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DIRECTORATE OF FISHERIES RESEARCH

THE SCIENTIFIC ESSENTIALS OF FISHERIES MANAGEMENT AND REGULATIONS

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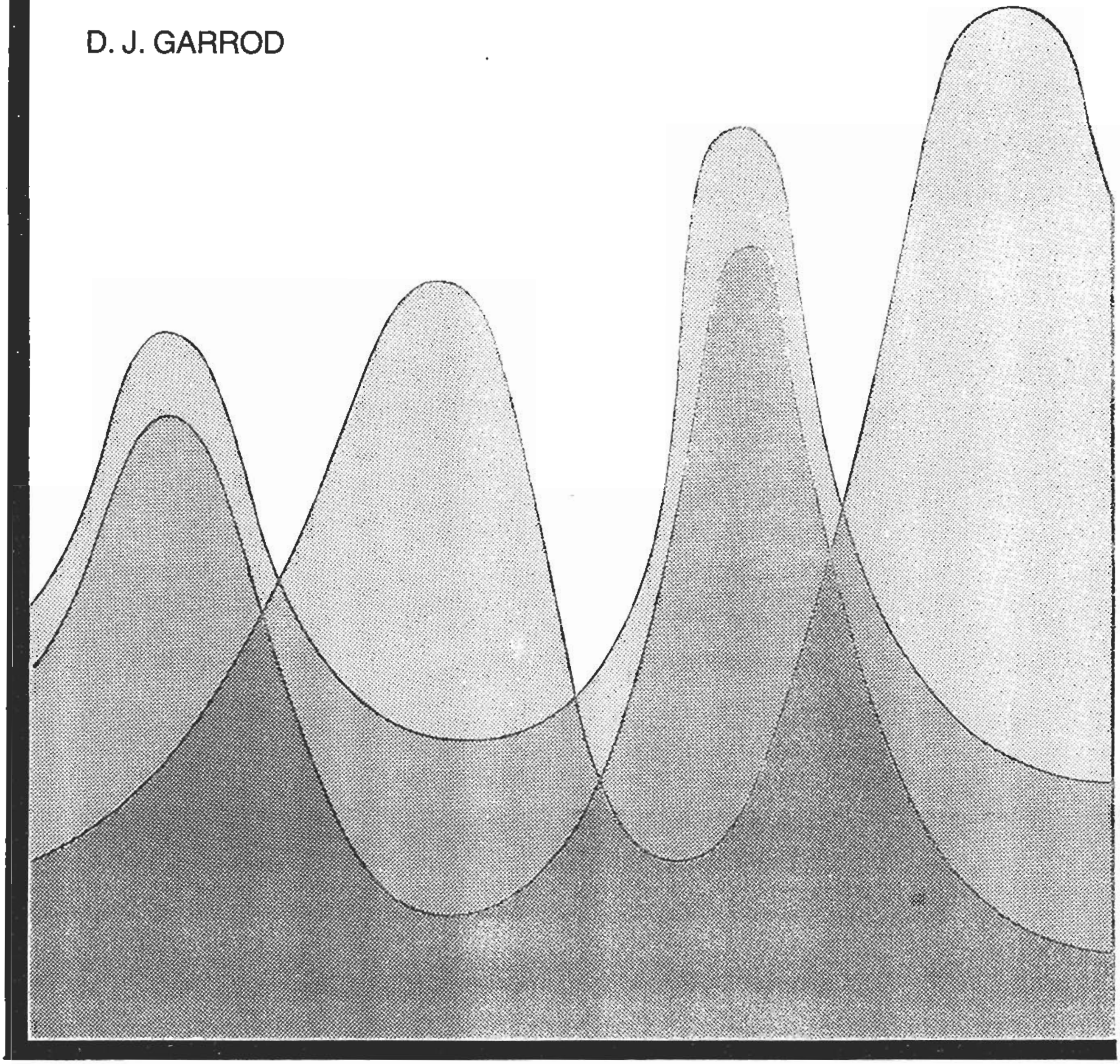

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by D. J. Garrod

1. STOCK DISTRIBUTION

All fish undergo some seasonal movements in relation to water conditions, or, for example, when migrating to and from spawning grounds. A few individual fish may 'take-off' over very long distances but the majority, especially demersal fish, do not move far (over tens rather than hundreds of miles). As a result, they become associated with particular areas which can be grouped to identify self-contained stocks. Pelagic fish, especially mackerel, tend to move further, with seasonal movements following water temperature changes, but even they can be associated with the particular divisions of the north-west European shelf waters shown in Figure 1. The continued existence of each of these stock units depends on the number of fish caught being replaced by young fish bred into the same area and stock unit.

