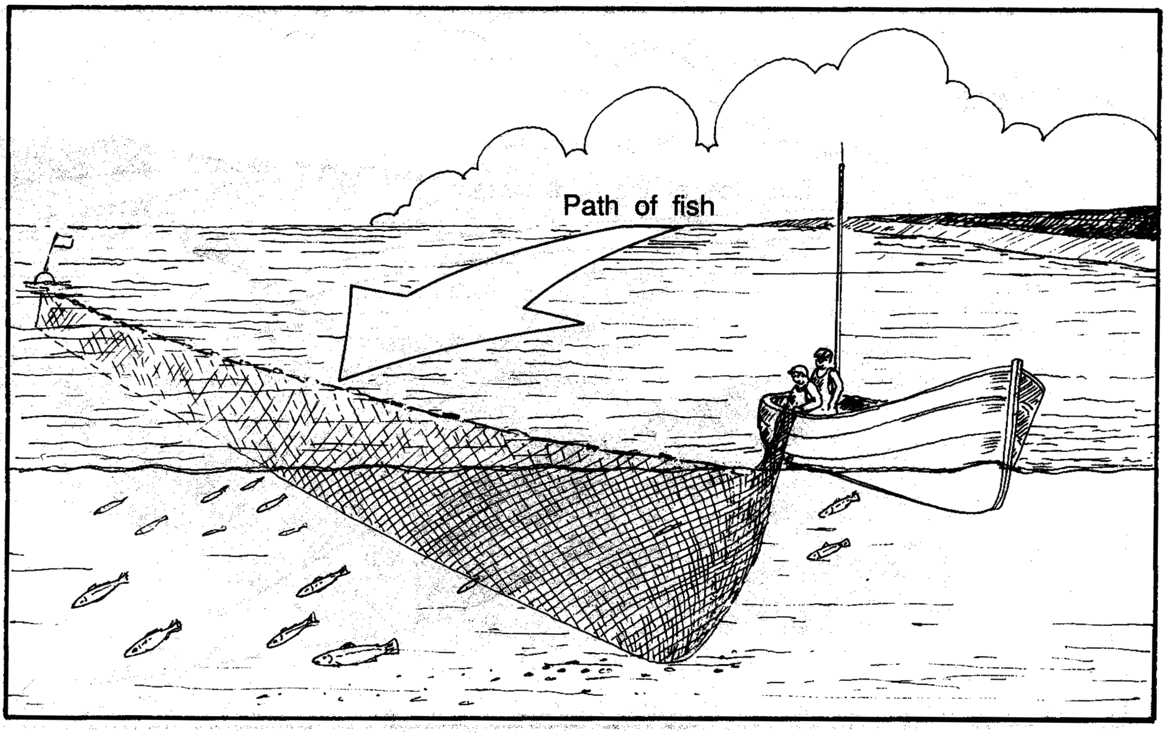


Figure 4. Operation of a drift net

4.2.2 Fixed nets

When a net is fixed to the sea or river bed, fish may still swim actively towards it, but they may also be brought into the vicinity of the gear by drifting passively with the current (Figure 5). Fixed gill nets are generally shot along the tidal axis in order to reduce the amount of debris that is caught, and those fish swimming actively across the tidal stream are more likely to be caught. These nets fish most effectively on the slack part of the tide when their headropes are not being pushed down by the force of the current.

Fixed net fisheries for migrating fish exploit both active and passive movements. Salmon and sea trout, returning to fresh water on their spawning migrations, often follow the shoreline very closely and are therefore vulnerable to nets set at right angles to the beach. At times, they also move passively with the tides, which once again makes them vulnerable to fixed gear.

4.3 Response of fish to nets

Most gill and trammel nets work on the principle that, having swum or drifted into the vicinity of the gear, a proportion of the fish will fail to detect the netting or to take adequate action to avoid it. The lower visibility of synthetic materials in the water, compared with twines of natural fibre, is probably largely responsible for the greater effectiveness of modern gill nets. However, it is possible that the strong preservatives used on the natural materials may deter fish, and vibrations from the heavier netting yarns may also be more easily detected.

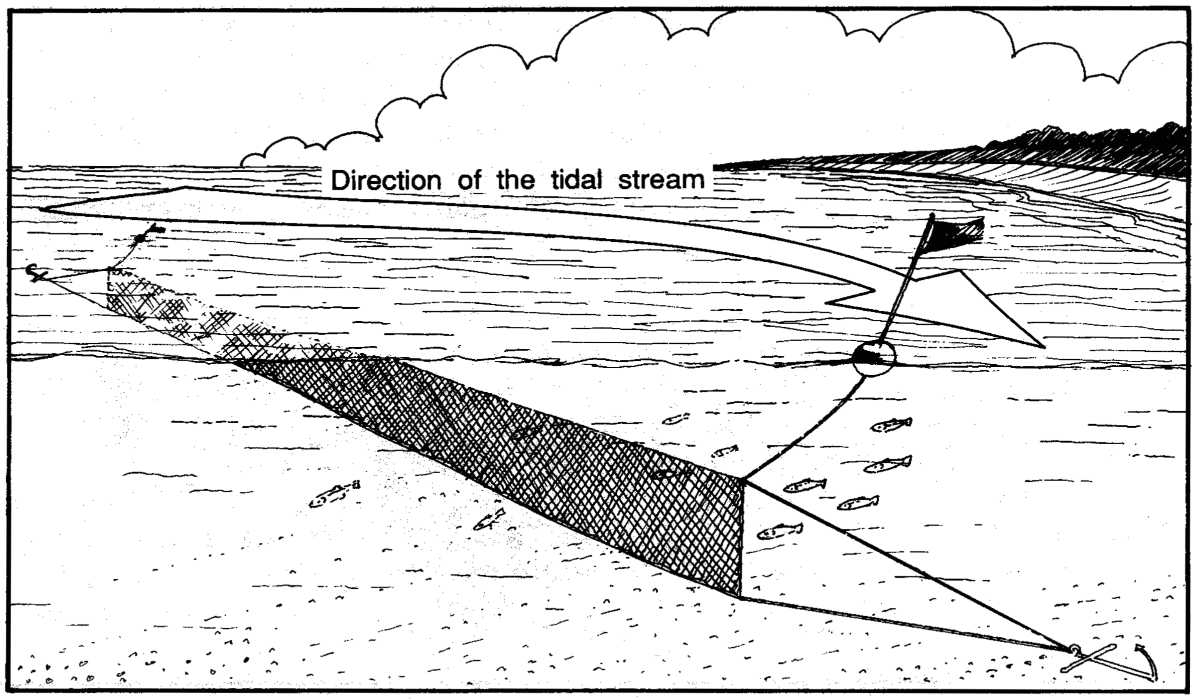


Figure 5. Operation of a fixed net

If a fish senses the net, it will often turn and swim parallel to it. This behaviour is exploited in the Northumbrian 'T'-net fisheries for salmon (Figure 6) and the similar Scottish stake and bag nets, in which a straight wall of netting is designed to intercept fish swimming parallel to the shore and lead them into a bag or compound of netting. The mesh size of this 'leader' can be chosen so that it does not enmesh the fish, though in England they often have meshes of a size similar to those used in the neighbouring drift-net fisheries. They may also include sections of smaller mesh designed to catch sea trout swimming in shallow water.

Traps and other encircling nets are usually made from relatively heavy multifilament netting yarns for durability, and fish can therefore see the net and will often swim around in the enclosed area. However, when the less visible monofilament nets are used, more fish become enmeshed. The 'T or J' nets used on the Yorkshire coast, to catch mainly sea trout, employ a leader and a simple trap, but only retain fish by enmeshing them. The trap compound is used to increase the probability of fish coming into contact with the net, which is normally made from monofilament yarn. Seine nets made from monofilament yarns also enmesh a larger proportion of their catch than similar nets made from multifilament materials.

4.4 Behaviour of fish in nets

Fish are usually caught in gill nets, either by trying to swim through a mesh and becoming wedged ('gilled'), or by becoming snagged or tangled in the netting. In tank experiments, Angelson and Holm (1978) observed the behaviour of salmon when they became caught in a gill net. The fish initially struggled quite powerfully, usually for less than 30 seconds, although in a few cases they swam vigorously for 2 or 3 minutes. This was followed by long periods in which the fish remained motionless or made only occasional weak movements. Investigations of fish energetics by Zhou (1982) suggest that, at normal sea temperatures, a salmon could only swim vigorously for one or two minutes before becoming totally 'exhausted' through the accumulation of lactic acid in the muscles.

