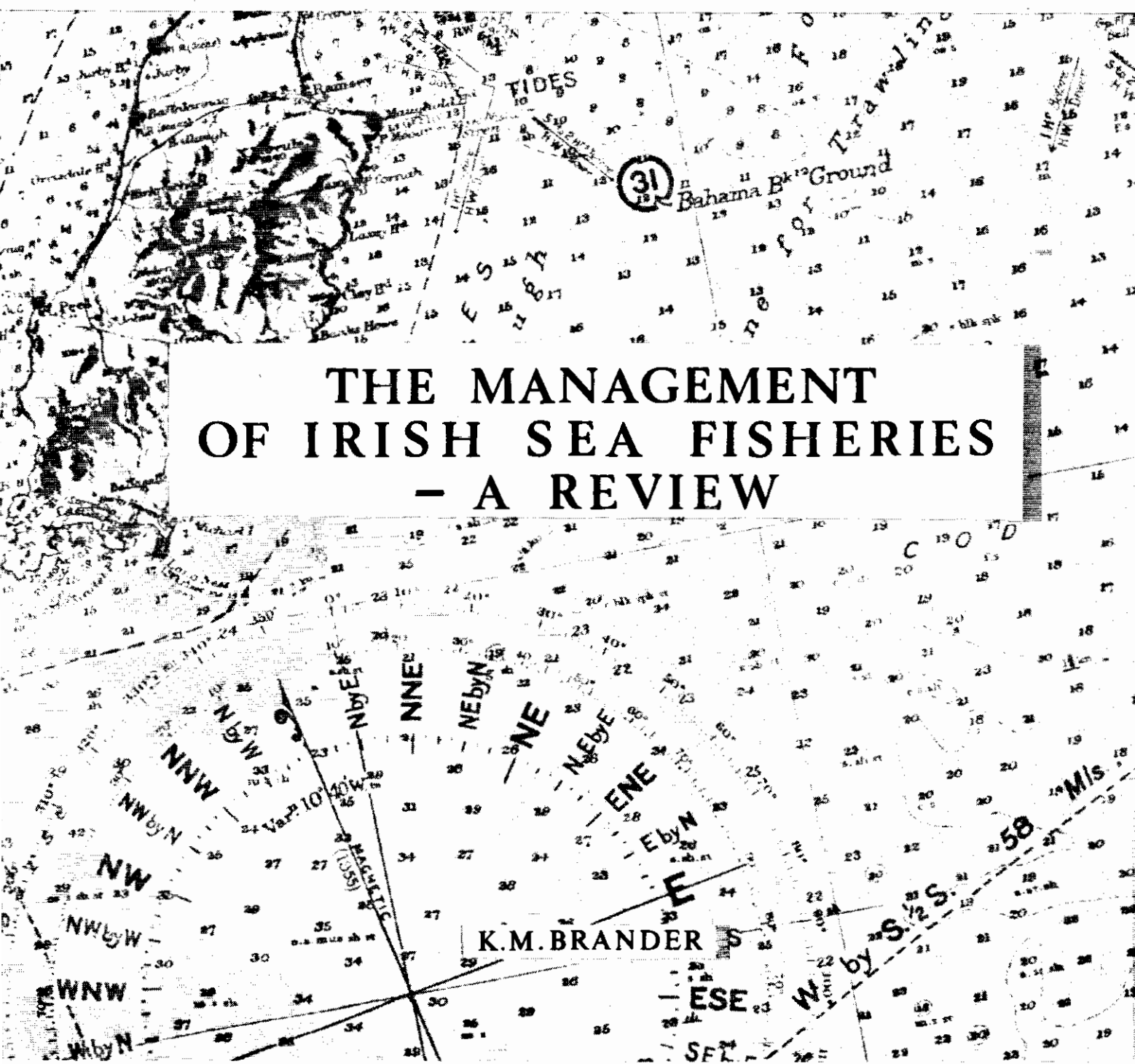


MINISTRY OF AGRICULTURE FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH



THE MANAGEMENT
OF IRISH SEA FISHERIES
- A REVIEW

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THE MANAGEMENT OF IRISH SEA FISHERIES - A REVIEW

by K. M. Brander

INTRODUCTION

The purpose of this paper is to review the population dynamics and biology of the major commercially exploited species in the Irish Sea in order to provide a basis for considering possible management measures. Those involved in the fishing industry will have their own views on what the aims of fisheries management should be. It is hoped that the information contained here will be of use in furthering those views. No attempt is made here to list and consider the various objectives which might be pursued but the need for long-term, strategic planning rather than short-term measures such as annual catch quotas is emphasized.

The present situation is critical because of the recent changes in the concepts of ownership of living marine resources and because throughout much of the North Atlantic there is now more catching capacity than is needed to take the harvest of fish. In this situation early agreement is necessary on what should be the long-term future of the fishing industry in different areas. What kind of industry do we want five or ten years from now? Broadly speaking, the objective of strategic planning should be to adapt the size, composition and activity of the fishing fleets to the resources available in the area. In the case of the Irish Sea we have sufficient knowledge of the stocks to consider such a strategy and to provide guidelines which will allow the industry to maintain a high catch from the area.

The Irish Sea, from St George's Channel in the south to the North Channel, has an area of approximately 45 000 km². It is almost totally enclosed by land and goes down to a maximum depth of over 100 fathoms in the deeper parts of the North Channel. When discussing the fisheries of the Irish Sea it is usually necessary to include the Bristol Channel, because the international statistics of catch and fishing effort have, until recently, been reported for the two areas combined. Figure 1 shows the topography, the place names used and the boundaries of the ICES (International Council for the Exploration of the Sea) statistical Divisions, which will be referred to as VIIa (Irish Sea) and VIIf (Bristol Channel).

In 1973 Division VIIa accounted for 2.7% of the total English and Welsh fish catch and VIIf for 1.7%, and this figure of around 5% of the total catch from the two Divisions combined is typical over a long period. The English and Welsh catch in 1973 represents 16% of the total international catch in both VIIa and VIIf, but when the catches for Scotland, Northern Ireland and the Isle of Man are included the UK share is 45% in VIIa (Table 1). In fact 1973 was an unusual year in that the largest share of the total catch in either area was taken by the USSR and consisted of 31 000 tonnes of mackerel and horse mackerel taken just north of Seven Stones. If this is excluded, the UK proportion of the catch in VIIf rises to 38%, which is more typical of recent years.

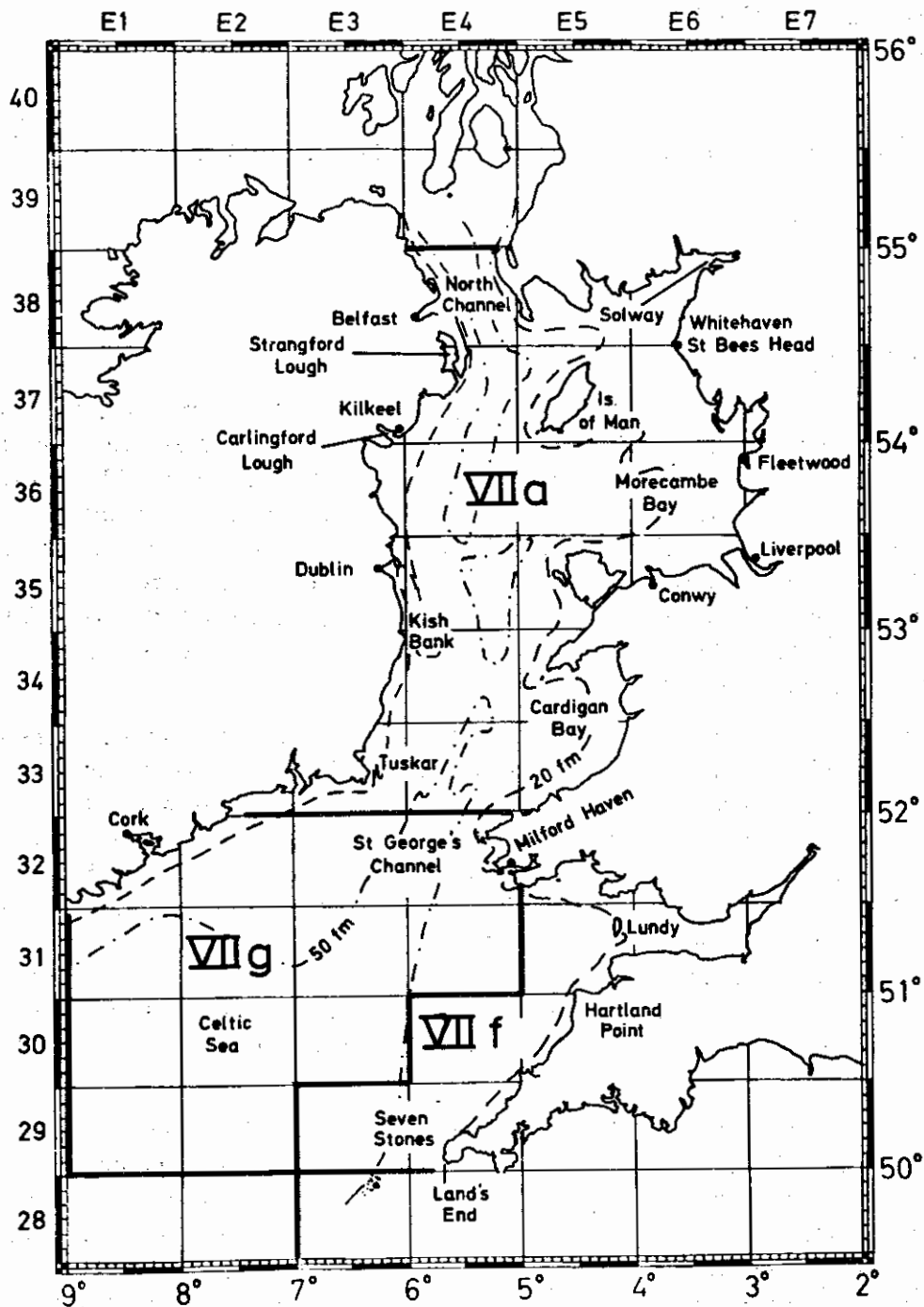


Figure 1 Map of the Irish Sea and Bristol Channel showing topography and ICES statistical areas.

These figures do not include shellfish, which make a major part of the earnings in the area. Within the English and Welsh catch, lobsters represented the single most valuable element in 1973, but *Nephrops* probably accounted for the biggest share of international earnings in VIIa. Table 2 shows the weight and proportion of the more important fish and shellfish species taken in the two areas in 1973. The international area has been divided into zones of 100 miles and consisted of 100 miles of water and land around the UK coast. The proportion of the catch in VII rises to 28% which is more typical of other areas.

Table 1 Total fish catches in tonnes nominal weight and proportions taken by all countries in the Irish Sea (VIIa) and Bristol Channel (VIIb) in 1973

	VIIa		VIIb	
	Weight	Percentage	Weight	Percentage
Belgium	2 198	3	1 909	9
France	12 726	15	11 573	52
Ireland	29 733	35		
Netherlands	748	1	121	1
Norway	995	1	77	+
England + Wales	13 766	16	8 585	38
Isle of Man	10 244	12		
Northern Ireland	11 793	14		
Scotland	2 045	2		
USSR			(31 646)	
Total	84 248		22 265	

Perhaps the most striking feature of these catch statistics is the variety of species going to make up the total catch. There are seasonal fisheries for herring, cod, sole and, in the past, whiting. There are also local fisheries for shrimps, cockles and mussels and occasional fisheries for mackerel and horse mackerel. While most species show a regular annual fluctuation in catch there are also longer-term trends brought about by changes in abundance and in the market price. The increases in landings of Nephrops and, more recently, of queen scallops seem to be due mainly to marketing factors.