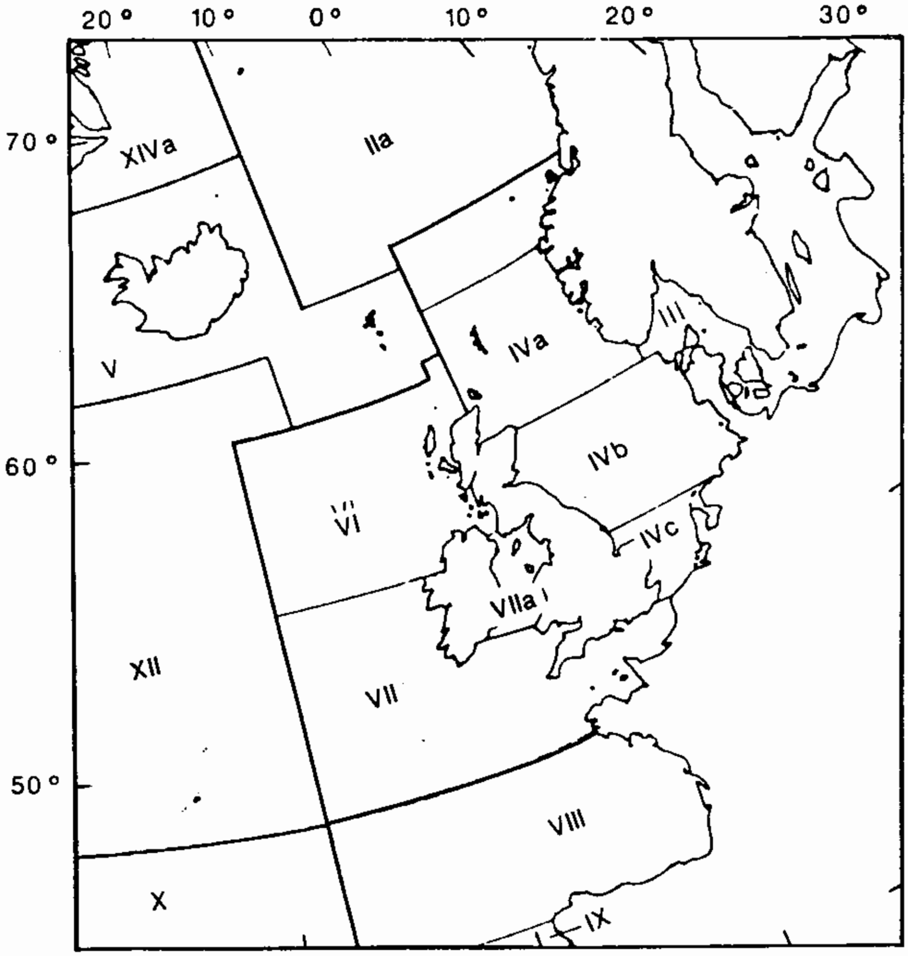

Figure 1 International Council for the Exploration of the Sea (ICES) statistical divisions for the north-east Atlantic as used by fisheries management authorities.

2. AIMS OF MANAGEMENT

At the broadest, international, level the aims of fisheries management include maintaining the overall stability of the 'Industry' with agreed shares for each of the participating countries. At the more practical level which seeks to relate the catching industry to its raw material (the fish), the aim is to maintain a catch as large as possible from each stock at a catch rate which is profitable to the fishermen.

The catch rate (that is the number of tonnes of fish caught per hour or per day) determines the balance between costs and earnings and itself depends on the abundance of the stock. Thus, because the abundance of the stock goes down as the level of fishing goes up there is a balance that has to be struck. History shows that left to its own devices a fishery will expand and catch rates decline until there is no profit margin left. This forces the 'Industry' either to contract, or to seek financial support from its Government. In many cases, this is accelerated by a fall in catches and if fishing is maintained at too high a level the stock may suffer the severe collapse already seen in the herring fisheries in the 1970s. The aim is to manage the stocks at a level which maintains both the catches and a profitable catch rate, based on the biological potential of the resources concerned.