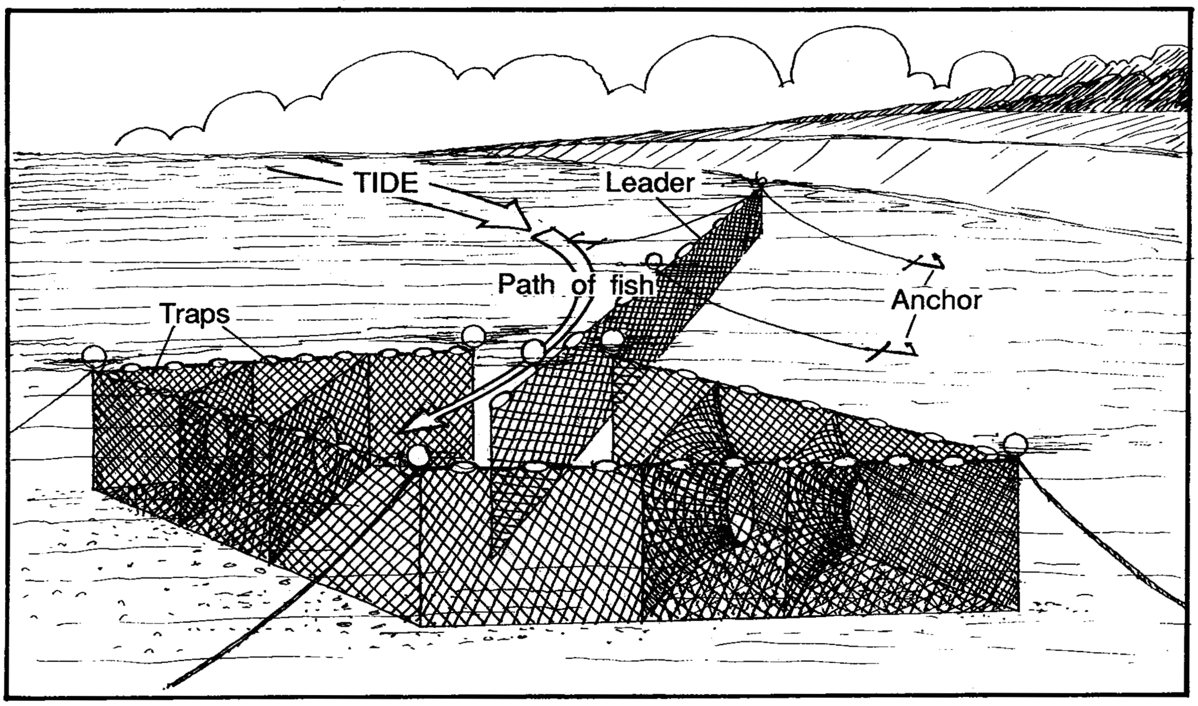


Figure 6. A 'T'-net, which catches migratory salmonids by using a gill net to lead fish into the traps

Angelson and Holm also noted differences in the behaviour of salmon that were enmeshed and those that were snagged or tangled. Gilled fish tended to swim strongly forwards, pulling the net with them. If they were still held, they would then turn and swim in the opposite direction. Thus, if the net were hung fairly loosely, the fish would swim back into it and become caught in more than one mesh. Salmon that hit the net and became snagged without being gilled tended to wrench strongly with their head or tail, at the same time moving backwards or alongside the net. Once again, a loosely hung net offered more chance of the fish becoming entangled.

No corresponding observations have been made on the capture of marine species by gill nets. However, it seems likely that their behaviour would be similar to that of salmon, although some species might struggle less strongly but for longer periods.

4.5 Probability of capture or escape

The probability of a fish being caught after it comes into contact with a gill net is largely dependent upon its size. Gill nets are therefore said to be 'size selective'. A fish with a maximum girth less than the mesh circumference will be able to swim straight through, while a fish so large that it can barely get its head into a mesh is unlikely to become firmly wedged and may escape (Figure 7). Tangle nets are designed so that some large fish may still be held even if they cannot be properly enmeshed and, in traps and seines, such fish should still be retained within the enclosed area of netting.

In fact, because of the elasticity of the netting yarn and the compressibility of their bodies, fish with a girth somewhat larger than the circumference of the mesh may also be able to escape through the net.

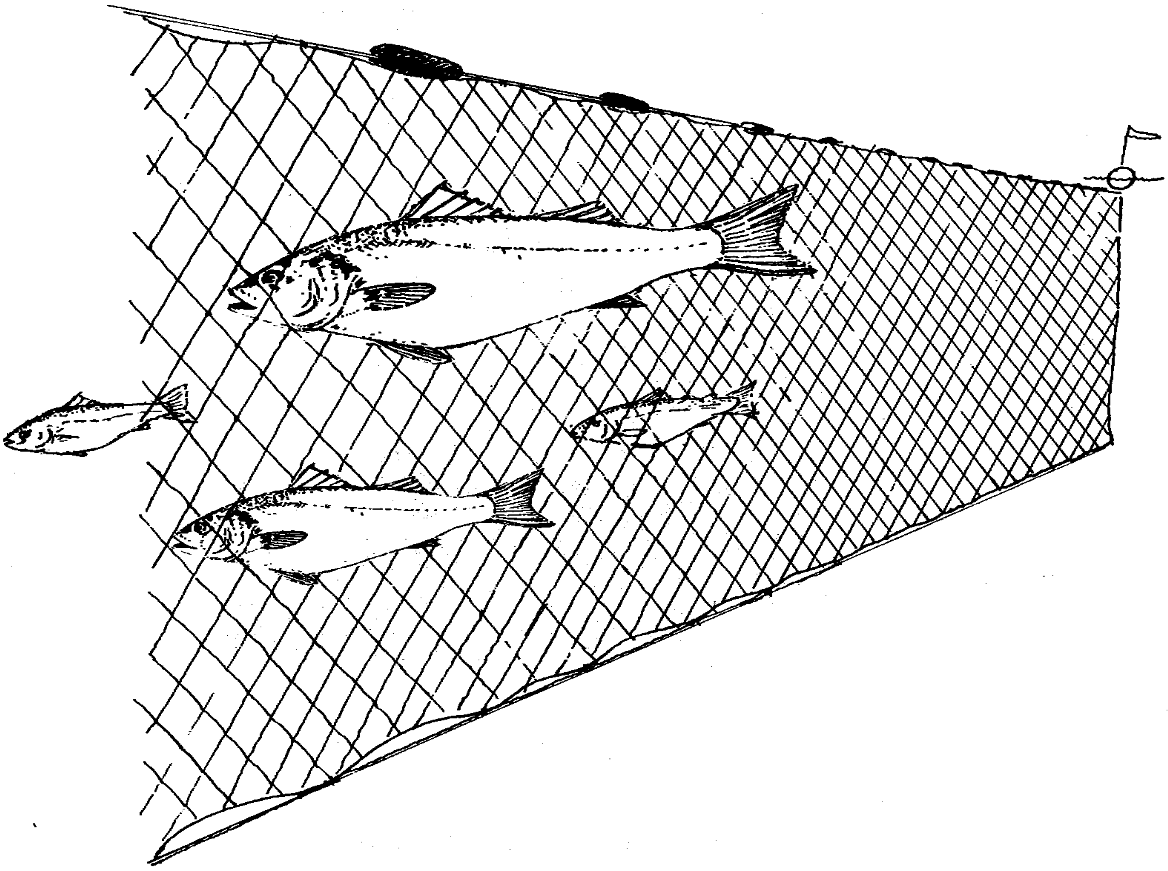
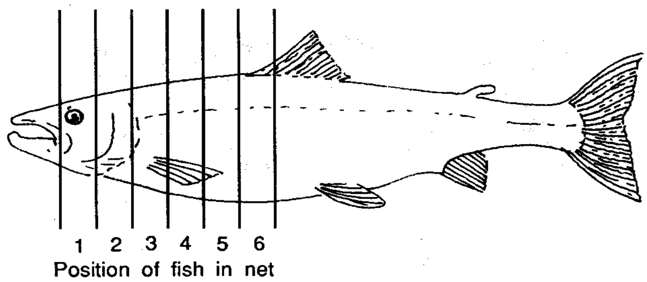


Figure 7. A gill net showing that small fish can pass through while large fish might bounce off without becoming firmly wedged

The bodies of fish of many species are like smooth, narrow wedges, and most fish can therefore force themselves well into a net mesh. The girth of an adult salmon, for instance, increases by only about 10 to 15% between the gills and the dorsal fin, a distance of 10 to 15 cm. Experiments have demonstrated that salmon can exert a considerable force on a mesh, generating a tension in the twine equivalent to a load of several kilograms. This will not only stretch the mesh by 10% or more but may also compress the fish's body at that point by a similar proportion (Potter, 1983). Thus, for example, a gill net with a mesh circumference of 260 mm will retain few salmon with a maximum girth of less than 300 mm, and some fish with girths as much as 330 mm may be able to force themselves right through a mesh. Fish with maximum girths about 20% to 40% greater than the circumference of the mesh are those most likely to be firmly enmeshed; they will be small enough for the mesh to pass over the gill covers, which act as barbs making it difficult for the mesh to slide forward again, but too large to be able to squeeze right through the mesh. However, fish only a little larger again may not penetrate as far as their gills on their first impact with the net, and may thereafter drop out under their own weight or wriggle loose. Figure 8 shows the maximum girths of salmon caught in a net with mesh circumferences of 260 mm, plotted against that part of the body around which they were held in the net. This demonstrates the differences in the way in which various sizes of fish are held, as illustrated in Figure 9.

A gilled fish may also escape if it can apply sufficient force to the net to break a mesh or make a knot slip. Large salmon can sometimes distort and break meshes of drift nets, even where the breaking strain of the netting yarn is 15-20 kg, and will frequently burst right through small-meshed nets which are made of fine yarns.