The need to regulate fishing activity in the area has been recognized and there are catch quotas on plaice and sole, but because of the very mixed nature of the fisheries in the Irish Sea and Bristol Channel it is unlikely that either catch quotas on only a few of the more important species or an overall annual effort restriction will be effective in regulating the exploitation of all the species involved. The interactions between the different kinds of fishing activity taking place (e.g. the catches of small flatfish and roundfish in the small-mesh shrimp and Nephrops fisheries) mean that no regulation on a single species or group of species can be considered in isolation. There are two ways in which the interaction between species can work: firstly, if the catch or fishing effort on a particular species or fishing area is restricted by regulations, then fishing vessels may switch to other species or areas; secondly, there may be a direct or indirect biological effect on other species, either because a predator is removed or because competition for a scarce resource is reduced. An example of the first kind of effect is the recent increase in purse-seine effort on Cornish mackerel because herring fishing was restricted elsewhere. A possible example of the second is the assertion that one of the reasons for the large increase in demersal catches in the North Sea during the 1960s may have been the decline in pelagic species, which preyed on or competed with the larval stages of the demersal fish (Cole and Holden 1973).

Table 2 Weight (tonnes, nominal) and percentage of main demersal, pelagic and shellfish species taken in the Irish Sea (VIIa) and Bristol Channel (VIII) by all countries in 1973. (From ICES Bulletin Statistique, Table 5)

	VIIa		VIII	
	Weight	Percentage	Weight	Percentage
DEMERSAL SPP.				
Brill	134	+	35	+
Dab	274	1	139	2
Lemon sole	54	+	198	2
Megrim	28	+	210	3
Plaice	5 060	12	543	6
Sole	1 428	3	778	9
Turbot	125	+	57	1
Cod	10 057	23	387	5
Haddock	2 169	5	1 848	22
Hake	1 775	4	756	9
Ling	500	1	126	2
Norway pout	42	+	121	1
Pollack	476	1	34	+
Saithe	1 005	2	41	+
Whiting	9 414	22	301	4
Conger eel	334	1	71	1
Gurnards	735	2	110	1
Monk	966	2	295	4
Sea breams	268	1	2	+
Picked dogfish	1 054	2	5	+
Dogfish + hounds	298	1	169	2
Rays and skates	4 265	10	686	8
Total all demersal	43 770		8 389	
PELAGIC SPP.				
Horse mackerel	6	+	6 129	13
Herring	33 532	84	196	+
Pilchard	0		595	1
Sprat	5 354	13	11	+
Mackerel	1 035	3	38 412	85
Total all pelagic	39 990		45 425	
SHELLFISH				
Edible crab	216	1	86	2
Spiny lobster	9	+	84	2
Lobster	199	1	33	1
Norway lobster	5 911	24	21	1
Pandalid shrimp	403	2	0	
Periwinkle	618	3	0	
Mussel	3 281	14	99	2
Escallop	8 286	34	12	+
Queen scallop	5 164	21	0	
Cockle	0		3 041	76
Squids	111	+	612	15
Total all shellfish	24 257		4 014	

Knowing the size and range of the fishing vessels available to work in the area, it is possible to make some assessment of what they would do if prevented from carrying on a particular fishery either by conservation measures or because it ceased to be economic. The biological interactions between species are very much more difficult to study and understand and this makes it very difficult to devise a rational management policy for a mixed fishery.

In the analysis which follows, the fisheries for a number of the more important species are considered separately using yield per recruit models (Beverton and Holt 1957) and an assessment is also carried out on the 'total demersal' catch using general production techniques. The two types of approach are intended to be complementary and may enable us to evaluate both detailed and overall management strategy in a critical way.

The first type of approach, using so-called 'analytical' models for individual species, enables one to assess the benefits of various forms of regulation on the stocks in question. The kinds of regulation which can be considered include mesh regulation, closed areas, catch quotas and limitation of fishing effort. The analytical models are fairly reliable when it comes to looking at the way in which a fishery is likely to change over the next year or two. If there is some advance information about the size of incoming year-classes, which may be obtainable from records of small-mesh fishery by-catches or from special surveys, the models can be used to assess the effect on the future size of the stock of allowing a particular level of fishing activity or catch. They are tools used to evaluate different management options and they can also be used to give good forecasts of catch rates over the next year or two (see MAFF 'Fishing Prospects'). In the longer term and when predicting the effects of big increases or reductions in fishing, these models are less reliable, because they usually assume that the recruitment level, growth rate and natural mortality will remain constant. Very little is in fact known about the changes which may take place in these parameters.

The second type of approach, using a general production model on 'total demersal' biomass, is a crude attempt to interpret the long-term changes in yield in the light of changing fishing effort. By grouping all the demersal species together, some allowance is made for their interactions. The results from this approach, which are based on the course taken by the fishery over the past decades, can be used to set an upper limit to the sum of individual species assessments carried out using the analytical model. This implies a degree of constancy in the way fishing effort is directed and provides a way of evaluating a management strategy which takes account of the overall levels of fishing effort applied to all the demersal stocks. In assessing the profitability of fishing in an area the overall catch rate is a most important criterion and the relationship between catch rate (i. e. biomass) and overall fishing effort is the part of the general production model to which most attention will be paid in this case.

FISHERY PRODUCTION

Before going on to apply the two types of model to the major fish stocks in VIIa and VIII it is worth looking briefly at the long-term trends in the catch of the more important species, the changes which have taken place in the fishing fleets of the different countries and the comparable level of production in the North Sea.

(a) The long-term trends in demersal fish catches

The total international catches of the seven major demersal species and total demersal catches in Divisions VIIa and VIII f since early this century are shown in Figure 2. With the exception of skates and rays, the catches of all species are at present above the long-term average and the total demersal catch has been running at about twice the long-term average since the early 1960s. Haddock and whiting show the greatest increases since the early part of the century, although it is not clear whether this is due to marketing factors, an increase in their abundance, or improvements in the recording of statistics.

The steady increase in the total demersal catch since 1950 also took place in the North Sea, but there has been a rather dramatic decline in that area since the record level in 1970. The increase in catches in the Irish Sea and Bristol Channel has been accompanied by an even faster increase in fishing effort so that catch rates (e. g. tonnes caught per hour of fishing) have been declining even while total catches go up.

(b) Changes in fishing fleets

Since fishing vessels vary in size, horse-power and gear and their skip-pers and crews vary in ability and fishing intention, it is very difficult to make comparisons of the fishing effort (e. g. hours spent fishing) between fleets from different countries or over long time periods. In Appendix A an attempt is made to standardize the effort on all demersal species by Belgian and English and Welsh trawlers and to correct for trends in fishing power, but for present purposes the figures are as given in the statistical bulletins (MAFF Sea Fisheries Statistics; ICES Statistical Newsletter).

Figure 3 shows the number of hours fishing by English and Welsh steam and motor trawlers in Divisions VIIa and VIII f since 1924. Other methods of fishing, of which seining is the most important within the English fleet, are not included here, but are included later on when the overall effort levels are calculated. The greatest amount of fishing by English and Welsh trawlers in both the Irish Sea and Bristol Channel took place during the 1930s and at that time probably accounted for about a third of the total international effort. After the 1939-45 war, fishing resumed at a lower level and the steam trawlers were gradually replaced by motor trawlers during the 1950s. There were 145 first-class steam trawlers registered at Fleetwood in 1930, nine at Liverpool and 59 at Milford Haven, but most of these fished outside the Irish Sea. (A first-class steam trawler is one over 40 ft making voyages of longer than 72 hours.) The numbers of first-class inshore motor trawlers (under 70 ft but over 15 tons) were not recorded until 1948 when there were 15 at Fleetwood and eight at Whitehaven. By 1974 there were 52 under 80 ft but over 40 ft motor trawlers registered at Fleetwood, with a mean horse-power of 161, and six at Whitehaven with a mean horse-power of 213. The English and Welsh fishing effort in the Irish Sea and Bristol Channel has not varied greatly since the Second World War, except for the period in the late 1950s when steam trawl effort declined more rapidly than it was being replaced by motor trawl effort.

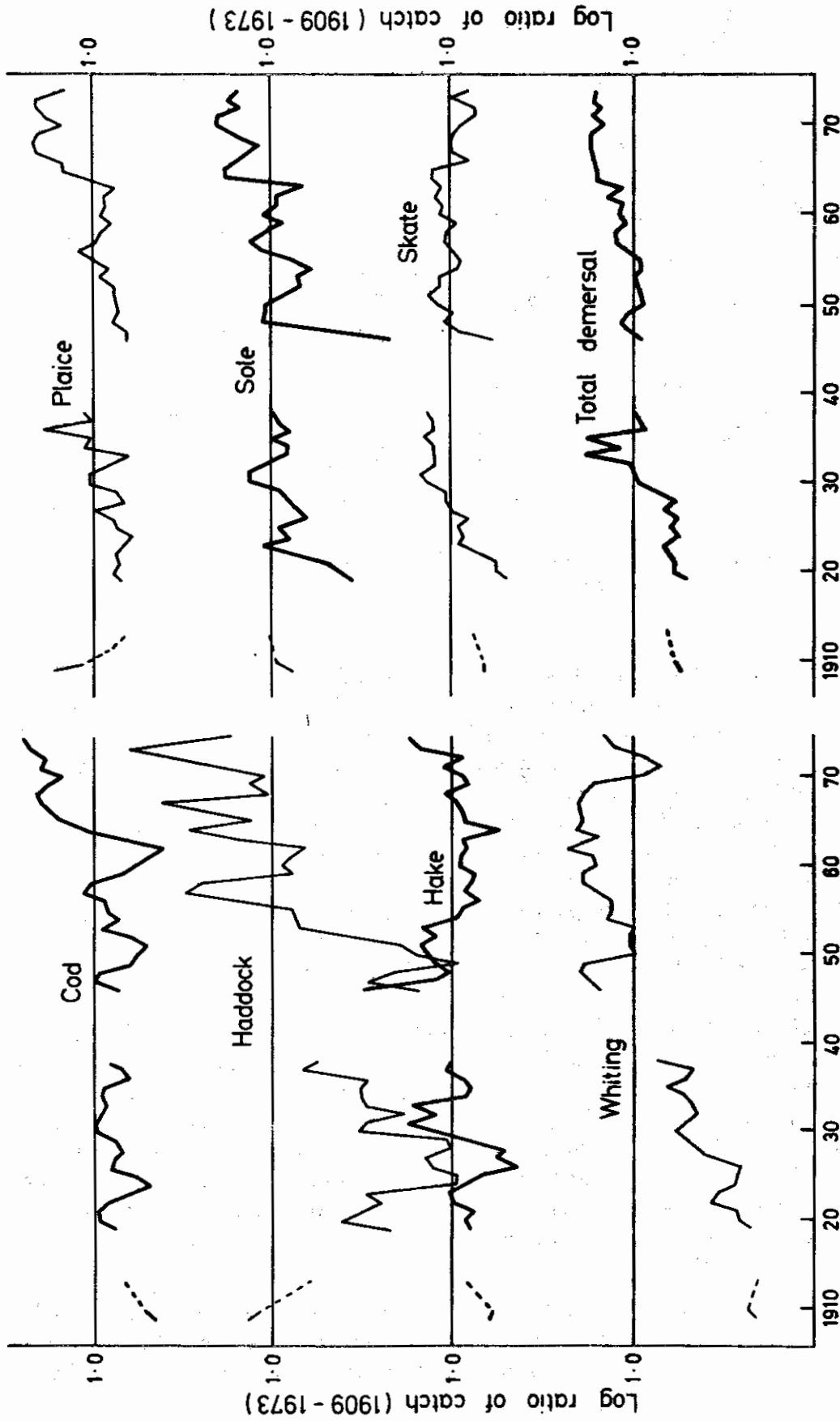


Figure 2 Annual total international catches of seven demersal species and total demersal catches in Divisions VIIa and VIII plotted on a logarithmic scale about the long-term mean for the period 1909-73.