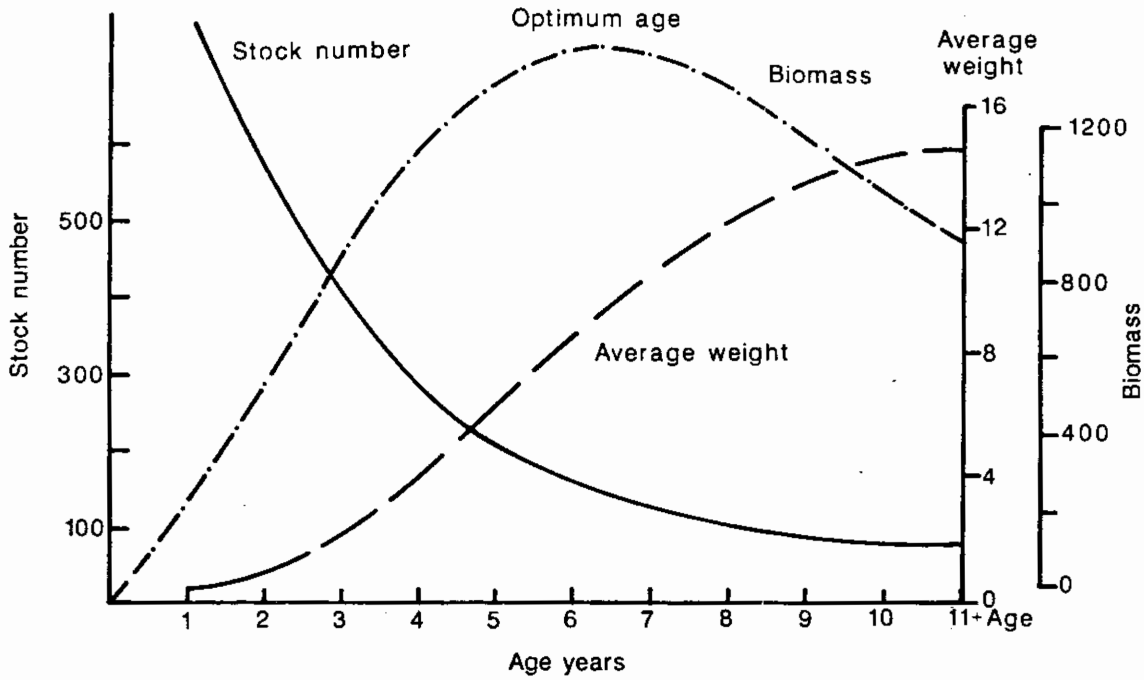

Figure 2 The relationship between the growth in weight of individual fish of a stock and the change in number and weight of a year class as it grows older.

3. BIOLOGICAL BACKGROUND FOR MANAGEMENT

Each stock is made up of year classes (the young of each annual spawning). As each year class gets older the numbers of fish are reduced by death from natural causes and from fishing, but the survivors get bigger. Details differ between stocks but the total weight (biomass) of a year class has a characteristic maximum at some optimum age (Figure 2).

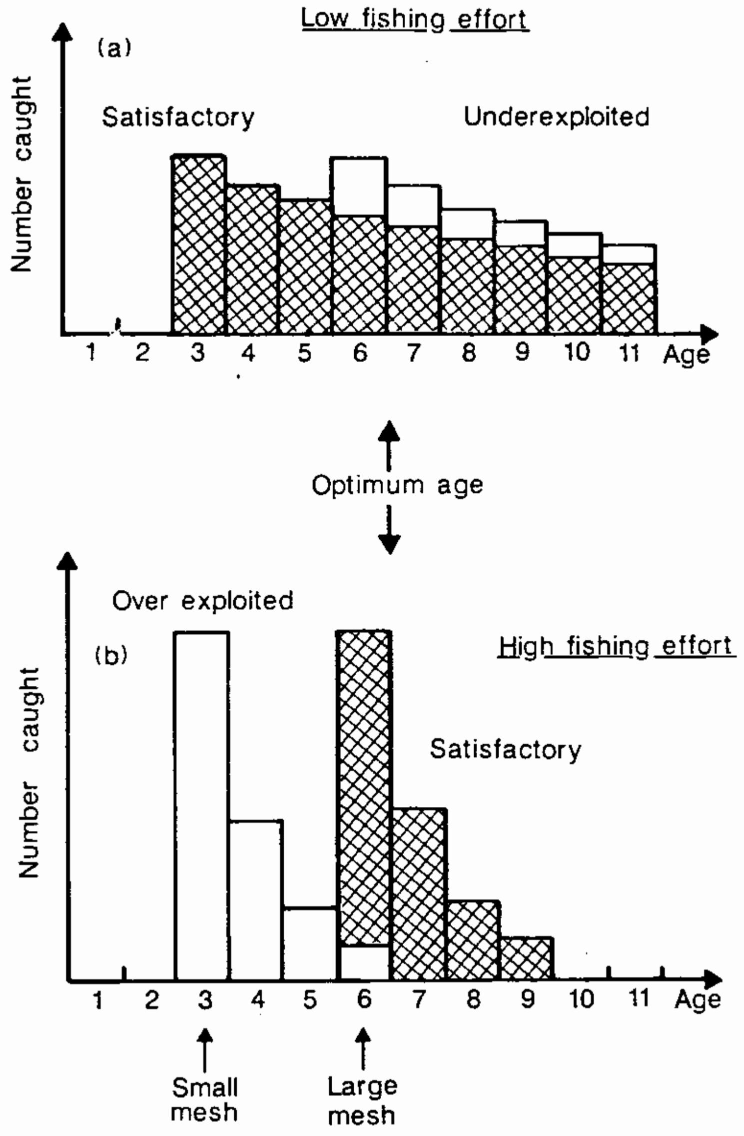

Figure 3 Examples of the age composition of a stock under different combinations of fishing rate and age at first capture, as determined by mesh size: (a) with low fishing effort; (b) with high fishing effort. Cross hatching identifies the more satisfactory exploitation pattern for the given level of exploitation.