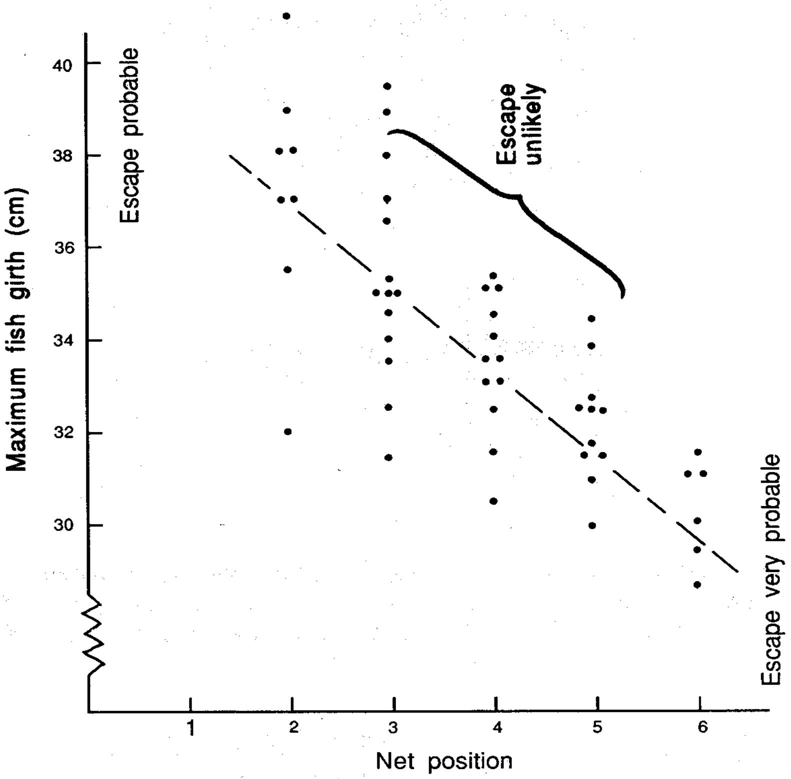


Figure 8. The relationship between a salmon's girth and the position at which it might be held in a mesh

The force which a fish can apply to a mesh, and thus the way in which it is held, will be affected by the hanging coefficient of the net. If the net is hung loosely it will tend to 'give' as the fish strikes, making it more difficult for the fish to apply sufficient force to squeeze through or break a mesh. A low hanging coefficient also makes it more likely that, after having been held, at least momentarily, in a single mesh, the fish might swim into other meshes; the force required to escape might then be proportionally greater. However, it would also make it more difficult for a large fish to apply the force required to become firmly gilled. Drifting nets are able to 'give' more than fixed gill nets with the same hanging coefficient, and therefore behave as if their hanging coefficient is relatively lower. Thus, small fish may be more likely to escape through a fixed gill net than from a drift net of the same mesh size.

Fish of all sizes may be held by the net if they are caught or entangled on jaws, teeth, spines or other projections. Tangle nets are specifically designed to operate in this way, and are also often made from multifilament netting which is softer and is generally thought to be more likely to snag the fish than the harder and more springy monofilament yarns.

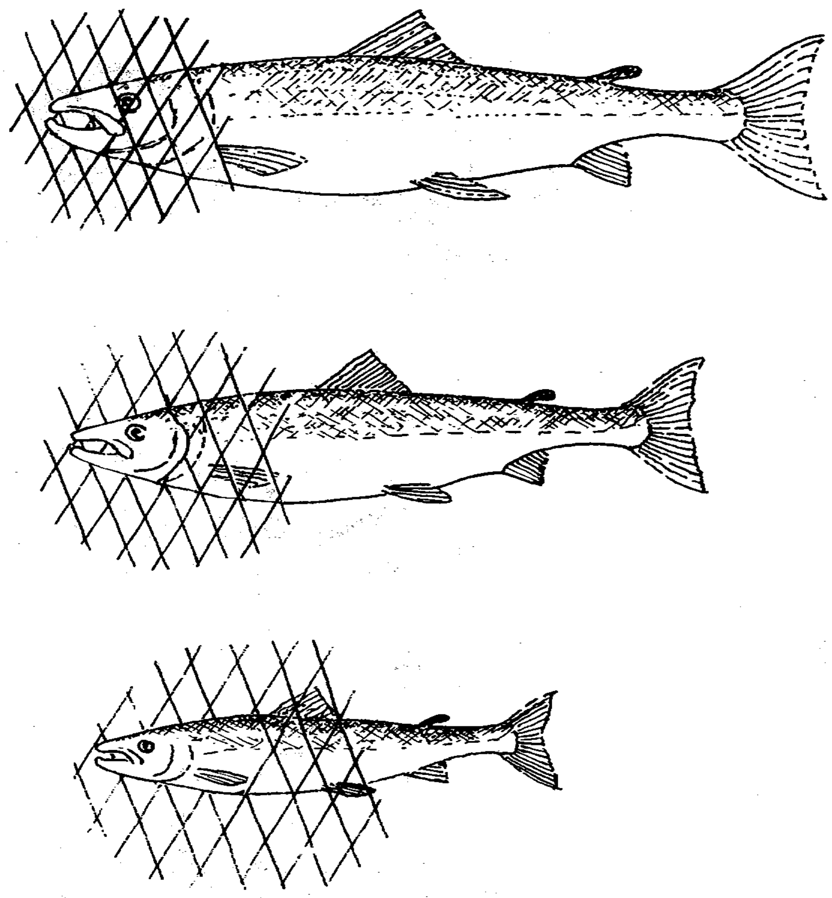


Figure 9. Positions of fish held in gill nets: (a) large fish wedged around head (probably also snagged); (b) medium-sized fish wedged around body behind gills ('gilled'); and (c) small fish wedged at maximum girth in front of dorsal fin

4.6 Selection and retention curves

The selectivity of a net is defined as that proportion of fish of a particular size encountering a net which will be held. For gill nets, the selection curve (Figure 10(a)) is often assumed to approximate to the classical, bell-shaped normal distribution; the chance of fish being held by a net falls fairly quickly for individuals progressively smaller or larger than the optimum length. However, the shape of this curve will vary for different species and may be affected by the way in which the net is constructed and used. For example, Ueno *et al.* (1965) observed that, for salmon encountering drift nets, individuals smaller than the optimum size are less likely to be held than those which are a similar increment larger than the optimum size. This occurs to an even greater extent in tangle and trammel nets, which will catch some fish which are much larger than the size range that can be gilled in the net. For seine nets and traps, small fish may escape through the meshes as they do in gill nets, but larger fish are retained without being held in the net's meshes.

Figure 10(b) shows the hypothetical size distribution of bass in a population which is usually fished by gill nets having a mesh size of 89 mm. The length distribution of bass caught by these nets is shown in Figure 10(c) (Reis and Pawson, in press). These latter data can be used to determine retention curves but, although it is very much easier to obtain data of this type than to calculate selectivity values, it

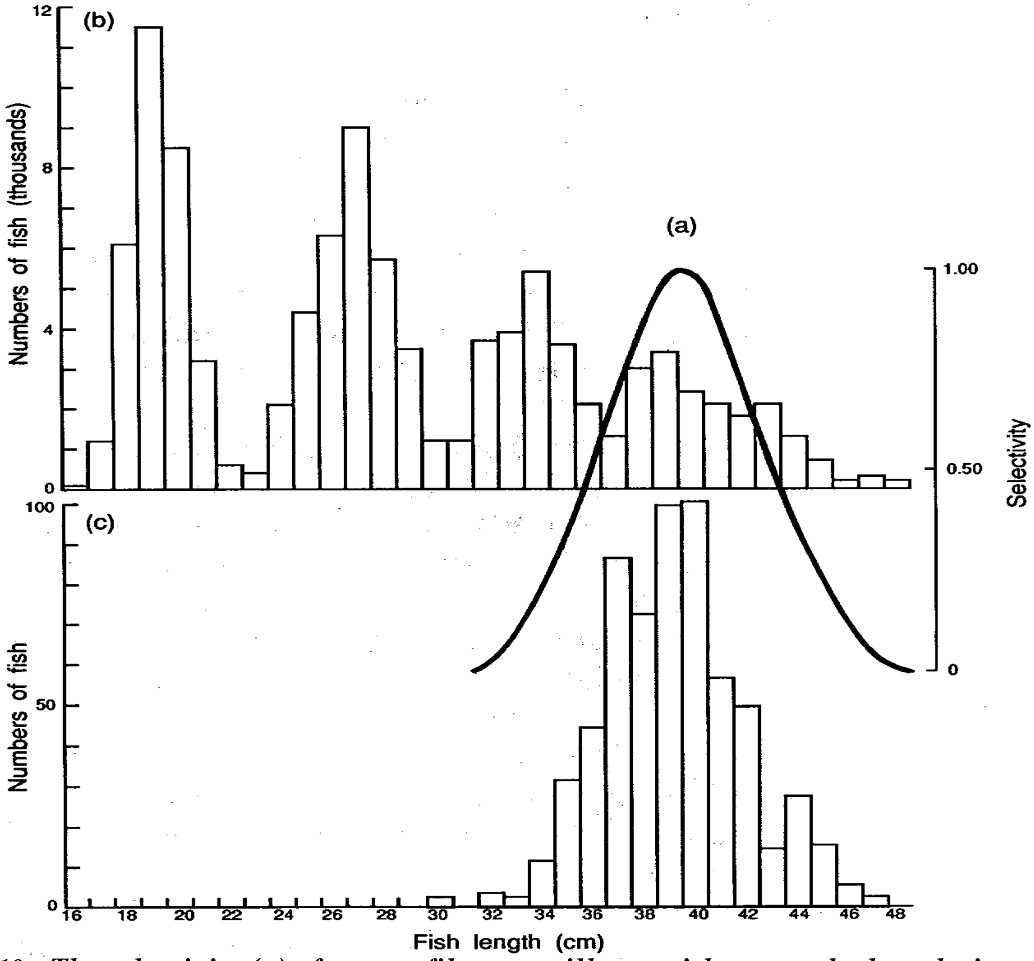


Figure 10. ***The selectivity (a) of a monofilament gill net, with a stretched mesh size of 89 mm, in catching bass from a population (b) with a wide size distribution, and the resulting catches (c) of retained fish (from Reis and Pawson, in press)***