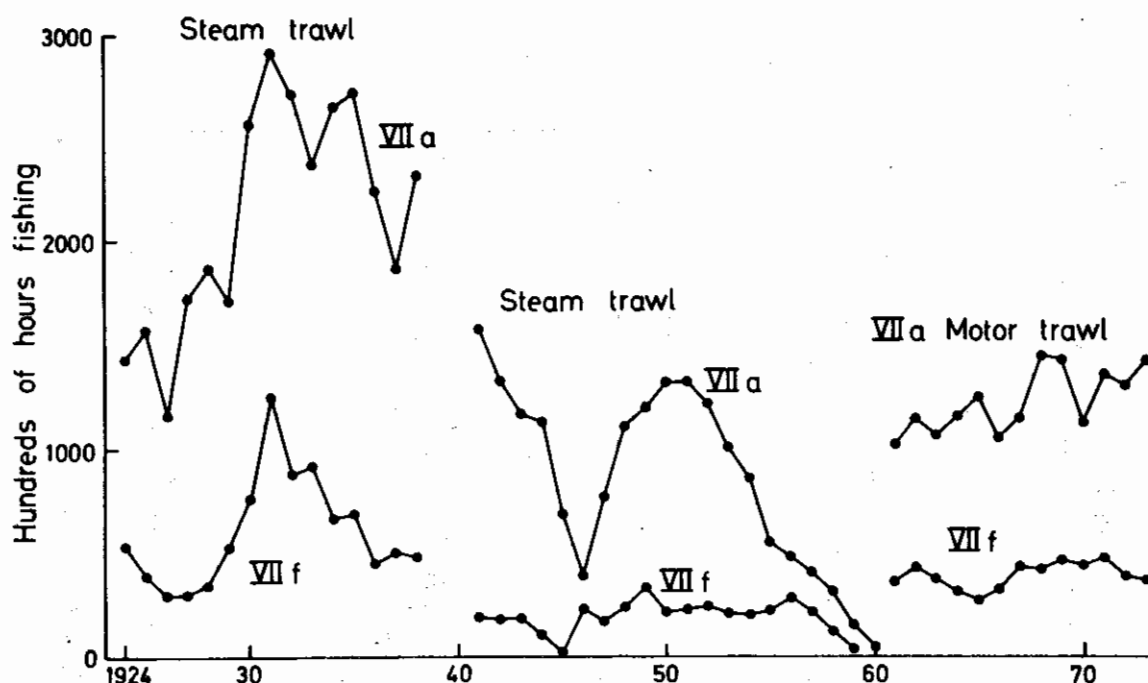


Figure 3 Long-term trends in English and Welsh fishing effort in VIIa and VIIf (uncorrected).

The main English and Welsh ports at which demersal fish from the Irish Sea and Bristol Channel are landed at present are Whitehaven, Fleetwood, Conwy, Milford Haven and Newlyn, with a number of others such as Workington, Maryport, Swansea and Port Penrhyn increasing or declining in importance. In the southern part of VII f, south of 51°N , most of the fishing in 1972 was by Newlyn boats landing skates and rays, cod, pout whiting and haddock. North of 51°N the effort was evenly split between Swansea and Milford Haven, with catches consisting of plaice, rays and sole. Milford Haven accounts for most of the UK fishing effort in the part of VII a south of 53°N extending also to Caernarvon Bay and sometimes Morecambe Bay on the eastern side and as far north as the Kish Bank and Carlingford Lough on the Irish side. Conwy vessels fish all along the North Wales coast from Caernarvon Bay to the Dee and may go further afield for particular seasonal fisheries. At Fleetwood, which accounts for over half of the English and Welsh demersal fish landings in VII a, the fleet is divided into small inshore trawlers working mainly along the Lancashire and Cumbrian coasts and the larger vessels which work between Cumbria and the Isle of Man and in the North Channel. About 10% of the demersal fish catch by over 40 ft vessels at Fleetwood is taken by seiners. At Whitehaven almost 80% of the demersal fish catch is taken by seiners working from the Solway Firth to the banks off the north-east corner of the Isle of Man and down to the 'cod holes' just north of 54°N .

The overall distribution of fishing effort in VII a and VII f by English and Welsh motor trawlers over 40 ft in length over the past ten years is shown in Figure 4. There have been large fluctuations in the distribution of effort but the total amount has not changed very much.

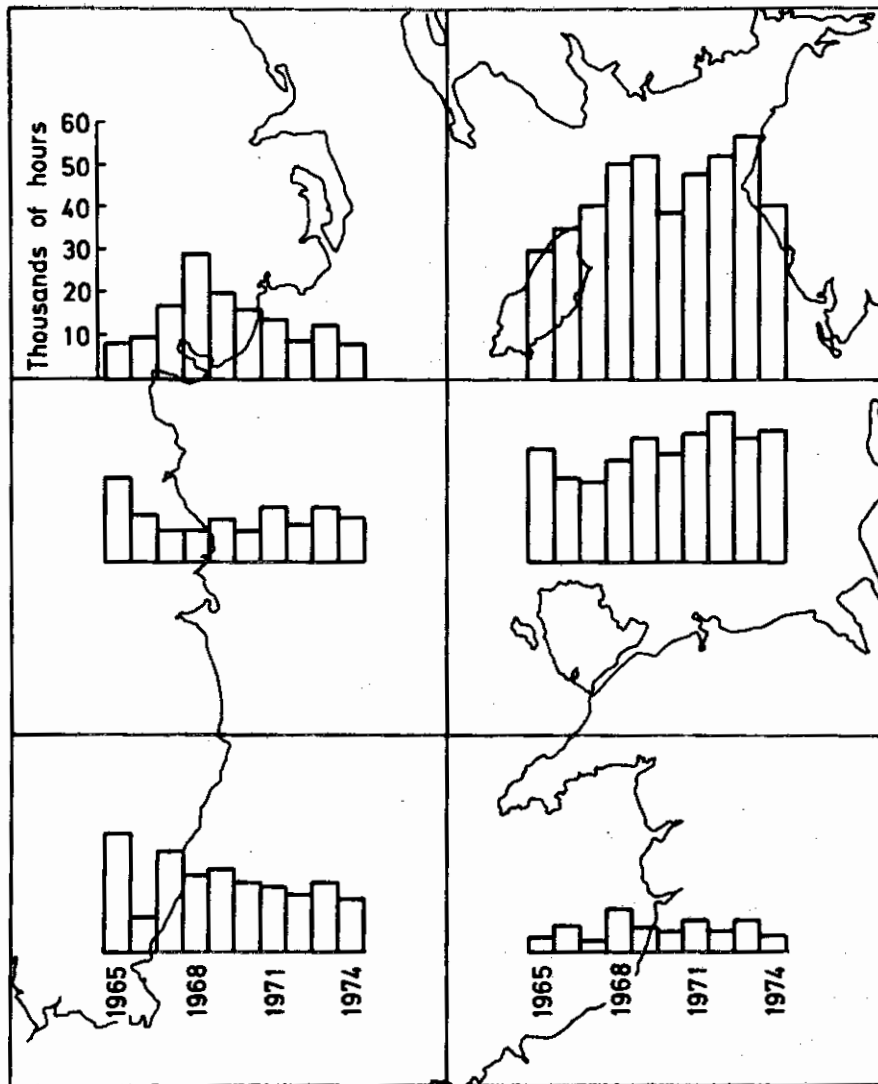


Figure 4 Fishing effort (motor trawler hours) by English and Welsh trawlers, 1965-74.

In contrast to this the fishing effort by Northern Ireland and other countries has increased fairly steadily (Figure 5). Unfortunately, there are no statistics of fishing effort from France but this has been allowed for in calculating the total international effort figure later on. Judging by the proportion which they take of the total catch (Figure 6), the French fishing effort has increased enormously since the early 1950s and was particularly high during the late 1960s. Irish fishing effort has been rising throughout the period and is given in Figure 5 (Griffith, pers. comm.) in total Gross Registered Tonnage (excluding vessels of < 26 G. R. T.).

Belgian fishing effort is divided fairly evenly between the Irish Sea and Bristol Channel; this makes Belgium the major consistent contributor to demersal catches from the latter area. The Belgians began beam trawling in the Bristol Channel in 1966 and by 1973 their beam trawl effort exceeded their otter trawl effort in both areas. This has also led to a shift in the composition of their catches away from general mixed fish towards flatfish, although they still account for most of the cod landings from the Bristol Channel.

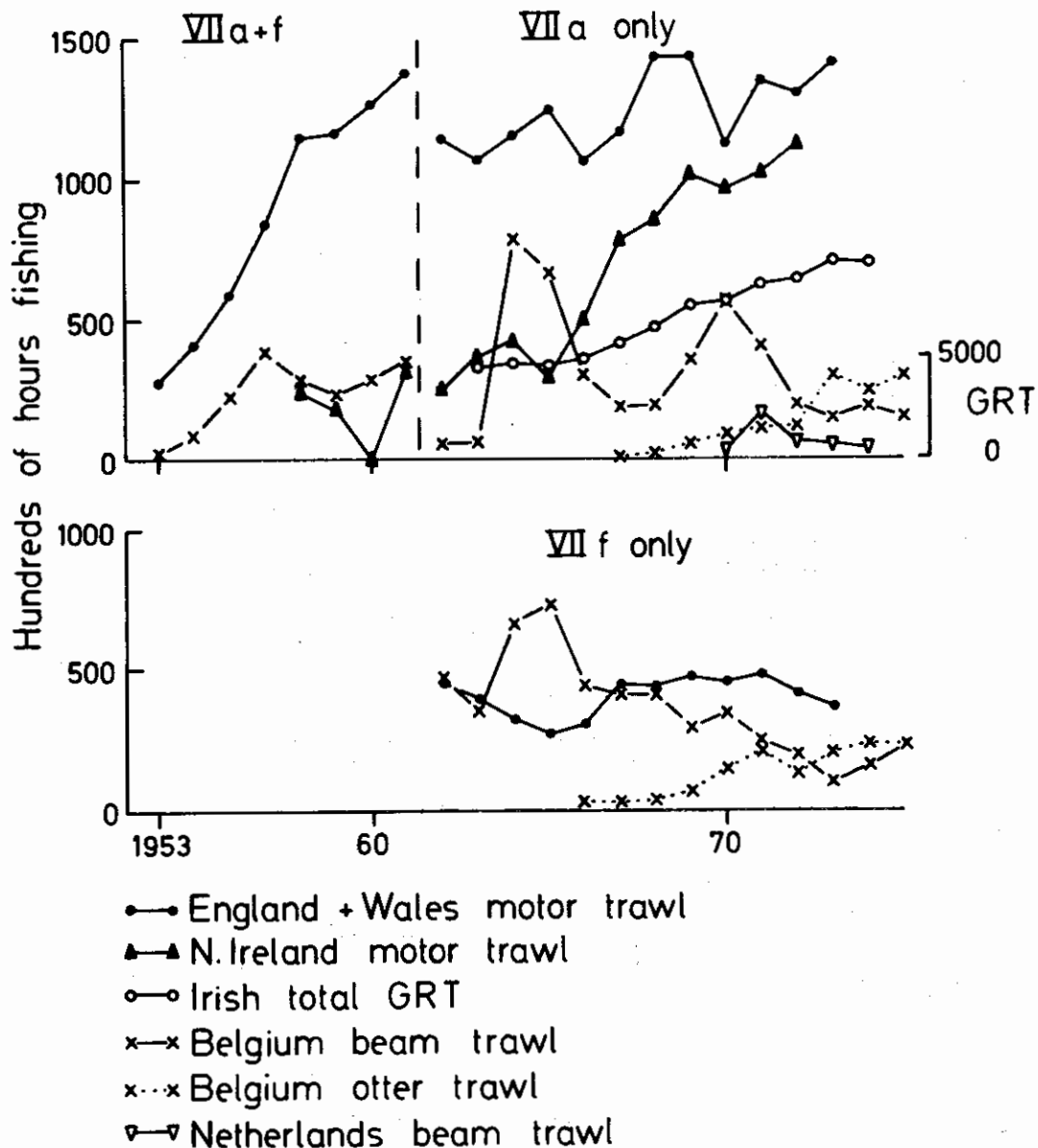


Figure 5 Long-term trends in motor trawler effort in VIIa and VIIIf (uncorrected).