The maximum catch would be achieved by catching all fish of a year class at the optimum age. But it is not possible to catch every fish, and because year classes mix together fishing gears catch more than one age group of a stock. The nearest equivalent to catching all of the fish in one age group is to manipulate the fishing to keep the average age at which fish are captured near to the optimum age. This can be achieved by balancing the age at which fish are caught against the percentage caught each year (Figure 3).

When fishing effort is low (Figure 3a) fish survive in the fishery for several years and the average age of capture can be close to the optimum (i.e. satisfactory) even if the age at first capture is low. If the age at first capture is too high the average age of fish caught is too high, fish are wasted and the stock is underexploited.

With high fishing effort (Figure 3b) the fish are removed very soon after they arrive in the fishery. If they are caught when they are small very few reach the optimum age and fish are wasted. Satisfactory exploitation requires capture to be delayed until the fish have grown to a reasonable size.

In a well-managed fishery the age or length at which fish start being caught is matched to the level of fishing (fishing mortality), so they advance together towards the optimum giving the maximum sustainable yield (MSY) per young fish (recruits) entering the fishery (MSYR) (Figure 4).

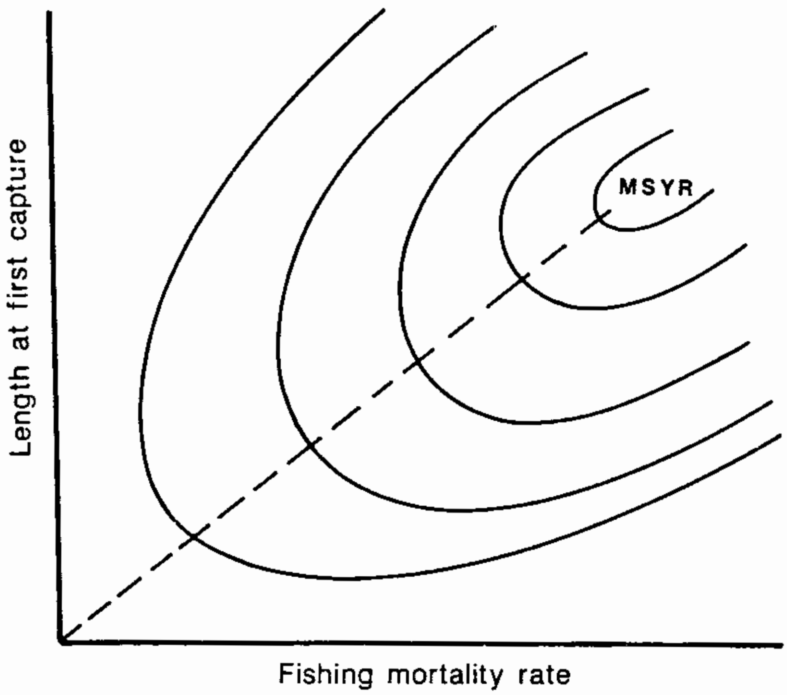

Figure 4 A more general theoretical relationship between length at first capture and fishing mortality rate. Each line represents a constant catch level and the levels increase towards maximum sustainable yield per recruit (MSYR).

4. TOOLS OF MANAGEMENT

There are two main tools used to manage fisheries at the international level. These are total allowable catches (TACs), which limit the amount of fishing (i.e. the percentage of the stock caught each year) and technical measures (closed areas and seasons, mesh size, minimum size of fish), which influence the type of fishing and 'tune' the age and size of fish caught. At the national level, in the UK at least, these are augmented by additional catch controls to ensure a fair share-out of catch within the national fleet, and vessel licensing to provide control of fishing capacity where this is necessary. The fishing capacity problem is also being tackled within the EC by the Multi-Annual Guidance Programme and structural aspects of the Common Fisheries Policy.

4.1 TACs

TACs are being applied to a large number of stocks as a basis for negotiating shares of the resources between countries and to achieve a given percentage harvest of the stock each year. They are based on an annual analysis of the size of each stock, to determine the numbers left from the previous years' fishing and the numbers of new fish just growing to a catchable size.