should be noted that the shape of the retention curve is dependent on the length frequency distribution of fish available to be caught in the vicinity of the net. For this reason, retention data are most useful when comparing catches for the same or similar nets fished in several different areas, or to compare the impact of a variety of mesh sizes on one fish population.

5. CONTROL OF MESH SIZE

Because of the selective nature of gill nets, mesh size can be controlled to restrict the size of fish captured, and either selection or retention curves can be used to calculate the mesh size required. A minimum mesh size can be used to limit the catch of immature fish or to reinforce minimum landing size regulations. A 'target' mesh size can sometimes be used to control the catch of both small and large individuals; an example may be found in the West Greenland salmon fishery (Anon., 1982a). Salmon originating from Europe tend to be larger than North American salmon when they occur together in the fishery area. Thus, a net which optimally selects for fish of an intermediate size may balance the exploitation rates on the two populations.

Mesh size restrictions can also be used to protect some species of fish while allowing other, usually larger, species to be caught. For example, on two reefs off the Cornish coast a minimum mesh regulation of 250 mm (stretched mesh) has been introduced to protect bass, while still allowing tangle nets to be fished for rays, monkfish and crawfish. Most gill nets will catch more fish which are larger than the optimum selection size than fish which are smaller. However, it is also possible to afford some protection to a large species (for example salmon) by specifying maximum mesh sizes for fisheries where smaller fish like mullet or sole are the 'target' species.

In contrast to gill nets, many other fishing gears, in particular rod and line, long-lines and small-meshed trawls, are relatively unselective with respect to the size of fish caught. As a result, it is often more difficult to avoid the capture of fish smaller than the minimum landing size by these methods than it is with gill nets.

In many districts, there are several species for which gill nets of a particular type might be used. Thus, although there will usually be a primary 'target' species in any seasonal fishery, a range of mesh sizes may be required to maintain earnings throughout the year. This seems to be the stumbling block for mesh size regulations aimed at one species, since the capture of other vulnerable species must be taken into account. Because the selection characteristics of a gill net vary between species, one minimum mesh size is unlikely to conform to the minimum landing size of all of the species available. A mesh size which is too low will result in undersized fish of some species being caught which, even if discarded, will probably not survive. If the mesh size is set too high, the minimum catchable size of some species will be increased, which may help conservation but might not satisfy the fishermen or market. As a consequence, in a fishery which takes several species, there is unlikely to be a single minimum mesh size that will satisfy all management requirements. Mesh size restrictions are usually most important in inshore fisheries, where the juveniles of valuable commercial species, such as sole and bass, are more likely to be found. In these fisheries, the minimum mesh size will be specified accordingly. In most offshore fisheries, however, fishermen tend to use large mesh sizes which select only adult fish.

6. THE CATCHING ABILITY OF GILL NETS

6.1 'Effectiveness' and 'efficiency' of nets

Different types of gill nets are often said to have high or low 'efficiencies', but it is not always made clear what is meant by this word. It has been suggested that monofilament gill nets are very 'efficient' because they catch a lot of fish. However, it is also claimed that they are 'inefficient', because more fish encounter them than are landed and those that escape may be damaged and die later. In fact, two terms can be used to define these different characteristics of nets; here, these are called 'effectiveness' and 'landing efficiency'. Effectiveness is the attribute of a fishing gear that enables a fisherman to catch fish of a desired species and size, and landing efficiency is that proportion of the fish killed as a result of the fishing activity that is actually landed and can be recorded.

The effectiveness of a gear will depend upon many factors. In order to compare the effectiveness of two types of net it is important to determine the time and place and, where necessary, the extent and mode of operation of the gear. For example, in comparing the use of monofilament and multifilament drift nets, one would have to test nets of the same lengths and construction fished at the same time and place. However, it would also be reasonable to compare the effectiveness of similar sized gill and trammel nets operated in a particular area throughout a fishing season. Effectiveness is likely to be the primary concern of the fishermen, who will wish to increase their catch per net or per hour fishing. However, fishery managers would also consider landing efficiency to be important.

Landing efficiency is a measure of the wastefulness of the gear. The operation of most fishing gear results in some fish being killed which are not landed; the ways in which this can occur are discussed in Section 7, which deals with 'non-catch fishing mortality'. A gear with a high landing efficiency will allow few dead fish to fall out and few live fish to escape in such a damaged condition that they will subsequently die. From a management point of view, this is a desirable quality in a net, although such gear will not necessarily be the most effective in other ways. Clearly, effectiveness is a straightforward measure of the number of fish landed in a given situation. Landing efficiency, on the other hand, may be very difficult to estimate. By inference, it is difficult to monitor those fish that die during a fishing operation but are not landed by the fisherman. As a result, it may be necessary to examine landing efficiency on an experimental or theoretical basis in order to compare the operation of nets and assist with management of the fishery.

6.2 Monofilament netting versus multifilament netting

Previous sections have described differences between monofilament and multifilament netting and how fish may be caught in, or escape from, gill nets. Monofilament nets are often thought to be more effective than multifilament nets, principally because they are less visible in the water; the difference in catch tends to be greatest when the nets are used in clear water.

Other differences between monofilament and multifilament yarns, for example in strength or elasticity, are likely to influence the relative landing efficiency of different nets. It may be assumed that weaker, more elastic, nets will usually have a lower landing efficiency, but it is dangerous to generalise about the two groups of materials because there is so much variation within them. Potter (1983) examined monofilament and multifilament netting materials used in particular salmon fisheries in the British Isles. Although these materials were found to have similar strengths, the multifilament net meshes were more easily stretched than monofilament ones, suggesting that the latter could have a higher landing efficiency (i.e. that a higher proportion of the fish coming into contact with the gear would be retained and landed). Because it is likely that more fish fail to avoid monofilament gear, however, both the number of fish caught and the number escaping are generally greater than with multifilament nets.
It is usually thought that larger fish are more likely to become entangled in multifilament nets than in monofilament nets because of the softer texture of the twine. Stewart (1987), investigating the use of shallow, loosely hung gill nets (E 0.4) in Scottish inshore cod fisheries, found that more fish were caught by tangling in both multifilament and multi-mono nets than in monofilament nets, in which they were more likely to be gilled. However, MacMullen (1983) found that hake were more likely to become entangled in deeply fished monofilament gill nets than in multi-mono nets, although both had a hanging ratio of 0.5. These differing results probably reflect the variability in the materials used and suggest that the twine thickness, net dimensions and hanging ratio can have an effect on the way in which fish are caught, which is as great as the effect of the net material itself.

7. FISHING MORTALITY NOT RECORDED IN CATCH STATISTICS

The mortality of fish, which is generated directly or indirectly by fishing but does not appear in recorded catch statistics, is termed ‘non-catch fishing mortality’ (NCFM). Such unrecorded losses will occur in any commercial or recreational fishery, although their causes may vary with the fishing method. For analytical convenience, various forms of NCFM have been defined (Ricker, 1976). These include:

- ‘escapement mortality’: fish that encounter the gear and are caught temporarily but escape and subsequently die from injuries or stress or from increased predation due to their greater vulnerability;
- ‘drop-out mortality’: fish that are caught and killed by the gear but are lost prior to

retrieving the gear;

- 'haul-back mortality': fish that are caught and killed by the gear but are lost as a result of the process of retrieving the gear;
- 'discard mortality': fish that are discarded dead (e.g. those which are undersized or otherwise unmarketable), or die after being discarded from injuries or stress suffered during capture or handling;
- 'predation mortality': fish that are caught in the gear but are subsequently removed, eaten or lost due to the activity of predators (e.g. seals, gulls, crabs); and
- 'other mortality': fish not appearing as recorded catch (e.g. any unreported or illegal landings).