Dutch interest in Divisions VIIa and VIIIf has never been great, but aroused concern in 1971 when a fleet of 40 beam trawlers worked for sole in Morecambe Bay with considerable success. In 1972 only 13 boats took part and since then their effort has been small. But since it is concentrated within two months of the year and directed entirely at sole it has had a noticeable effect on that stock.

Northern Ireland motor trawl effort has increased approximately fourfold since 1960. This is due partly to expansion of the fleet and partly to the switch from seining, which was complete by 1970. The switch to trawling took place as the whiting fishery declined and the *Nephrops* fishery increased. Many Northern Irish vessels use dual-purpose trawls for *Nephrops* and whitefish and switch over to herring fishing during the autumn. Whiting and cod make up the bulk of their demersal fish catches with some hake, saithe and monk, but the flatfish component is negligible.

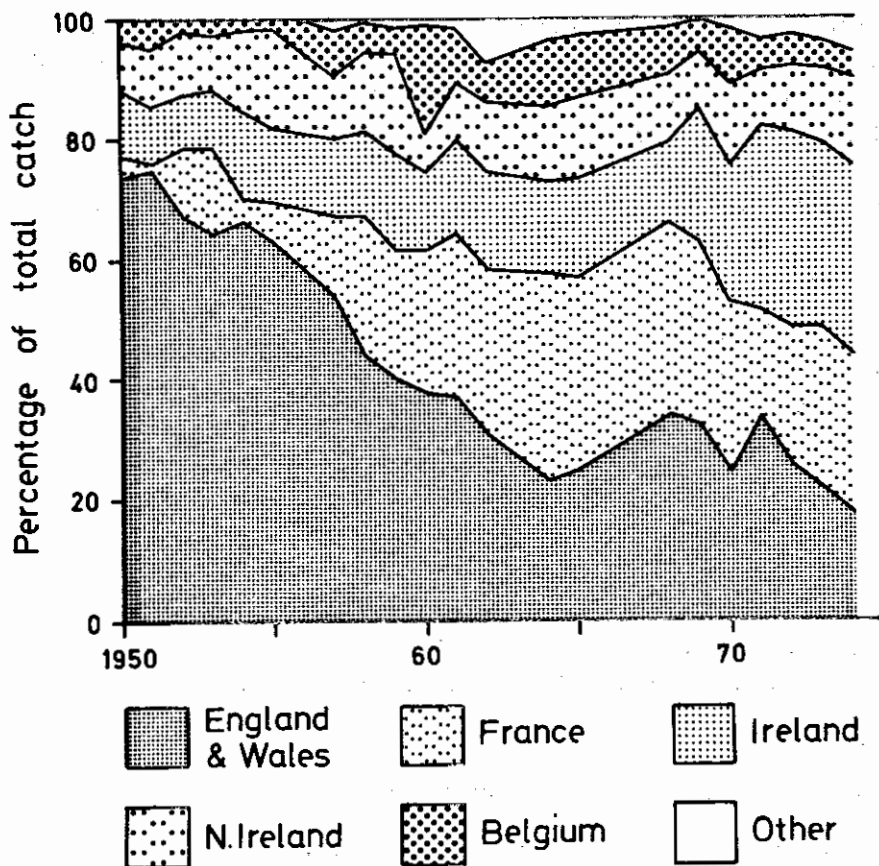


Figure 6 Proportion of total catch in VIIa and VIII taken by different countries, 1950-74.

(c) Production in the Irish Sea compared with the North Sea

In his review "The Fish Resources of the Oceans", Gulland (1970) estimates the potential pelagic and demersal catches of different areas of sea bed at depths less than 200 m. Table 3 compares his estimates of potential catches of pelagic and demersal species in the North Sea and westerly areas with the actual catches (means of the period 1951-73) from the North Sea and VIIa and VIII. All values are in kilogrammes per hectare (kg/ha).

Table 3 Comparison of estimated and average actual total catches (kg/ha), 1951-73. The estimates are from Gulland (1970) and 'westerly' refers to ICES Sub-areas VI and VII; the actual westerly catches were from Divisions VIIa and VIII

	North Sea		Westerly	
	Estimated	Actual	Estimated	Actual
Pelagic	38	25	21	3
Demersal	17	16	17	7
Total	55	41	38	10

This table shows that the overall fish catch per unit area in the Irish Sea and Bristol Channel is only one quarter of that in the North Sea and only one quarter of the potential estimated for the westerly area by Gulland. In fact the pelagic catch per unit area is only one eighth of the North Sea catch and one seventh of the estimated potential. In 1973 North Sea fish production was precisely at Gulland's estimated potential values, while for Divisions VIIa and VIIf the pelagic catch was 15 kg/ha and the demersal catch 9 kg/ha. The massive pelagic catch was however entirely due to Russian mackerel and horse mackerel landings from the southern tip of the area, off Land's End.

It is possible that there may be some unexploited pelagic stocks in VIIa and VIIf, although herring is certainly not one of them, but they are unlikely to make up the enormous difference between Gulland's estimate of potential and the actual catches. There is no evidence of unexploited demersal fish stocks in the area and the conclusion must therefore be that the Irish Sea and Bristol Channel are very much less productive of fish than the North Sea and fall far short of Gulland's estimates of potential production for the westerly areas.

No satisfying explanation for this large difference in productivity can be put forward. Among those which have been suggested are

1. lower primary productivity;
2. greater degree of coastal influence;
3. smaller proportion of the total area open to fishing;
4. major small-mesh fisheries for shrimps and Nephrops;
5. overall area is smaller.

A point of similarity between the North Sea and the Irish Sea, which has already been mentioned, is that total demersal fish catches in both areas increased rapidly during the mid-sixties and are still well above the long-term mean. Cole and Holden (1973) suggested that declining recruitment to the North Sea pelagic fisheries, due to overfishing, may have reduced competition in the larval stages of demersal species, but they found no evidence to support this. In the Irish Sea the upsurge in demersal fish catches has been matched by an upsurge in pelagic catches, particularly herring, which also seems to rule out reduction in competition between the two as a cause of the change. If the comparison is narrowed to looking at the southern North Sea, which is the least productive part of the North Sea, one can see a number of similarities. The southern North Sea and the area east of the Isle of Man are bathymetrically similar, are probably subject to about the same degree of coastal influence, and have fairly extensive small-mesh fisheries for shrimps and other shellfish. Ramster (1973) has pointed out the similarities in physical processes between Morecambe Bay and the German Bight yet, in spite of the many similarities, the southern North Sea is a great deal more productive than the Irish Sea. As long as there is a possibility that part of the reason for the differences in productivity is under human control, it is worth devoting some effort to determining what those reasons are.

SUMMARY OF THE ASSESSMENTS

(a) Single species assessments

A flow chart of the scheme followed in carrying out the single species assessments is given in Figure 7. The four questions in the flow chart are taken in sequence for each species and the answers are given under the same four headings in Table 4. The detailed reviews of each species on which these answers are based are given on pages 16-33. Since the quality and age of this source material is variable, the results should not be regarded as definitive. They are intended to indicate the present state of exploitation of the stocks and to show what management action is needed.

Question 1: Spawning stock size

Since the trend in spawning stock size for most stocks in the area has been downward, we are in the process of learning what happens to recruitment at low stock sizes. At the same time we should be endeavouring to ensure that there is no decline in recruitment. Skates and rays are the only species which are as yet suffering from declining recruitment due to reduced spawning stock size, but the Mourne herring may be approaching critically low levels. For all species except skates and rays the average recruitment for the last 12 years has probably been higher than at any time this century.

Question 2: Exploitation pattern

For all the species assessed the yield per recruit could be increased by reducing mortality on the younger ages, i. e. by adjusting the exploitation pattern.

There are three measures which would give large improvements in exploitation pattern:

- (i) raising the minimum mesh size in use for Nephrops to 70 mm; this would greatly reduce the mortality on juvenile whiting and cod and would also increase the yield per recruit of Nephrops;
- (ii) raising the minimum mesh size in use for whitefish to increase the age of first capture of cod, plaice and skates and rays;
- (iii) using selective, closed seasons or closed areas in order to prevent directed fisheries on recruiting fish, e. g. the local autumn codling fisheries.

Other measures which should be considered, and in some cases have been tried, include reducing the mortality on whiting and herring in the industrial fishery, bringing in a minimum landing size of 20 cm for herring, and reducing the mortality on juvenile flatfish in the shrimp fisheries. The proposal to raise the minimum mesh size in use for Nephrops to 70 mm is the outstanding conservation measure needed at present because, as well as giving the benefits mentioned above, it would make enforcement of other mesh regulations easier.