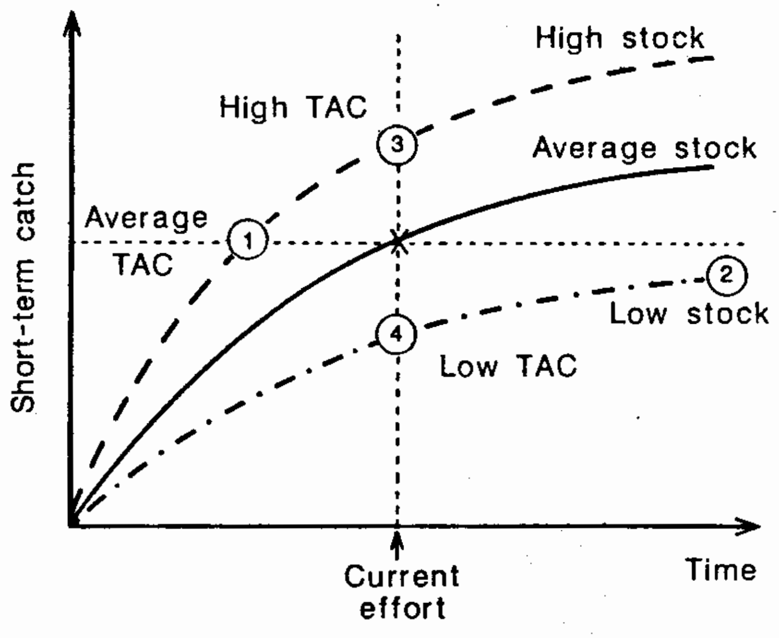

Figure 5 Representation of the effect of variations in stock size (year classes) on the TAC and length of fishing season: if TACs were based on an average catch level and kept constant from year to year, in years of high stock the TAC would be reached and the fishery closed early (1); in years of low stock the TAC might not be reached at all (2); if TACs are set to take a constant percentage of the stock and keep the fleet fishing the whole year, then in years when the stock is high the TAC must be increased (3); and *vice versa* (4).

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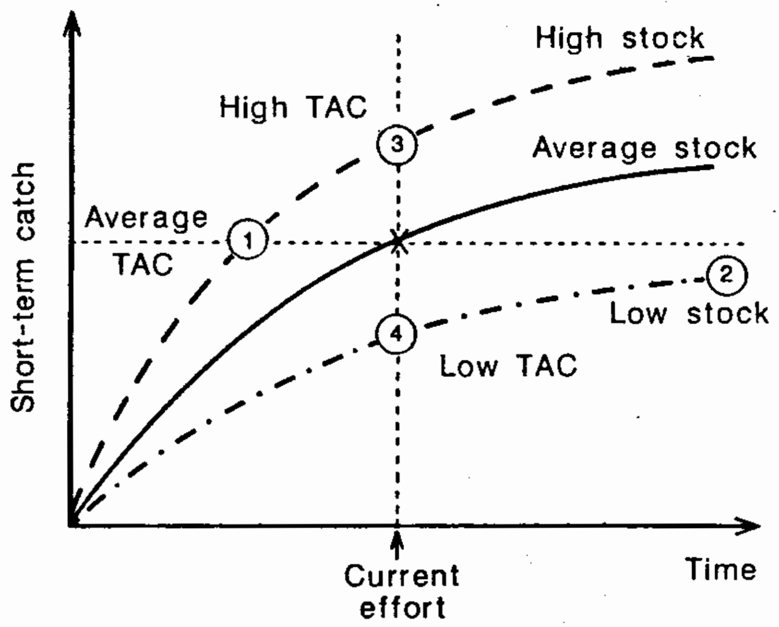

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The immediate environment and longer-term changes in the climate both affect the numbers of new, young fish (year classes) so there is a natural variation in stock size as well as from changes caused by fishing. If the stock size changes then so do the catch rates. So, if the level of fishing is managed to take the same percentage of the stock catch each year then the catch will vary from year to year as the stock size changes. Fishermen, fish processors and the market would prefer a constant TAC, but even if that approach were adopted the stock and catch rates would still vary. In years of high stock the fishery would have to be closed early (Figure 5), and, conversely, in years of low stock there would have to be a rapid and expensive injection of extra fishing effort or the TAC would not be reached. Constant TACs would have the added risk of causing severe damage if they were set too high for any length of time, and if the TAC were set on the low side to avoid that risk, then the managers would be wasting fish and potential earnings. Negotiated TACs generally place more emphasis on a fixed percentage harvest to maintain fleet utilisation levels whilst at the same time reducing, as far as possible, the year to year fluctuation in catch.