The level of NCFM is defined as that proportion of the total fishery-induced mortality which is not recorded, for one or more of the above reasons. Thus, an NCFM of 0.09 means that for every 100 fish reported as landed, a further 10 are killed by fishing, but not recorded (10/110 = 0.09). The importance of the various forms of NCFM depends on a number of factors. For example, the level of predation mortality will largely depend on the fishing location and the disposition of the nets, whilst 'haul-back mortality' will be strongly influenced by the fishermen's method of operation; 'drop-out mortality' by the construction of gear; 'escapement mortality' by the size range of the exploited population and the mesh sizes used; and 'discard mortality' by the mix of species in the fishing area and the length of time that a fixed net is left to fish.

NCFM may constitute a significant part of the total fishery-induced mortality for many species and, where fishing effort is high, it could be a critical factor in exploitation rates. However, it has rarely been regarded as a serious problem in gill-net fisheries, except in fisheries for species such as salmon and bass; this is most probably due to the local nature of these fisheries and the relatively high value of individual fish. In the case of the salmon, a particular fishery usually exploits a population for only a single, short period in the life cycle. The success of any one fishery may, therefore, be more than usually limited by the numbers of fish caught or killed by other fisheries operating earlier in the fishes' life cycle.

It is unusual to see evidence of large-scale discarding of fish, except when fish are dumped wholesale at sea (e.g. mackerel from purse seines and trawlers (Anon., 1976)). However, the discarding of even small numbers of unsaleable sea fish by gill netsmen has at times elicited complaints from recreational fishery interests (Anon., 1982b). Although the scale of these discards is not easy to assess, the available data suggest that it is most unlikely that the losses pose any threat to stocks or to catch rates.

It is difficult to measure NCFM. Lost fish are rarely seen and any attempt to recapture or retain fish that have escaped alive will also affect their chance of survival. Potter and Swain (1979) estimated that predation mortality (by seals) in the English north-east coast salmon fishery amounted to about 5%, and observations in this fishery suggest that 'haul-back mortality' is normally less than 1%. 'Escapement mortality', which often causes the most concern, is probably the most difficult to estimate, since it is necessary to determine both the number of fish that free themselves and a mortality rate for the escapees. This is discussed in more detail in the following section.

8. DAMAGE TO FISH ENCOUNTERING GILL NETS

8.1 Damage to landed catch

Fish that are caught by any type of net are likely to suffer some damage, the extent of which will depend upon the method of capture, the species and the subsequent handling of the catch. The types of damage include scale loss, surface bruising, internal haemorrhaging and general softening of the flesh. It is only in the most exceptional circumstances that capture by a net will cause any type of laceration, although open wounds can appear subsequently as a secondary result of skin damage on fish that escape from a net, or are removed and kept alive (Lockwood *et al.,* 1983).

Scale loss and surface bruising result from the abrasive action of the nets when the fish struggles to escape, and tend to be more extensive when fish are entangled than when they are gilled. Gilled fish often suffer relatively little scale loss when they are caught, because the net passes over the scales in the direction in which they lie. However, the action of removing the fish from the net usually results in many more scales being lost. These effects are rarely considered to be problems with gadoids or flatfish, but tend to be more noticeable in species like salmon and bass which have larger scales and a more attractive, silvery appearance. Salmon and bass are also more highly priced and frequently sold whole, so superficial damage is more likely to reduce their value.

Deeper haemorrhaging in the muscle blocks may occur when the fish is very firmly wedged and the mesh 'digs in' like a ligature. Haemorrhaging appears to be more common in salmonids than in other species, probably because of the prolific network of capillaries around the muscles. Skeletal muscle lesions, near the point where the fish is held by the net, have been observed in salmon caught in Canadian gill-net fisheries (Murray *et al.*, 1968) and by the first author of this leaflet in sea trout caught in fixed nets, when the nets have been left unattended for 12 to 24 hours. Such damage seems to be uncommon in fish caught in attended drift nets for the following reasons:

- fish are rarely left in the net for long periods;
- they are unable to apply much force on the net because it tends to give as they struggle; and
- the net tends not to be pulled so tightly around the fish by the action of the tides.

Further problems may arise when nets are left for a long time before being hauled and the fish die in the net; the quality of the flesh will begin to deteriorate, and they may be attacked by crabs. However, deterioration of the catch often results from the careless treatment of the fish after they have been removed from the fishing gear, a problem which applies equally to any fishing operation.

Criticism of a particular fishing gear may be more common when alternative methods are available which are less damaging to the catch. Thus, gill netting for white fish attracts little criticism on these grounds, because the alternative of trawling may cause more bruising. But in the salmon and bass fisheries, gill nets compare unfavourably with traps, seine nets and rod and line, which cause less superficial damage.

8.2 Damage to fish escaping from gill nets

Fish escaping from gill nets can suffer damage similar to that of those retained and landed, but the extent of the damage tends to be slight. Angelsen and Holm (1978) recorded how quickly salmon in a tank escaped from a gill net. Out of 11 fish squeezing through the mesh, 8 did so in less than 5 seconds and all managed to escape in under 25 seconds. Furthermore, no visible damage could be seen on the fish. A similar pattern was noted for larger salmon disentangling themselves from a gill net, with 70% doing so within 10 seconds and 96% within 25 seconds; most of these fish also showed no visible signs of damage. These results are supported by observations made during comparative trials with drift nets on the north-east coast of England. Salmon were deliberately left in the nets with their positions being marked. Only three fish out of more than three hundred caught were seen to escape, and these all did so almost immediately after they first struck the net.

There are several reasons why a fish is unlikely to escape from being wedged in a mesh unless it does so quickly:

- the fish can only struggle strongly for a limited time before becoming exhausted;
- when it struggles, it is likely to become caught in more than one mesh, thus increasing the force that will be required to enable it to squeeze out; and
- once the fish stops struggling, the tension in the netting yarn around its body quickly forms a slight indentation in the skin and a greater force is then required to move the mesh further.

Most fish escaping from gill nets probably suffer only fairly superficial damage. Examination of over 3 000 salmon, which had been caught in drift nets off the north-east coast of England, revealed no signs of serious damage resulting from previous contact with nets. Tagging experiments with fish released from these drift nets, which were usually damaged in the same ways as those in the landed catch, have shown that, on recapture after a few days or weeks, this original damage was clearly identifiable. Thus, if fish were badly damaged on their first encounter with the nets, then they should have been identifiable if they subsequently appeared in the catch. The fact that no fish with signs of serious previous net damage was seen suggests either that the number of fish escaping from the nets was small or that the extent of the damage to escapees was slight. The good recapture rate (> 25%) from these experiments shows that the fishes' chances of survival after release from the nets were very high.

Attempts to examine the effects of damage from gill nets on survival (e.g. Thompson and Hunter, 1971; French and Dunn, 1973) have generally been unsatisfactory, because the fish used in the studies were removed from the nets by hand or escaped through rigidly held netting, and were therefore more badly damaged than normal escapees. In addition, the results were complicated by stress and damage caused by holding fish in netting cages. Where data are available, it can be seen that the eventual mortality of the control fish was also high. Hansen and Roald (1981) tagged both salmon marked by nets and those undamaged as they entered a Norwegian river and found no significant difference in their survival in fresh water.

Damage by nets is also more likely to be observed on salmonids than on marine species. When they enter fresh water, damaged salmon are easily seen, and are particularly obvious if fresh-water fungi like *Saprolegnia* spp. start to grow on areas of damaged skin. However, skin damage commonly occurs on otherwise healthy fish during upstream migration and may also be the result of attacks by predators and intra-specific aggression.

9. THE GILL-NET FISHERIES OF ENGLAND AND WALES

9.1 Fisheries for marine species

Although the traditional large-scale drift-net fisheries for herring and mackerel are now a thing of the past, the use of drifting and fixed nets for the capture of marine species in waters around the coasts of England and Wales has expanded rapidly in the past ten years, having been strongly influenced by the introduction of fine synthetic netting yarns and lower operating costs when compared to trawling. The proportion of the total nominal landings of fish taken by such gear has increased from less than 0.2% in 1973 to 4% in 1982 and 11% in 1989. In 1989, the total landing of demersal fish taken by English and Welsh vessels using enmeshing nets was recorded in official MAFF statistics as being 10 665 t, with a first sale market value of about £14M.

Synthetic gill nets have proved effective in catching a wide range of species, but one of their major advantages has been to enable fishing in areas where trawling is not possible. Many demersal fish tend to aggregate around features such as wrecks, rocky outcrops and shallow sand banks; gill nets can be fished very close to or even right over such features, enabling them to catch fish that are virtually inaccessible to trawls. Although the gear is frequently damaged, the cost of replacement is relatively low. Another advantage of gill nets is that they can be set and left to fish by themselves whilst the boat is being used to set or haul more nets, thus increasing the catching capacity of even small boats quite considerably.

Most commercial species are protected by restrictions on the minimum size that can be landed, and these rules are reinforced in the trawl fisheries by appropriate mesh size regulations. In most sea areas around England and Wales there are similar mesh size regulations for gill nets (Sub-section 10.3), and all salmonid fisheries have such rules (Sub-section 9.3). However, fishermen are generally quick to select the nets that give the best catches and the mesh size chosen is often greater than the legal minimum mesh size. Even so, because of the multispecies nature of many inshore fisheries, there may be considerable mortality of undersized fish which are caught in small-meshed gill nets being used for other species. Figure 11 shows the range of mesh sizes to which the major species are vulnerable and the mesh sizes currently used to catch them.