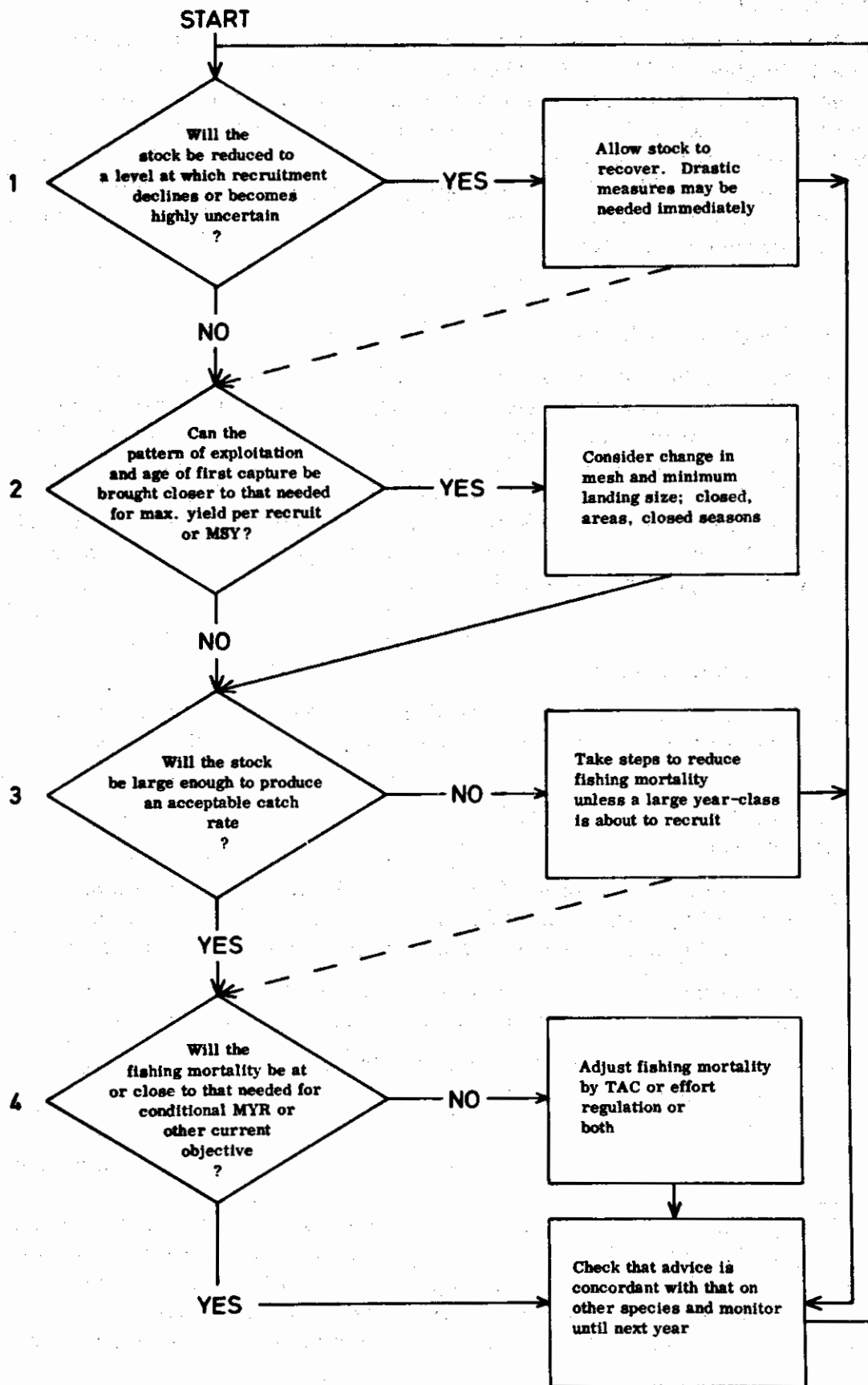


Figure 7 Flow chart for single species assessments.

Table 4 Summary of single species assessments for the Irish Sea and Bristol Channel

Species	Action required on				
	1	2	3	4	
	Spawning stock size	Exploitation pattern	Catch rate	Reduction in F	Increase in Y/R
Cod	No	Yes	No	60%	20%
Whiting	No	Yes	No	60%	4%
Sole	No	Yes	Yes	None	
Plaice	Possibly in Bristol Channel	Yes	No	50%	3%
Skates and rays	Yes	Yes	No	?	
Herring	Possibly on Mourne stock	Yes	No	Slight	?
<u>Nephrops</u>	No	Yes	?	75%	50%

Question 3: Catch rate

There are two reasons for maintaining a 'buffer stock':

- (a) to maintain a profitable catch rate;
- (b) to reduce the variability in catch due to fluctuations in recruitment.

Both of these require a judgement by the participants on what constitutes an acceptable catch rate. The role of a biological assessment is merely to advise on the likely outcome of different options (e. g. the reduction in fishing mortality which would be needed to secure a given increase in catch rate). There have been numerous complaints from fishermen that the catch rates of sole in Divisions VIIa and VIIf have fallen to a level at which it is uneconomical to catch them. Although the sole stock is big enough to produce high steady recruitment and Maximum Yield per Recruit (MYR), it is apparently too small to sustain the traditional mixed fishery of the area. The catch rate could be raised by reducing fishing effort, particularly by beam trawlers which fish selectively for sole, but there would be a small reduction in the total sole catch. Appendix B describes the 'trade off' between total catch and variability of catch of sole.

Question 4: Conditional Maximum Yield per Recruit

The MYR for the existing exploitation pattern is referred to as the conditional MYR. Only the sole and herring are close to conditional MYR and for both of these a previous question in the scheme which we are following has given grounds for restraining fishing mortality. For the sole, the need is to

improve the catch rate and for the herring the spawning stock size must be safeguarded. Table 4 shows that large reductions in fishing mortality are needed to maximize yield per recruit on the other species and gives the overall impression that the Irish Sea is heavily overfished. However, from consideration of the recent development of all the demersal fisheries in the area together, it appears that this impression may be exaggerated. It is hard to sustain the case for there being heavy overfishing when the total catches of most species have been at record levels for ten years. There is an overwhelming case for reducing the present level of fishing effort, but the reductions needed to maximize yields are less drastic than the individual assessments shown in Table 4 would suggest.

(b) Total demersal production model

The total demersal production model is an attempt to relate the change in the abundance of all demersal species, as measured by the catch per unit effort, to the change in total fishing effort. Details of the model are to be found on pages 34-36. It is one of the 'central dogmas' of fish population dynamics that as fishing effort goes up catch rate comes down. Figure 8 shows this relationship for the total demersal catch in the Irish Sea and Bristol Channel since 1956. The fit is remarkably good and the line can be transformed to give the yield curve shown in Figure 9. The curve indicates that total international fishing effort is at or above the level needed to take the Maximum Sustainable Yield (MSY) and catches have been at record levels since the late 1960s. The main reason why catches have increased so much since the early 1960s is that recruitment of most species has been very high, but the causes of the high recruitment are unknown. In view of this, the safest current policy for fisheries management is to aim for a reduction in total international effort over the next few years of about 20%, i. e. to return it to the level of the late 1960s. This is far less drastic than the reductions suggested by the single species assessments shown in Table 4 and the discrepancy between the two methods arises because the single species assessments assume constant recruitment.

The effect of a 20% reduction in the total international effort would, from the general production model, be a fall in total catch by less than 4% and an increase in catch rate by about 20%. With concurrent adjustments to the exploitation pattern there need be no fall in the total catch.

SINGLE SPECIES ASSESSMENTS

Cod

Since 1967 catches of cod in Divisions VIIa and VIIf have been around 9 000-10 000 tonnes per year compared with an average of only 4 000 for the period 1960-66. The increase was due to a series of very good year-classes. The fisheries for cod follow a regular seasonal pattern with highest catchability and peak catches during the spawning season from late February to early April. There are intensive directed cod fisheries at this time on the main spawning grounds off Carlingford Lough in the north-west Irish Sea, south-west of St Bees

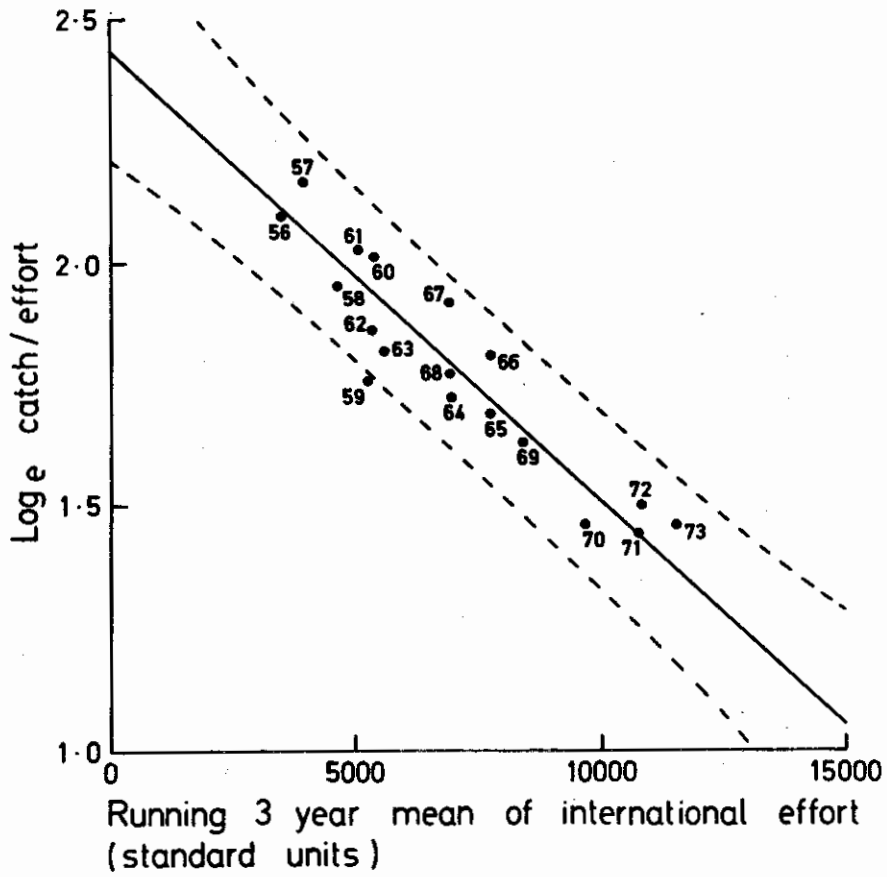


Figure 8 Variation of catch rate with fishing effort in VIIa and VIIf, 1956-73.

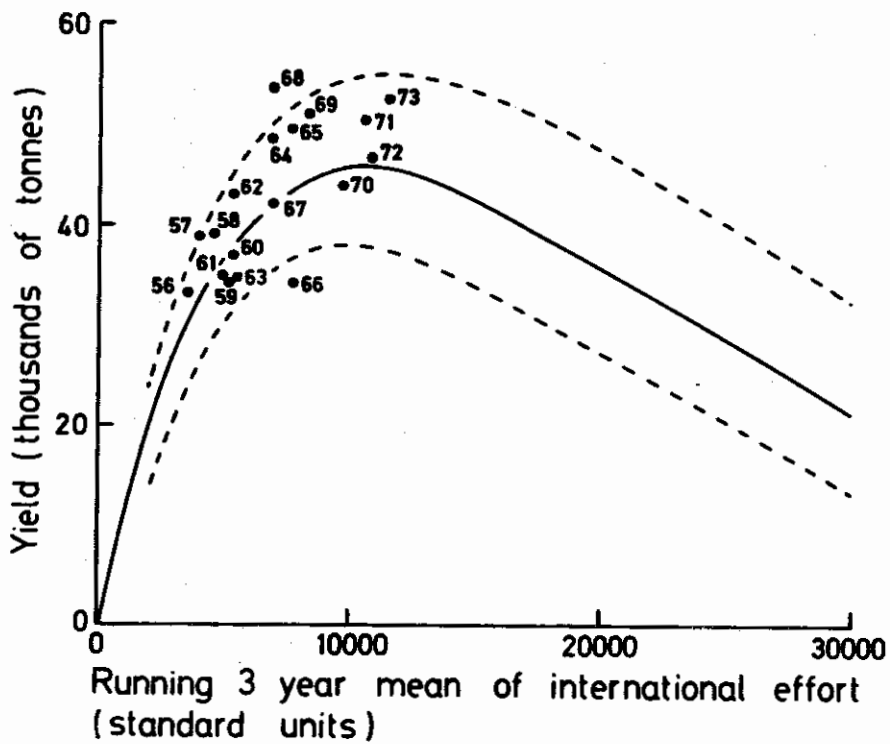


Figure 9 Variation of total demersal yield with fishing effort in VIIa and VIIf, 1956-73.

Head in the north-east Irish Sea and west of Hartland Point in the Bristol Channel. During the summer months catch rates fall to very low levels and there are no directed fisheries. Catch rates start to rise again in about September and there may again be intensive localized fisheries, particularly along the Irish coast and in Belfast Lough for codling, in early winter.