4.2 Technical measures: closed areas and seasons

The use of technical measures depends on the type of fishery. The options are closed areas and seasons, the control of mesh size (or some other characteristic of the fishing gear) and the minimum size of the fish.

The usefulness of closed areas and seasons depends on the nature of the problem. They can be especially helpful in preventing a fishery from concentrating on a particular age or size class which needs to be protected. These may be very small fish on a nursery ground, or fish congregating to spawn which would be disrupted and dispersed by intensive fishing activity. Closed areas and seasons are less helpful if the problem is control of the overall level of exploitation, because instead of reducing fishing they invariably lead to its diversion to another area where the problem will be perpetuated. Certainly, it is true that whatever their value the specific fishing grounds are often difficult to define, because fish distributions (including herring spawning grounds) move a little from year to year, and they are especially difficult (expensive) to enforce.

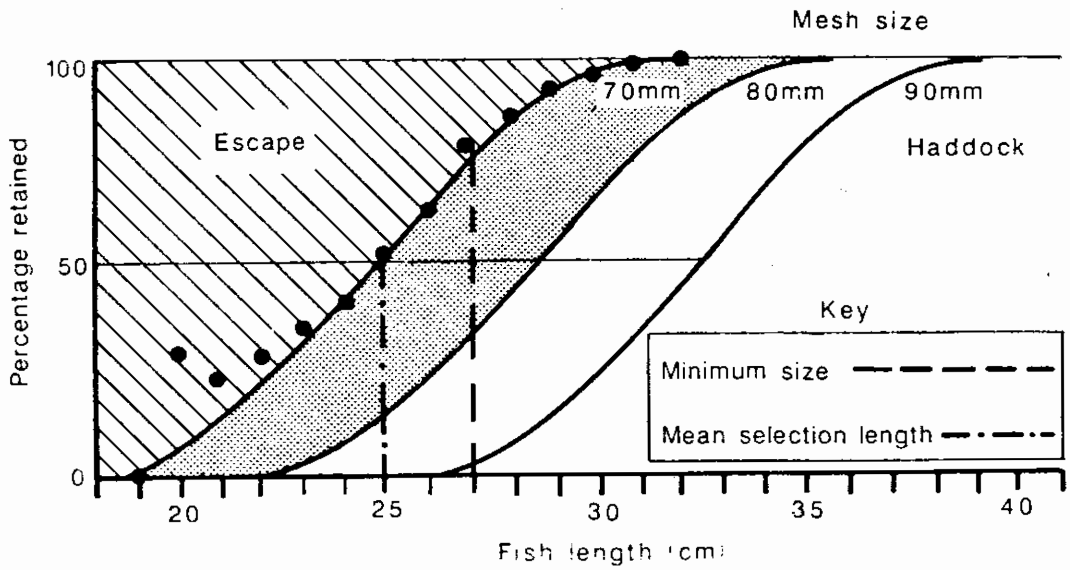

Figure 6 Mesh selection for North Sea haddock for three different mesh sizes.

4.3 Technical measures: mesh regulation and minimum size

4.3.1 Rationale for mesh regulation

Mesh regulation depends on the 'mechanical' selection of different sizes, and therefore ages, of fish by the gear being used. A small-meshed purse-seine catches virtually everything that it encloses and is unselective. At the other extreme, drift-nets catch only the fish which are just the right size to get stuck in the meshes, so individual drift-nets are highly selective. Long-lines have selectivities determined by the size of hook. For trawls and seines, it is possible to relate the selectivities of different fish species to different mesh sizes.

Figure 6 shows the selectivity of haddock using a 70mm cod-end mesh. Each dot represents the percentage of the length group retained in the cod-end. A 'selection curve' is drawn through these points. The areas above the 70mm cod-end mesh curve describe the numbers of fish which escape through the cod-end; those below are caught and retained. The size of fish at which half are retained and half are released is called the 'mean selection length' (in this case 25cm). The stippled area between the curves for the 70 and 80mm mesh sizes represents additional numbers of small fish, released by the 80mm mesh compared to the 70mm mesh, which would be available to be captured later at a larger size.

The minimum size (MS) is related to the mean selection length but, inevitably, some fish which are smaller than the MS are caught and must therefore be discarded (usually dead). The mesh size regulates the size and therefore the age at which fish start being caught. This age is related to the level of fishing. In general, as fishing increases the mesh size needs to be increased.

4.3.2 Application of mesh regulations

Mesh regulation can be applied to many types of net but for some species it is either unnecessary or it does not work. For example, sandeels or Norway pout, used for industrial purposes, are by their nature small fish and the stocks do not benefit by careful manipulation of the age at first capture. On the other hand, shoaling pelagic species (e.g. herring and mackerel) are caught in such large quantities that they blind the meshes of either trawls or purse seines, so even though it might be useful, selection is not very effective. In these instances, even though a mesh size may be prescribed, more reliance is placed on the broad protection of a minimum size limit to prevent deliberate fishing on the juveniles of a species.