Although the introduction of monofilament and multifilament nets to traditional gill-net fisheries has undoubtedly increased their fishing power, the recent development of set-net fisheries for hake, cod, spurdog, ling, pollack, monkfish, rays and turbot has, in general, replaced the fishing effort exerted by other methods, or has been applied to previously under-exploited stocks.

Table 1 gives the proportions of total landings of the main fin-fish species, which were taken by enmeshing nets around the English and Welsh coasts, averaged over the years 1985-89. These statistics are those recorded officially by MAFF, and probably underestimate gill-net catches of such species as bass, mullet and sole taken by small boats (which are more likely to use such gear), and of other species landed from mixed-method trips by larger vessels. Catches of crustaceans, such as crawfish, lobsters, and spider and edible crabs, which have increased considerably with the development of bottom set gill- and tangle-net fisheries, are particularly poorly recorded.

Where gill-net catches comprise only a small proportion of the total landings of a species, it should not be assumed that these are merely ‘by-catches’. Most fishermen who use gill nets are specialists, and the annual landings by this method, although seasonal, are often their main source of income. Moreover, it is apparent that for some species (e.g. cod, hake, monkfish, rays, spurdog and turbot) and in some districts, the gill-net catch represents a substantial and increasing part of the fisheries’ yield. However, few fishermen use gill nets all year round; most only choose this type of gear in preference to other catching methods when they expect gill netting to be more profitable, given their own vessel’s limitations. As a consequence, use of the method follows seasonal and sometimes longer-term patterns depending on the availability of resources (including shellfish), market demands or opportunities, and legislation restricting the use both of gill nets and other fishing methods. A significant minority, however, use gill nets throughout the year (for example, fishermen in the Thames estuary, the eastern English Channel and particularly around Cornwall).

9.2 The regional fisheries

The distribution of the various types of fixed-net fishery for marine fish species has been described by

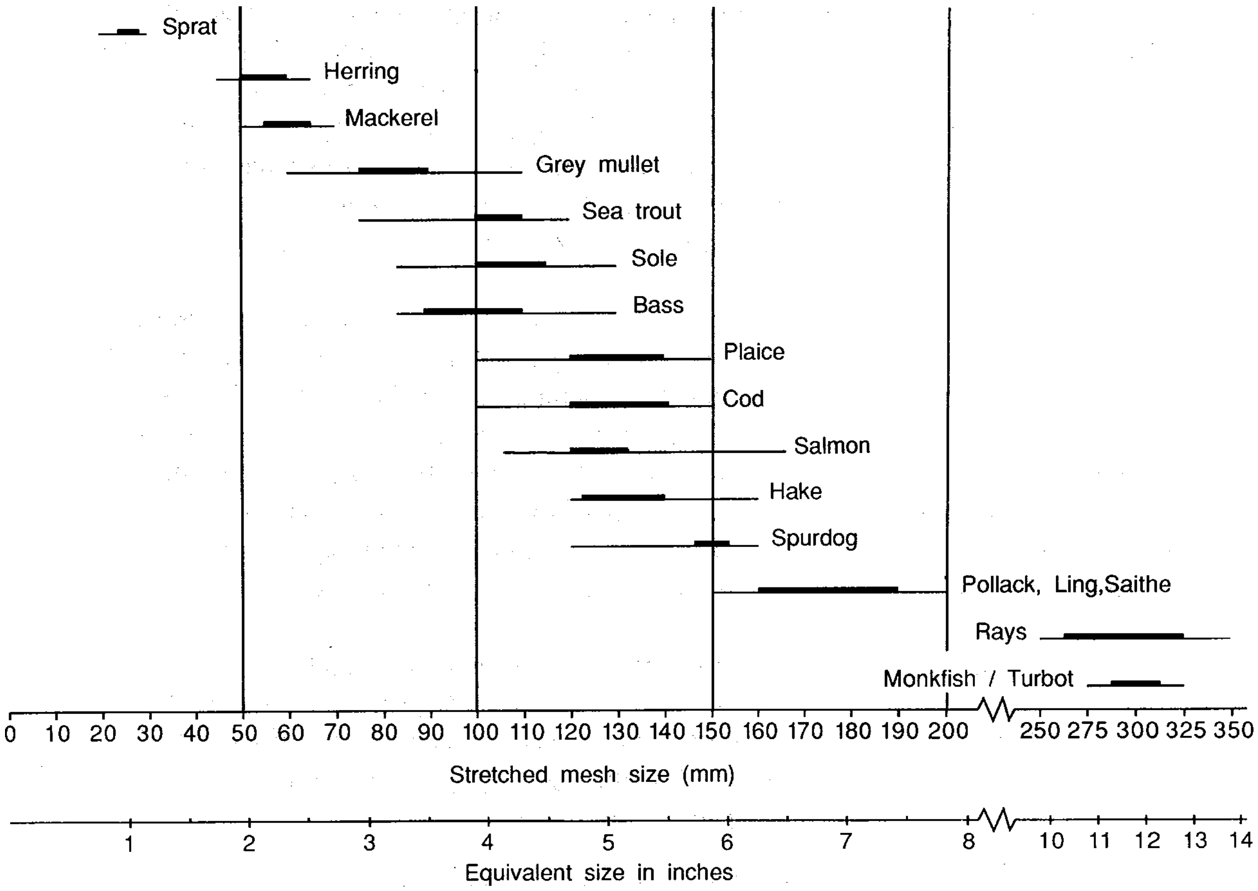


Figure 11. Mesh size ranges used in gill-net fisheries around England and Wales, with the sizes most frequently used to catch species which are particularly targeted indicated in bold

Millner (1985). Figure 12 shows the pattern of all gill-net fisheries as they stood in 1989. In most cases, gill nets are operated with the aim of catching only one or two targeted species. Thus, types of netting, mesh sizes, modes of rigging and the areas and method of fishing are selected with particular species in mind although, of course, any other fish with commercial value that are caught will be landed.

Gill-net fisheries take a small but increasing proportion of the total landings in the north-east of England, and the catch of cod by these nets contributes over 9% of the total nominal landings and is worth around £2M. Both monofilament and multifilament nets are used in this fishery, and the mesh size is usually 130-150 mm for gill nets and around 100 mm for the inner wall of trammel nets. Large-meshed tangle nets are used for turbot (200-300 mm) on rough ground and to take cod and ling (160-190 mm) around wrecks, for which purpose they are specially constructed to minimise damage or losses if the netting becomes snagged on the wreck.

Further south, around East Anglia, the strong tides and abundance of weed make gill netting a less popular fishing method, although small-meshed nets (90 mm) are used, mainly for mullet, in some sheltered areas. A wider variety of fish species are taken in both gill and trammel nets in and around the Thames estuary, including herring, cod and dogfish in the winter and soles, rays, mullet and bass in the summer.

Fixed-net fisheries are widespread along the south coast of England, where large numbers of part-time fishermen use this method. In the eastern English Channel, gill nets account for a substantial part of the total catch of demersal species during the winter (50% of cod) and a large trammel net fishery for sole

Table 1. The mean percentage of total landings (by weight) of the main finfish species taken by enmeshing nets in Sea Fisheries Inspectorate Districts of England and Wales, with an indication of whether this proportion was stable, increasing (+) or declining (-) over the period 1985-89

Species	SFI district							Total for England and Wales
	NE Border-Redcar	Staithes-Immingham	Boston-Leigh-on-Sea	Faversham-West Bay	Seaton-Bristol	Wales	Dee-NW Border	
Bass			71+	36-		24-	61+	**40-**
Brill				22+	5			**4+**
Cod	9+	7	5+	44+	36+		2	**9+**
Conger					18			**14**
Dab				13+				**2+**
Flounder				13		72-	26-	**19-**
Grey mullet			91	58-	62-	50	63-	**70-**
Hake					63+			**48+**
Herring		2	98-	25	7	60		**19+**
Ling	46-	10		3-	66			**53**
Mackerel			70	20-	2-			**2-**
Monkfish	1+	1+		7+	16	2-		**13**
Plaice				18+		1-		**2+**
Pollack	33-	17+		19+	84	1		**77-**
Pout				14+	2			**3**
Saithe	6-	1-			82+	1-		**9**
Salmon	100	100			2	42+	41+	**70**
Sea trout	100	100			2	29+	6	**79**
Skates and rays	1+	7+	6+	18+	15+	10	1-	**10+**
Sole	10+	6+	3	48+				**10+**
Sprat			2	3+			100	**1**
Spurdog		1+	1+	49+	75+		2	**9+**
Turbot	15-	14+		34+	40+	17-	6+	**24+**
Whiting			4+	7+	4+			**1+**
Total	**6+**	**5**	**4+**	**26+**	**16**	**3**	**1**	**9+**

and plaice operates in the spring. Netsmen fishing for sole tend to use mesh sizes around 100 mm, although studies have shown that the catch per day of marketable fish was higher using nets of 119 mm mesh, because less time was spent clearing debris from them (Watson *et al.*, 1979). This fishery has often been curtailed in late spring when spider crabs have moved inshore and become fouled in the gear.