Tagging experiments on cod spawning in the three main areas show that there is virtually no movement of mature fish between them. Studies of meristic characters, particularly vertebral count, also indicate a degree of separation, particularly between the two spawning stocks in the northern Irish Sea. The limited data available on blood group characteristics do not distinguish genetic differences between the spawning areas clearly, but do in part show lack of homogeneity within a single spawning population. In all, therefore, there would be good reasons for assessing the populations from the two sides of the Irish Sea and from the Bristol Channel separately, but such a separation is not possible at present, because the international catch statistics do not distinguish between the two areas. As regards differences in growth rate, the cod in the southern part of VIIa are on average 3 cm bigger by the age of two than those from the northern part and this difference increases with age. Growth rate also increases going from east to west, but it is difficult to distinguish this from the effect of other factors; for example, during the spawning season, when the biggest cod catches occur, the average length of fish of a particular age on the spawning grounds is much higher than the average length of the same age group elsewhere.

After spawning at St Bees the mature fish stay mainly in the area between the Solway, the Isle of Man and the Cumbrian coast, but a small proportion of tagged fish were recaptured in the Clyde and occasional fish from south of the Irish Sea. In contrast, the fish tagged off Carlingford Lough during the spawning period showed large-scale migrations to the south along the Irish coast, with a high proportion of recaptures from south-east of Ireland during the summer months. The return rates on fish tagged on the Bristol Channel spawning ground were too low to allow any firm conclusions, but most recaptures were within 90 miles of the tagging area.

Apart from a fairly large and consistent migration into the area south-east of Ireland and very minor movements into the Clyde, the cod stocks of the Irish Sea and Bristol Channel appear to be self-contained. A major gap in our knowledge concerns the movement of pre-recruit and recruiting cod; there are indications of large migrations into the Irish Sea from areas to the south.

In order to work out yield curves or yield per recruit curves for the combined populations of the Irish Sea and Bristol Channel it is necessary to have some common values for growth, mortality, selection and recruitment. The 'best' estimates of these parameters should take account of the relative levels of exploitation in the different parts of the area and during the different seasons of the year. Table 5 gives the mean length and mean weight of cod on 30 June derived from the UK catch over seven years. By using the growth curve one may also derive the mean length and weight on 1 January which can be multiplied by the population numbers to give an estimate of the weight of the stock at the beginning of each year.

Table 5 Mean length (cm) and weight (kg, whole weight) at age of Irish Sea and Bristol Channel cod from English and Welsh catch statistics, 1968-74

Age	Catch		Stock	
	Length	Weight	Length	Weight
1	37.4	0.53	18.2	0.06
2	50.9	1.36	37.5	0.53
3	66.6	3.09	59.0	2.13
4	75.7	4.57	71.5	3.83
5	82.5	5.94	79.2	5.24
6	87.1	7.01	84.6	6.41
7	92.0	8.29	89.8	7.70
8	95.6	9.33	94.0	8.86

The fishing mortality on cod over the last few years may be derived from catch and effort statistics or by Virtual Population Analysis (VPA) (Cushing 1975) for earlier years and the results using the two methods are shown in Table 6. The catch per effort (cpe) statistics used were for English and Welsh trawlers, corrected for the trend in fishing power. Natural Mortality (M) has been taken as 0.2, the conventional figure for cod, which is supported by the results from tagging experiments in the area. (This is an instantaneous coefficient equivalent to 18% annual mortality.) Fishing mortality (F) since 1968 has averaged 0.8-0.9 (equivalent to 55% annual mortality), with the estimates from catch and effort giving slightly higher values. The fishing mortality on fully recruited ages is fairly constant, but the age of recruitment is somewhat variable. There is no evidence of increased total mortality on the oldest fish.

Table 6 Fully recruited fishing mortalities on Irish Sea cod calculated by two methods

	From VPA	From cpe
1968	0.83	0.87
1969	0.94	1.10
1970	0.84	1.08
1971	0.70	0.88
1972	0.59	0.76
1973	0.92	0.62
1974	0.87	1.05
1975	0.91	0.99

The process of selection and recruitment in Irish Sea cod is quite straightforward, but plays the key role in yield assessments and possible management strategies based on these assessments. The minimum mesh size in Divisions VIIa and VIIf is 70 mm, and the selection factor is about 3.4. Mean selection length, the length at which half the fish are retained in the net, is equal to the mesh size times the selection factor. This gives a mean selection length of 23.8 cm, but the minimum legal landing size is 30 cm. One-year-old fish start to enter the catch in midsummer and often become the object of very intensive localized fisheries along the Irish coast. There is good hearsay evidence from fishermen that these intensive fisheries occur only when the fish are present in sufficiently large numbers and the limited sampling of them shows that the catches are very largely one-year-old fish. Thus the age of recruitment may well depend on year-class strength, and the mortality on fish in the third and fourth quarters of their second year is inversely related to their abundance. A tagging experiment on such a local fishery in Belfast Lough gave a fishing mortality of 1.8, with 171 fish out of 614 released being recaptured in the same area within three months.

As a simple approximation to this variation in mean age of recruitment, yield curves will be calculated in two different ways. The first assumes that a fishery on one-year-old codling occurs and that the mortality on them due to fishing in the last quarter is 0.45 regardless of the level of adult mortality. The second yield calculation sets the mean age of entry at two years of age, when the full adult mortality applies. The resultant yield curves are shown in Figure 10 and, as can be seen, the yield per recruit at the current level of F (0.8) is about one third higher if no fishing takes place on one-year-old fish. This is the extreme case because it assumes

1. that mortality on one-year-olds in the last quarter is 0.45 regardless of what the adult fishing mortality is;
2. that no emigration of one-year-olds occurs, whereas a small proportion probably do leave the Irish Sea (there may be some balancing immigration, although tagging to the west of Scotland gave no recaptures from the Irish Sea);
3. there is no mortality due to rejection, which would narrow the gap between the yield curves by reducing both in the manner of higher 'natural' mortality.

Nevertheless, the yield per recruit will always be lower if any fishing occurs on one-year-old fish and the loss in yield may be up to a third. The loss in yield between the present level of fishing mortality and that needed to take the maximum sustainable yield is between 18 and 24%, assuming recruitment and other parameters constant at the different stock levels. The mesh size required to raise the mean selection length to 30 cm, the minimum legal size of cod, is about 88 mm. In order to raise the mean age of selection to two, the mesh size would have to be about 118 mm.

There is no firm evidence of what might happen to recruitment or other parameters if the stock size were allowed to increase by reducing the fishing effort, but the fluctuations in both stock and recruitment which have occurred since 1960 have been large without showing any indication of reduced recruitment. The stock size if fishing mortality were reduced to 0.3 would be just over three times higher than at an F of 0.8, i.e. catch per effort would be three times higher than at present.

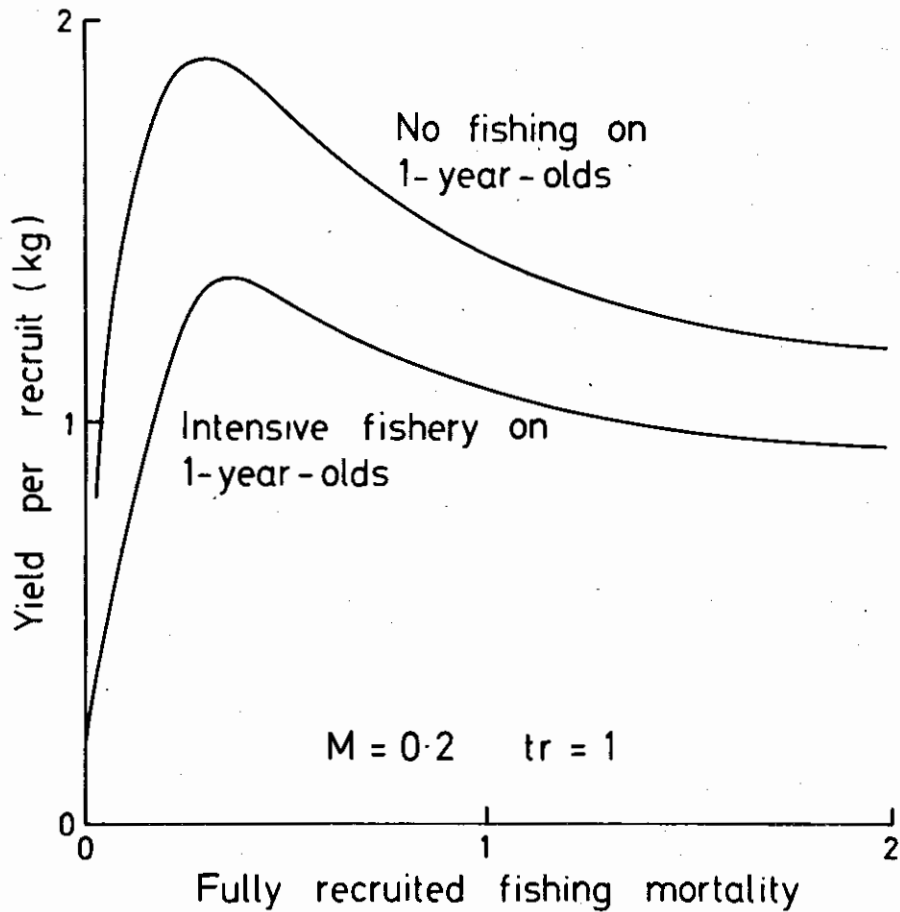


Figure 10 Yield curves for Irish Sea cod, showing effects of fishing on young fish.

Whiting

The most recent assessment of Irish Sea whiting was carried out by an ICES Working Group in 1973 (Anon. 1973). Whiting landings in Divisions VIIa and VIIb have shown an enormous increase since the early part of the century and are once again at high levels after a period of poor catches in the late 1960s and early 1970s. Garrod (in Garrod and Gambell 1965) looked at the history of the whiting fishery from just before the Second World War to 1961 and analysed the trends in catch and in catch rate. He felt that the exceptionally high catch rates in the immediate post-War years could not be attributed to reduced fishing effort during the War, since the missing English and Welsh effort had been largely replaced by Irish effort, which started to concentrate on whiting during the winter at that time. He concluded "...it seems that there were a number of phenomenally strong year-classes which, by 1947, had built up a population of adult whiting which gave the peak English catches." The seasonal distribution of the Irish and UK fisheries for whiting in the early 1960s is shown in Figure 11 (adapted from Garrod, *op. cit.*). The French catch, which in the years for which reliable statistics are available makes up some 30% of the total international catch, comes mainly from the 'Chickens' area, south-west of the Isle of Man. The Conwy spring fishery has virtually disappeared as a directed fishery.