The minimum mesh sizes applicable in different areas are listed in EC Regulation of Technical Measures, Annex I (EC, 1986); the minimum sizes of protected species and other regulated fish and shellfish are at Annexes II and III (EC, 1986). Where both minimum mesh and minimum sizes are used it is usually advised that the minimum size be set near to the 25% retention length on the mesh selection curve to minimise waste through discarding, but the guidelines are not always followed exactly when reaching an international agreement.

Minimum sizes are there to support the mesh size and are not necessarily closely related to the maturity of the fish. Without the minimum size there would be continual pressure to reduce mesh size because, in the short term, there are always relatively more small fish available for capture with a smaller mesh.

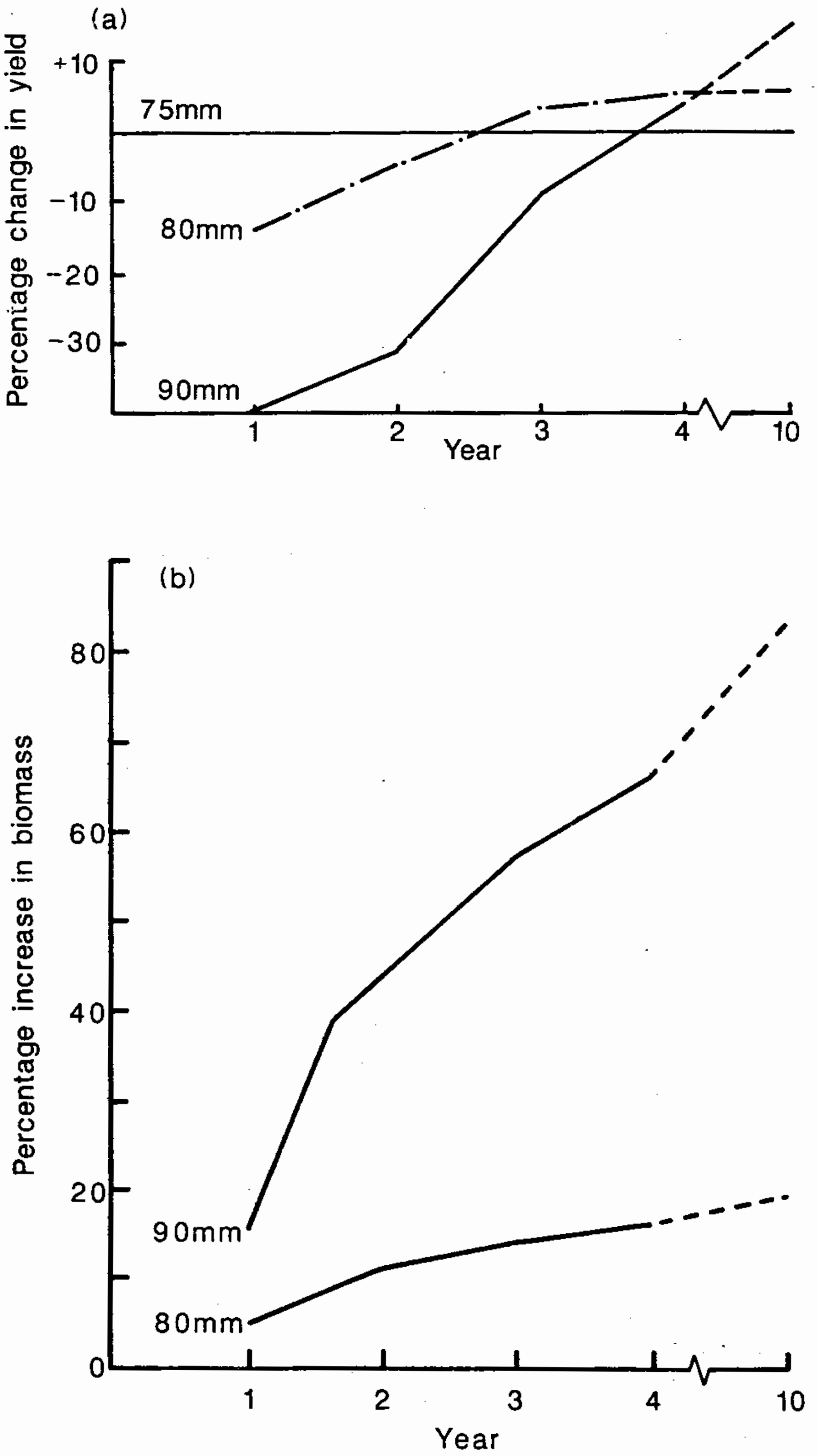

Figure 7 North Sea sole: (a) Percentage change in yield with time following changes in mesh size from 75 to 80 or 90mm; (b) Percentage change in weight of stock (biomass) following changes in mesh size from 75 to 80 or 90mm.