Gill nets accounted for about one-third of the total commercial catch of bass in England and Wales in 1989 (Pickett and Pawson, in press), and a major fishery using monofilament drift and fixed nets has developed in the Solent area since the late 1970s. Mesh sizes of these nets are varied to catch the most abundant size group present, but the majority have been aimed principally at juvenile bass, using mesh sizes within the range 80-90 mm.

About half of the total catch by fixed nets in England and Wales is taken in the south west, and the fisheries in this area are the most diverse. Netting around wrecks is widespread in the area, with 127-152 mm monofilament and multifilament gill nets being used mainly to catch cod, pollack and ling. Anchored trammel nets are also used to take these species, along with rays, plaice and sole. More specialised fisheries have developed in some parts of the region, like those for hake and spurdogs, which mainly use 140-152 mm fixed monofilament or monoply gill nets. Large-meshed tangle nets (203-457 mm), traditionally used to catch crawfish, are now being used for turbot, rays and monkfish and also take lobsters and considerable numbers of edible crabs and spider crabs. Closer inshore and around the estuaries, fixed and drift nets, down to 64 mm mesh, have been used to catch small bass along with the grey mullets.

There is much less gill netting for marine species by full-time fishermen along the west and north-west coasts, although fixed nets are used by part-timers fishing mainly for flounder, mullet, rays, bass and codling. Many of these nets are set in the intertidal zone and emptied and cleaned at low water.

9.3 Fisheries for migratory salmonids

Salmon and sea trout are taken in various types of nets and traps operated along their migration routes, usually close to the shore and in estuaries. All commercial fisheries for migratory salmonids in England and Wales must operate under licences issued by the National Rivers Authority (NRA) and, in most cases, the number of licences is strictly limited by ‘net limitation orders’ under the Salmon and Freshwater Fisheries Act 1975 (Great Britain – Parliament, 1975). In many instances, the same or similar fishing methods have been used for at least a hundred years. The design of the nets and their mode of operation may be specific to particular regions or even to individual rivers and are laid down by the Act and NRA byelaws.

Some 42% of the licences issued for the capture of migratory salmonids by commercial methods in different parts of England and Wales in 1988 were for the use of some type of drifting gill nets; these are variously known as drift, hang, coracle, tuck, wade and whammel nets. In the Northumbrian region, some netsmen may use drift nets or ‘T’ nets, and a further 4% of licences apply only to the use of static ‘T or J’ nets in the NRA Yorkshire region. Most of the remainder (23%) were issued for the use of seine nets which, although not designed to enmesh fish, may capture smaller individuals in this way.

Drifting gill nets, used to catch salmon, generally have a mesh size of 120-130 mm, which is believed to be the optimal size to catch grilse (i.e. fish which have spent only one winter in the sea). However, on the River Ribble in the north west, the minimum mesh size permitted is 164 mm; this largely restricts the catch to ‘multi-sea-winter’ fish. Where sea trout is the main species targeted, mesh sizes tend to be closer to the national minimum mesh size of 102 mm for salmonid fisheries. Mesh sizes in the East Anglian sea trout fishery have tended to be dictated by the need to catch other species, and there have been derogations for mesh sizes to be used below 102 mm for this purpose. In the 1950s, 60 mm nets were operated along the Norfolk coast primarily to catch mackerel and herring but, more recently, the fishing effort has been aimed at bass and mullet, and nets of around 100 mm mesh have been used. As a result, there has been a substantial increase in the average size of sea trout caught.

Much of the fixed-net fishing for marine species is carried out in deep water well offshore, where few migratory salmonids are available to be caught. However, at certain times of the year, salmon and sea trout are particularly vulnerable to gill nets set close to the shoreline and in or near estuaries to catch bass, mullet or flounder. In such areas, by-catches of salmon and sea trout can often be reduced by restricting netting to certain times of the year or by setting nets parallel to the shoreline or in deeper

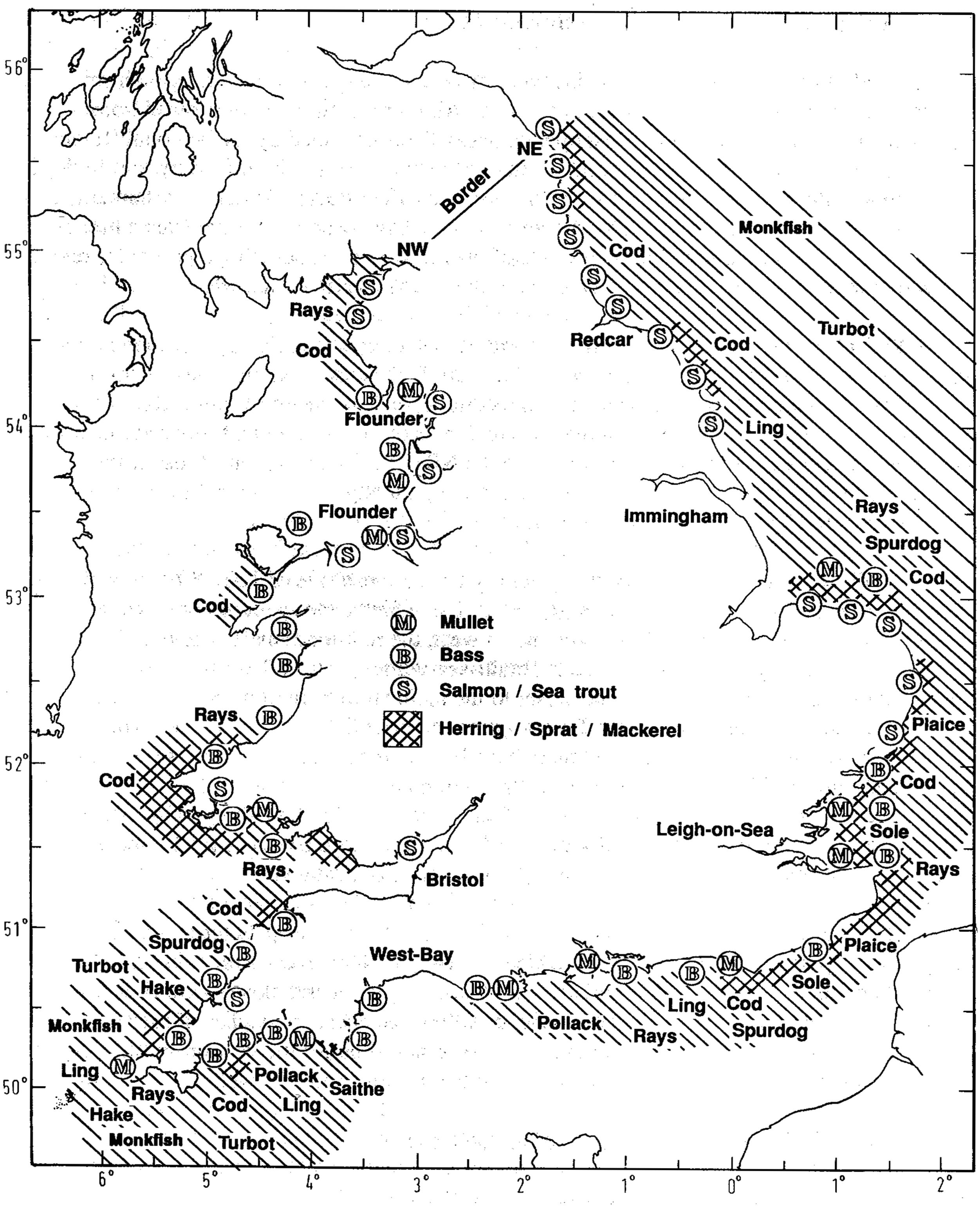


Figure 12. The distribution of English and Welsh gill-net fisheries in 1989, showing the regions used in Table 1

water where the headline remains well below the surface.

10. MANAGEMENT CONSIDERATIONS

10.1 Conflict in the use of fishing methods

There are three distinct and often conflicting aims for the management of fisheries:

- protection of fish stocks – to maintain a breeding population within 'safe biological limits' which is capable of providing maximal recruitment to the fishery in favour able environmental conditions;
- fisheries economics – to achieve a high and sustainable yield from stock resources, as either quantity or value of landed fish in relation to fishing costs; and
- social considerations – to provide adequate employment and recreational opportunities and to safeguard wildlife and the environment.

In previous sections, some mention has been made of problems that have arisen with the rapid expansion of gill-net fisheries. In general, conflicts between gill netsmen and other commercial and recreational fishermen have occurred in two ways – from competition for fishing areas and competition for a limited resource.

Gill netsmen often choose to operate their gear in areas around wrecks and on rough ground which are unsuitable for trawling and, in these situations, there should be no conflict. However, where the 'target' species occurs only in areas suitable for trawling, or where there are large numbers of netsmen, they may be forced to set their nets on grounds also used by trawlers. As a result, gill nets are frequently towed away, either deliberately or inadvertently, when markers indicating their position go unnoticed. Such difficulties are most easily resolved through local agreements to restrict fixed nets to particular zones, whilst requesting trawlers to operate elsewhere. Unfortunately, the success of these arrangements tends to be reduced when bad weather or the distribution of fish leads to significant differences in fishing opportunity between the designated zones.