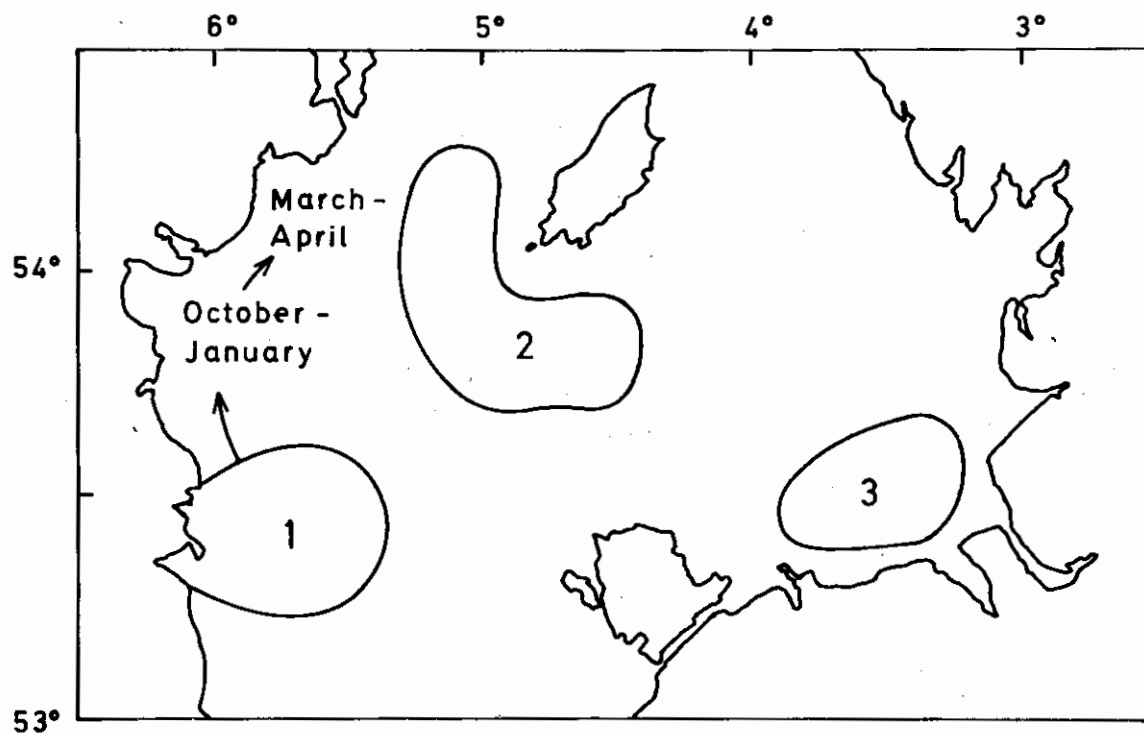


Figure 11 Distribution of UK and Irish whiting fisheries in the 1960s.

1. Rockabill-Lambay in August and September,
2. Chickens - French fish here all year,
3. Conwy - spring fishery February-April.

The decline in the catch rate and in the economic importance of whiting in the Irish and Northern Irish catch is documented in Tables 2 and 3 of the Report of the Working Group on Irish Sea Whiting (Anon. 1973) and in Table 1 of Watson and Parsons (1974). In Northern Ireland particularly the decline was accompanied by the switch from seining to trawling and from whitefish trawling to prawn trawling with a small-mesh net.

Within the Northern Irish catch of whiting the proportion of the landed catch taken in small-mesh trawls rose from 25% in 1966 to 67% in 1973 and rejection in the small-mesh fisheries in 1972 and 1973 averaged 83% throughout the year (Watson and Parsons, *op. cit.*). Thus at least 60% of the whiting caught by the Northern Irish fleet in 1973 were undersized and were rejected. Large quantities of whiting are also taken in the French small-mesh fisheries and in the Irish fishery for *Nephrops* and industrial species, but the exact amounts are unknown. The quantities of pre-recruit whiting taken as a by-catch in these small-mesh fisheries are so great that the benefits to be derived from adjustment of the whitefish mesh size or of fishing mortality in the adult fishery are quite insignificant by comparison. The annual total instantaneous mortality rate on pre-recruit whiting (between autumn of their first and second years) can be calculated from the work of Hillis (1974) and Watson and Parsons (1974). It is very high indeed, in the range 2.0-2.5 which corresponds to an annual mortality of 86-92%, and a large component of this is due to the small-mesh fisheries. At current levels of fishing mortality the yield of whiting would be expected to increase by 50-70% following abandonment of small-mesh fishing. By contrast, the improvement in yield which would be expected from a reduction in fishing mortality to maximum yield per recruit level under the current mesh regime would be only 4% or less.

Sole

As the recent history of exploitation of sole in the Irish Sea and Bristol Channel has been the subject of considerable comment it is perhaps worth looking at the catch statistics in a little more detail. The long-term picture shows that total yields are presently well above the long-term mean and in general rose, with large fluctuations, during the period 1954-71. The total catch in ICES Divisions VIIa and VIIf from 1962 (the first year for which separate data are available) to 1975 is given in Figure 12; Figure 13 shows the proportions of the total taken by different countries.

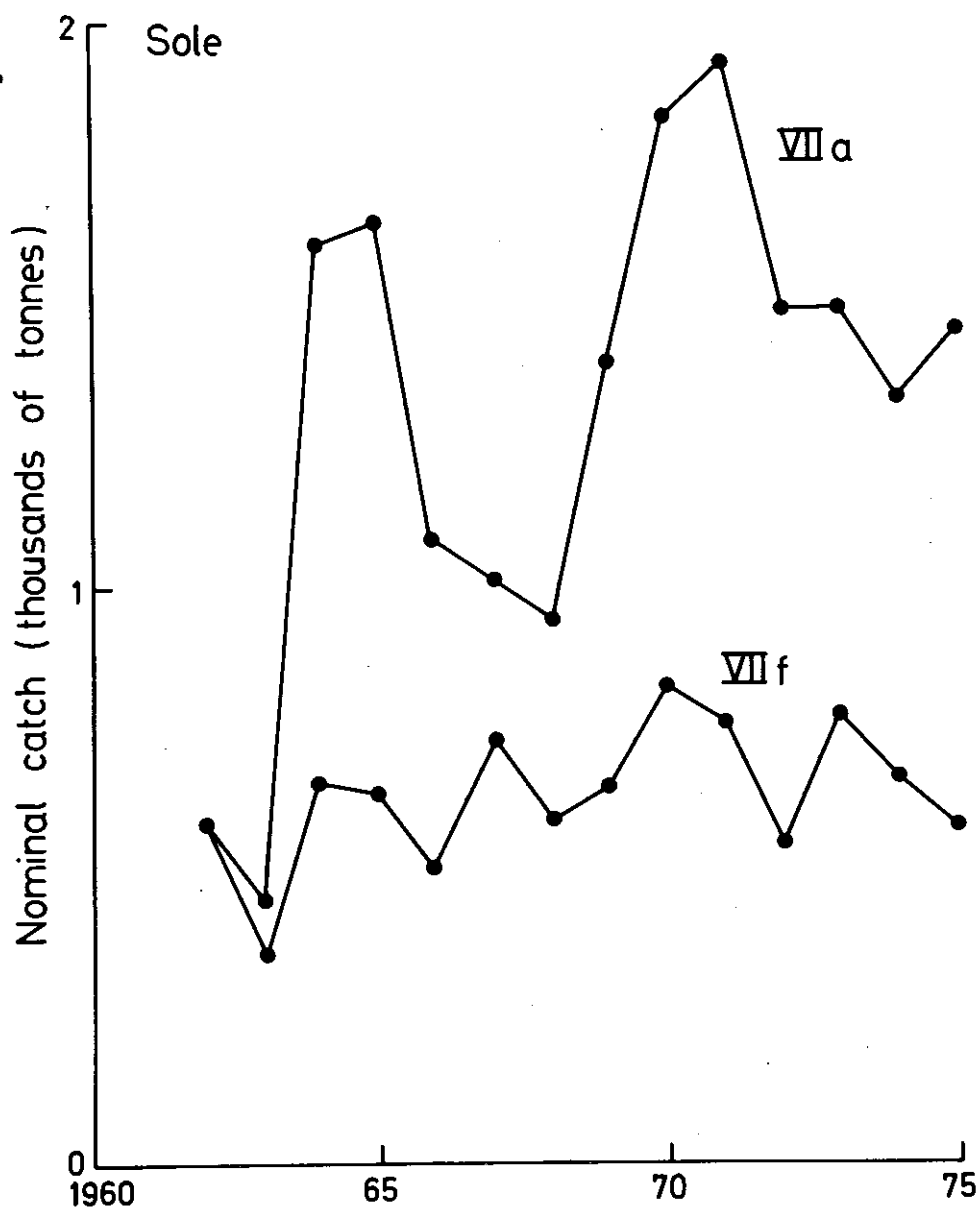


Figure 12 Total international catch of sole in VIIa and VIIf, 1962-75.

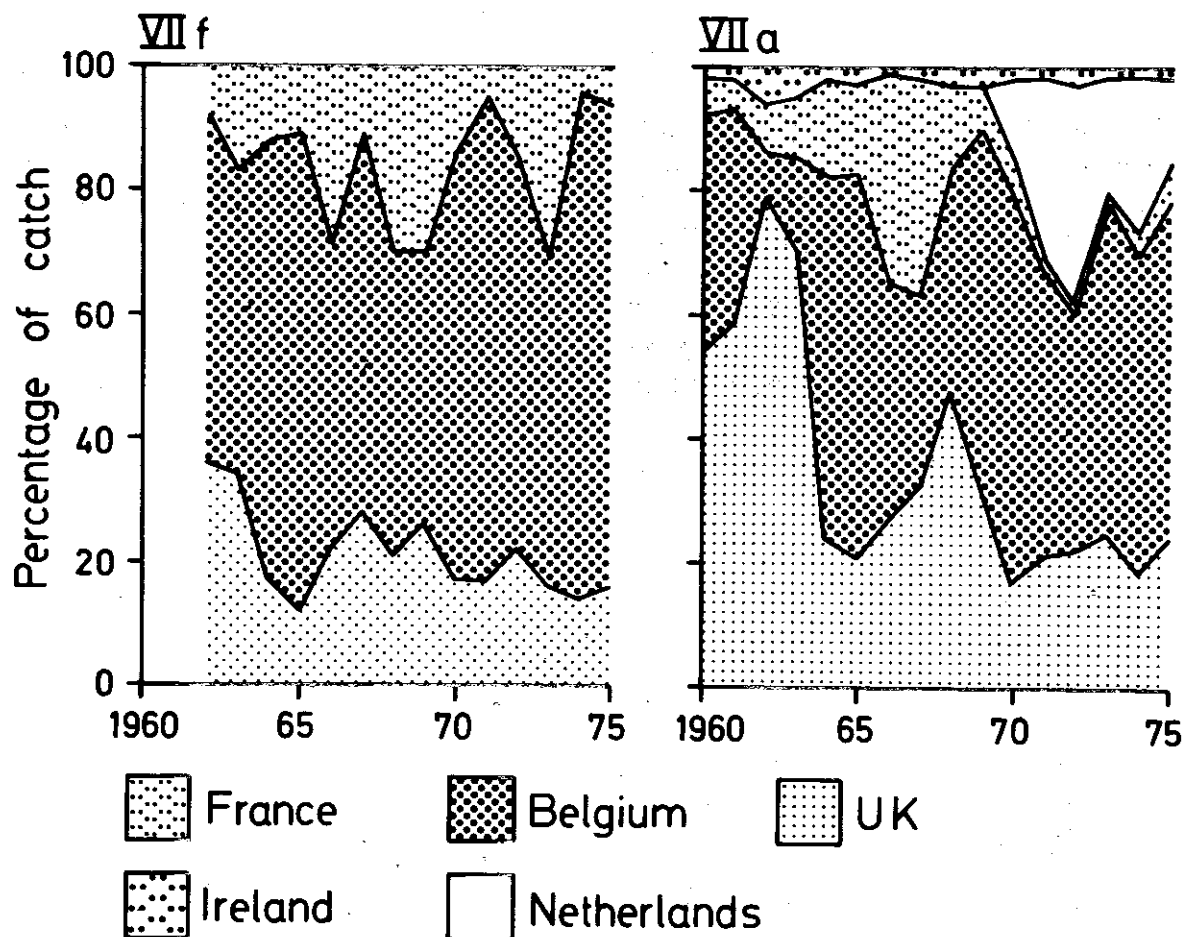


Figure 13 Percentages of sole catch taken by different countries in VIIa and VII f, 1962-75.