Depending on market characteristics, fishermen find a strong incentive to try to catch more small fish, if only to increase their scope for selection of better sized fish. This can lead either to the smaller mesh or various attachments to nets to reduce the effective mesh size. A range of permissible devices is described in the EC Regulation (EC, 1986).

4.3.3 Gains and losses of mesh regulation

Increase of the mesh size has both short- and long-term effects. In the short term, there is always some reduction in catches because most of the smallest fish are released, also including a few that might be above the minimum landing size. The effect may be small if the fishermen have been discarding a lot of small fish anyway but it will be large if they have been using undersized nets. The fish that escape from the larger mesh will remain in the fishery and grow to be caught at a larger size (Figure 7a). The delayed capture will also lead to a useful increase in the stock size in the sea, thereby improving the spawning stock and future catch rates (Figure 7b).

In reality, each species requires a different mesh size. Fishermen can direct their fishing to one species or another by choice of ground, time of fishing, rig of gear, etc., but inevitably they will catch a mixture of species at any one time, or even fish for different species at separate times during the same trip. Clearly, it is not practicable to enforce a different mesh size for each component of the mixed fishery, so the mesh size chosen for the regulation has to be a compromise. In some cases (North Sea), there are different short-term losses and long-term gains for different species, which bear more or less heavily on different countries and different fleet sectors within a country, depending on their special interest or area of fishing. It is not possible to provide practicable and separate regulations for each special interest. The mesh size is negotiated as being that which gives the best result for most participants.

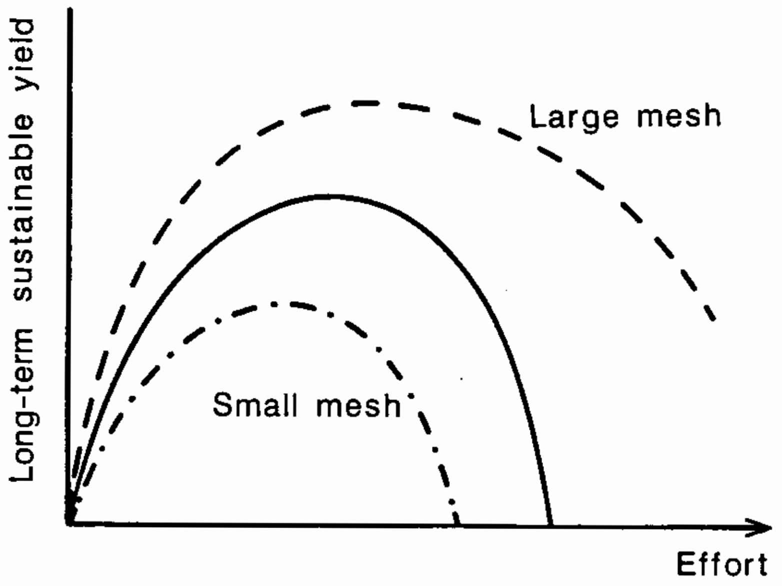

Figure 8 The effect of mesh size on long-term sustainable yield and permissible levels of fishing effort.

In extreme cases, a fishery has to be carried out with a small mesh to catch a particular, small species but it cannot then avoid catching the young of another species which should be fished with a larger mesh, which will affect the potential catches of that other fishery. This happened in the Irish Sea *Nephrops* fishery in the years when a derogation to use 60mm cod-ends led to a heavy bycatch of young cod and whiting (Anon, 1985); it also happens in the Bay of Biscay where another *Nephrops* fishery takes a very heavy bycatch of juvenile hake. But an increase in the mesh size to meet the requirements of the larger species would allow all of the smaller species to escape. Managers, therefore, must decide on the balance of interest between the two fisheries and regulate in the interest of one at the cost of the other. This may be achieved through bycatch regulations which are intended to control the amount of one species that can be caught in a fishery directed towards another.

4.3.4 Long-term effects of mesh regulation

Excessive fishing effort at any mesh size not only reduces potential catches and catch rates (profitability), it may in the long term reduce stock sizes to the point where the stock can no longer reproduce satisfactorily, causing it to collapse. This is much less likely to happen when the age of first exploitation is delayed until after the age at which the fish become sexually mature, by using a large mesh. A large mesh not only offers increased potential yields, but it also reduces the likelihood of stock collapse, and leaves a larger mature stock as a buffer against occasional bad years (Figure 8).

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