Conflicts also arise between gill netters and anglers fishing around wrecks, with both groups trying to operate in relatively small areas where the fish congregate. Moreover, when nets are set on a wreck it becomes difficult for anglers to fish because their hooks become caught in the netting. This conflict may be further fuelled by the hazard that lost hooks present to netsmen retrieving their gear and the competition for a limited local population of fish. It seems unlikely that such problems can be resolved at present without introducing discriminatory restrictions on certain methods in particular areas, which would prejudice the right of all fishermen to compete for access to a common resource.

10.2 Local overfishing

The second major source of conflict arises when the introduction of any new and effective method of fishing increases the exploitation rate on certain stocks in localised areas, leading inevitably to suggestions that some fish populations are being overfished. In the case of fisheries for migratory salmonids, these fears are frequently linked with the claim that gill nets have a low landing efficiency and that, in fixed-net fisheries in general, it is unlikely that salmonids and unwanted by-catches are returned to the sea and survive (Anon., 1982b). It seems, however, that whilst the development of a new gill-net fishery inevitably results in reallocation of catches between fishermen using different methods, there is little evidence of overexploitation of total stocks resulting from the use of gill nets *per se.*

Table 2 gives details of the species taken by gill nets either in directed fisheries or incidentally, and gives an indication of each species' level of exploitation and an estimate of the proportion of the catch which is due to gill netting. It appears that gill netting does not account for more than a small proportion of the catch of most of the stocks which are currently being heavily exploited, other than, possibly, hake. Nevertheless, fisheries which do not appear to be overexploiting the 'target' species might have a substantial impact on the exploitation level of others. The avail-ability and versatility of modern gill nets, which can be used in large quantities from small boats in areas where more traditional gear is either ineffective or cannot be used, has resulted in high levels of fishing effort in some fisheries. Claims of 'local overfishing' are mainly a consequence of decreased catch rates and increased competition for fishing space and markets, and do not necessarily indicate that stocks are endangered. It is possible that overall yields are being sustained, though often at levels below those that are possible with less fishing pressure.

10.3 Regulation

The most important management requirements for English and Welsh gill-net fisheries are as follows:

- to avoid the capture of fish less than the minimum sizes, judged necessary for rational exploitation of the various resource species;
- to monitor, and ultimately control, where necessary, the level of fishing effort on species which are already overfished or which are experiencing increased exploitation; and
- to control fishing effort to a level which is socially acceptable in view of its interaction with other activities.

At present, the only gill-net fisheries around England and Wales in which the number of nets used is controlled are those for migratory salmonids, although the manner of placement and dimensions of nets used for sea fish are specified in some areas under local byelaws (e.g. in South Wales). Salmon and sea trout, however, are especially vulnerable in estuaries and around river mouths. Although these species should not be landed by people using unlicensed nets, these circumstances provide ideal opportunities for illegal catches to be made while ostensibly fishing, quite legally, for other species. With the inception of the Salmon Act 1986 (Great Britain – Parliament, 1986), the setting of gill nets inside the English and Welsh 6-mile limit is effectively prohibited, though byelaws authorising the use of fixed nets in certain areas have been introduced by the appropriate regulating authority (Sea Fisheries Committee (SFC) or the NRA). Fixed nets will not be permitted in the estuaries of those rivers which have runs of migratory salmonids and which do not contain populations of marine species which would by themselves support viable gill-net fisheries. Under the same Act, legislation is also available to control the use of drift nets, which would otherwise be used to replace banned fixed nets in many localities. The overall effect will be a considerable constraint on the use of gill nets in inshore waters, and especially estuaries, around England and Wales. However, it should be said that NRA and SFC byelaws are normally introduced with due concern for the practical management and needs of local fisheries; this balance might be difficult to achieve if regulations were introduced on a national basis.

In 1986, a national minimum mesh size of 100 mm, designed to minimise catches in gill nets of bass under 38 cm, was proposed for the protection of juvenile bass. The major drawback with such a regulation was its likely impact on fisheries for other species. For example, some gill-net fisheries for mullet (particularly golden-grey mullet, which are more slender fish and grow more slowly than the other grey mullets) would require derogation to allow nets with meshes under 100 mm to be used. Similarly, for species such as mackerel, herring and sprat, mesh sizes below 65 mm would be needed. It has been possible to specify these and other relevant fisheries by season, geographical area and gear type so that arrangements can be made for them to continue to operate with appropriate mesh sizes, in areas where gill-netting would otherwise be unduly restricted with a 100 mm minimum mesh size.

For a mesh size regulation to be effective, it is necessary to ensure, as far as possible, that all vessels fishing in, or travelling through, a particular fishery area are subject to the same regulation. The bass fishery extends throughout coastal waters around England and Wales, from East Anglia in the east to

Table 2. Species taken in the main gill-net fisheries and level of exploitation in England and Wales

'By-catch' species	Directed gill-net fisheries													Overall level of exploitation **	% catch of each species due to gill nets (1985-89 mean)
	Salmon	Sea-trout	Bass	Grey mullet	Sole Plaice	Cod	Skates and Rays	Spurdog	Herring Mackerel	Sprat	Pollack Saithe Ling	Hake	Monkfish Turbot		
Salmon		x	x	x										3	70
Seatrout	x		x	x	x				x					2	79
Bass	x	x		x	x	x		x	x		x			3	40
Grey mullet	x	x	x						x	x				3	70
Sole			x	x		x						x		3	10
Plaice			x	x								x		3	2
Flounder				x	x									2	19
Cod					x		x				x	x	x	4	9
Whiting					x	x			x					3	1
Pout					x	x								3	1
Skates and Rays						x			x			x	x	x	4 10
Spurdog			x			x	x				x	x	x	3	9
Herring										x				3	19
Sprat									x					3	1
Mackerel			x	x						x				3	2
Pollack						x	x	x				x		2	77
Saithe						x		x	x			x		3	9
Ling						x	x					x		2	53
Hake								x			x			4	48
Conger					x	x	x				x			3	14
Dab					x									2	2
Monkfish						x	x							4	13
Turbot						x	x							4	24
Brill						x	x						x	3	4

**KEY Level of exploitation:

1. Lightly exploited;
2. Under-exploited;
3. Around optimal exploitation rate;
4. Heavily exploited.

Cumbria in the north west. In order to protect juvenile fish, a prohibited mesh size range of 65-89 mm has been introduced for all enmeshing nets used in fisheries to the south of Donna Nook (Lincolnshire) and Haverigg Point (Cumbria), with the exception of beach seines and drift and ring nets fished within the 3-mile zone between Beachy Head and Rame Head (Plymouth) (Great Britain – Parliament, 1989).

11. EFFECTS OF DISCARDED NETS ON THE ENVIRONMENT

An important property of synthetic netting materials is their resistance to rotting, and this had led to fears that lost or discarded netting will continue to fish almost indefinitely. It is unusual for drift nets (which have to be attended at all times) to be lost in fisheries in England and Wales, but there may be rare occasions when fishermen have to abandon their gear. Loss of nets may be more likely to occur when very long fleets are used in the open ocean as, for example, in the West Greenland and Pacific salmon fisheries.

Fixed gill nets may be lost more frequently; markers may become detached in rough weather and nets are sometimes towed away by trawlers, or sections of netting may be caught on rough ground or wreckage. May (1976) retrieved nets lost in deep water (300-350 m) off Newfoundland and found that some had continued to fish over a long period. It appeared that the presence of crabs was the main cause of nets becoming tangled and collapsing and, where they were present only in small numbers, the nets could continue to catch fish at a low level for up to two years. Millner (1985), however, found that a fixed net that became detached from one anchor quickly became entangled around the remaining anchor. In studies off the Devon coast (Anon., 1982(c)), divers made regular observations of experimental nets that had been 'abandoned' in sheltered shallow water (< 15 m). These nets quickly built up a covering of algae and, as a result, fished at only a low level of efficiency until the accumulation of fish and crabs resulted in them collapsing to the sea bed. Multifilament nets tended to remain tangled, while monofilament nets sometimes shook themselves clear of the debris and then were able to go through the process again. Even after they had collapsed, nets continued to catch crabs and lobsters.

The waters around the British Isles, however, usually have strong tidal currents, floating weed and other debris and an abundance of crabs. As a result, lost netting rapidly becomes tangled and clogged and probably presents little threat to populations of fish, marine mammals or sea birds. In addition, the potential dangers of lost gill nets must be viewed in the context of the large quantities of other synthetic materials, including ropes, fishing lines, trawl netting and industrial domestic waste that are found in the sea. Since 31 December 1988, all disposal of plastics (which includes, but is not limited to, synthetic fishing gear) at sea has been prohibited in the territorial waters of the UK (Great Britain – Parliament, 1988).

Marine mammals and sea birds are occasionally accidentally caught and drowned in gill nets during the course of normal fishing operations around the UK. Although these mortalities are thought unlikely to present a serious threat to any one species as a whole, there is concern for the impact which this might be having on some local populations, and attempts are being made to assess the frequency and extent of such incidents around the coasts of the British Isles (Robbins, 1991).

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