The highest catches of sole ever recorded in the Irish Sea and Bristol Channel took place in 1970 and 1971. In the former area the high catches were due largely to the exceptionally good 1964 year-class, whereas in the Bristol Channel, as in the North Sea, a good year-class occurred in 1963. At the same time there was a huge increase in the fishing effort on sole during the early 1970s, particularly in Morecambe Bay. As has been mentioned previously, a fleet of 40 Dutch beam trawlers worked this area with considerable success during the early summer of 1971, but even in that year their catch was less than that taken by the Belgians. Dutch effort at that time was largely replacing a declining French share of Irish Sea sole (see Figure 13) but since then Dutch interest has waned. The switch to beam trawling by the Belgian fleet has contributed greatly to the increased fishing effort on sole and their share of the total catch in 1975 was 54% for the Irish Sea and 78% for the Bristol Channel.

By contrast, the English and Welsh fleets fishing on sole in the two areas have remained virtually unchanged and they have therefore accounted for a declining proportion of the catch since 1960. Holden (1972) used cpe of English and Welsh trawlers during the period of the main sole fishery in the Irish Sea and Bristol Channel as an index of stock abundance. For the Irish Sea data for the ICES statistical rectangle E6 36 during the period May-September were used and for the Bristol Channel data for the rectangles E4 30, E4 29 and E5 30 for the period January-March. Figure 14 shows the fluctuations in catch rate since

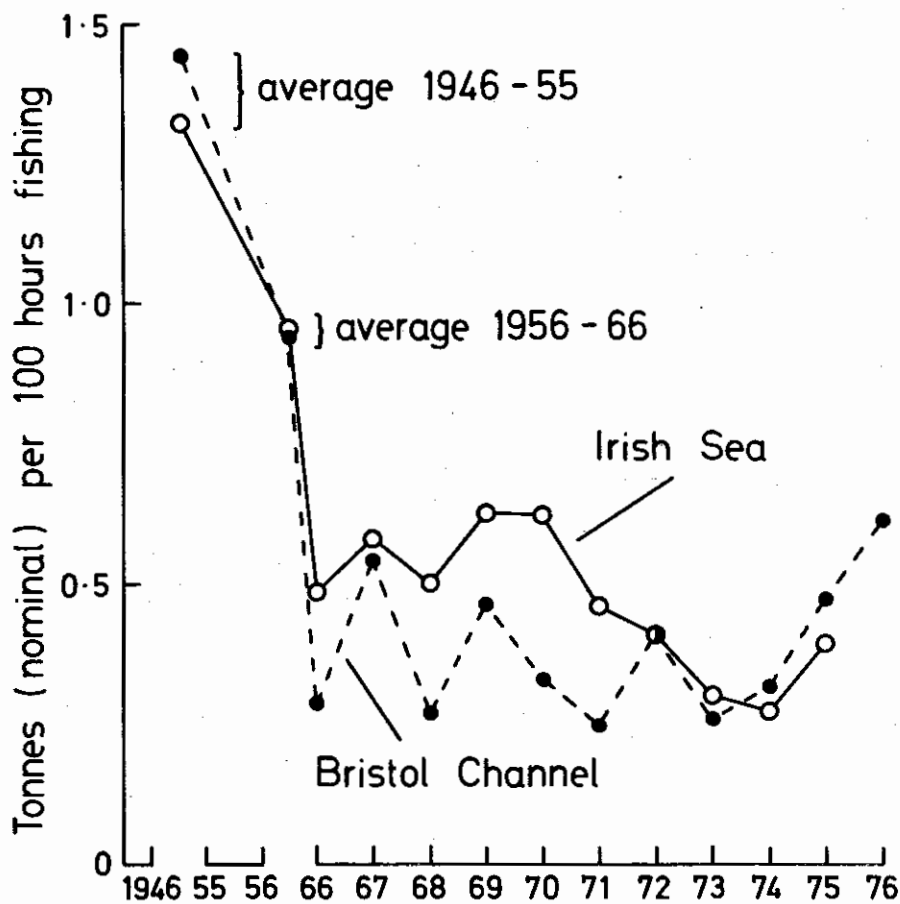


Figure 14 Catch per effort for sole in the Bristol Channel ●---● and Irish Sea O—O.

the War. In both areas there has been a roughly fourfold decline in cpe since the period 1946-55 and in the Irish Sea there was a particularly steep drop between 1970 and 1974. The total UK catch of sole in the Bristol Channel is now so low that cpe there is an unreliable index of abundance. In particular, there are three conflicting factors affecting cpe in recent years:

1. the advent of beam trawling at Newlyn which may be causing a rapid rise in fishing power and hence cause the index to be an overestimate of abundance;
2. opening up of new fishing areas as traditional grounds become unprofitable - this too may lead to unrealistically high estimates of abundance;
3. more vessels may have stopped fishing for sole in a directed way and they are now taken largely as a by-catch - this would effectively reduce fishing power on sole and cause abundance to be underestimated relative to periods when directed sole fishing took place.

The decline in the catch rate of sole may have serious consequences for the profitability of the whole mixed fishery at ports such as Milford Haven. A proposal has been put forward that selective fishing for sole by beam trawling should be banned, because if the sole element in an area of mixed fishery is

removed then the value of the remaining species is insufficient to make a fishery economically viable.

Recent assessments of Irish Sea and Bristol Channel sole (Holden 1971, 1972; de Clerck 1973; Anon. 1975, 1976) have all concluded that the present level of fishing mortality should be producing the conditional MYR. Nevertheless, the long-term yield per recruit would not fall by more than 5% if fishing mortality were halved; the catch rate then would be almost doubled (Figure 15).

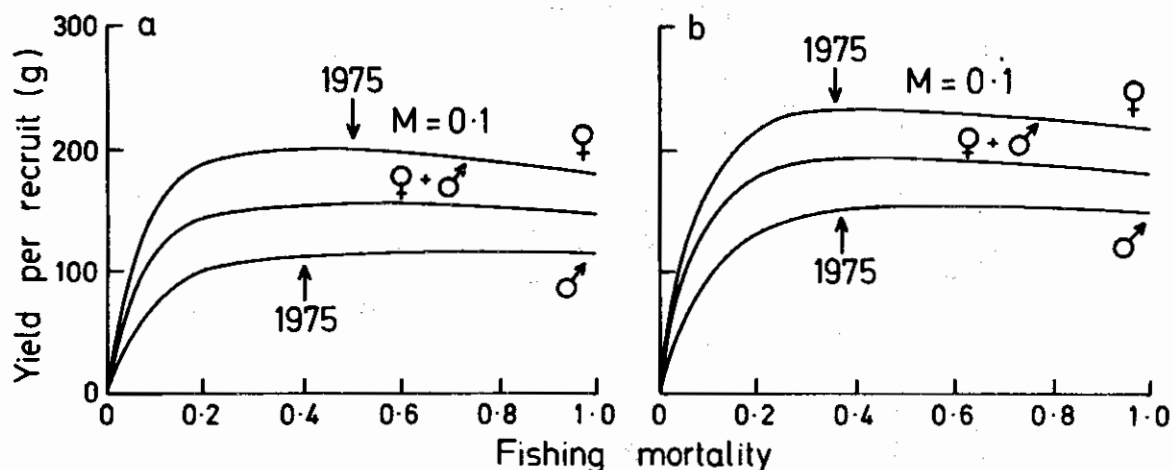


Figure 15 Yield per recruit curves for sole, (a) Irish Sea, (b) Bristol Channel.

de Veen (1976) has examined the causes of the present exploitation pattern for sole in the North Sea and how it could be improved by mesh regulation and seasonal or area closures. It would be worth while to carry out a similar analysis for the Irish Sea and Bristol Channel stocks.

Plaice

Irish Sea plaice have been the subject of more research than any other species in the area, with publications on spawning (Simpson 1959), movements (Macer 1972, Hill 1971), feeding (Jones 1952), parasites (Shelton and Wilson 1973), meristic characters (Purdom and Wyatt 1969), and an MSc thesis on their population dynamics (Griffith 1971). The fluctuations in their long-term catch are very similar to those of the total demersal category as a whole. The average annual catch in Division VIIa since 1967 has been around 4 400 tonnes compared with 2 800 tonnes for the period 1960-66. A large proportion of this, usually around 60%, is taken by English and Welsh trawlers and seiners in the eastern part of the Irish Sea. There is no marked seasonal fishery for plaice, although landings tend to be lower during the early months of the year because the quality of the fish is poor and the activities of the seiner fleet are curtailed.

Large tagging experiments on both sides of the Irish Sea show a similar pattern of migration to that of the cod. There is considerable movement north and south along the Irish coast and fish tagged in Red Wharf Bay also migrated into the areas south of Ireland. Apart from this area where mixing takes place, the fish from the two sides of the Irish Sea seem to remain separate, with very little migration across a line roughly at 5°W.

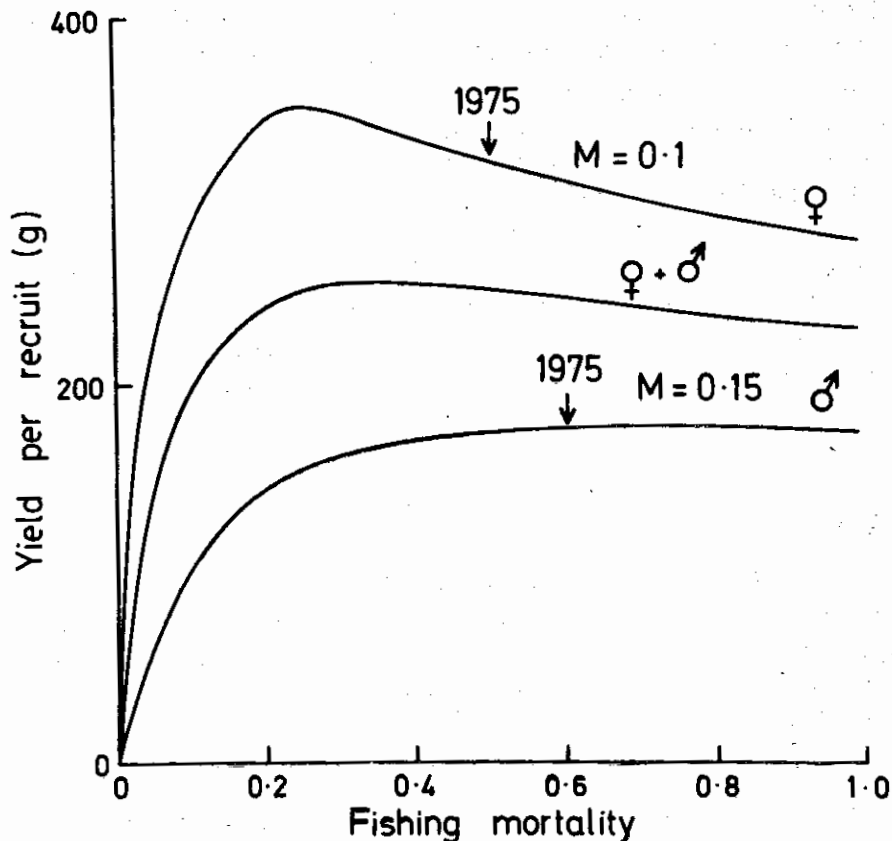


Figure 16 Yield per recruit curves for Irish Sea plaice.

As with the cod, there is clear evidence that growth is faster in the south and west of the Irish Sea. The 1976 meeting of the ICES Flatfish Working Group made allowance for this in calculating the combined growth curve. Their values of mean weight at age are used in the assessment of the area as a whole, which follows. It is also clear from the virtual population analysis that there is a trend in mortality with age such as occurs in North Sea plaice. Natural mortality is assumed to be 0.1 on females and 0.15 on males.

The yield per recruit curves based on these values are given in Figure 16 where the F values on the abscissa are the maxima from the F at age array. The combined curve for males and females peaks at a maximum F value of 0.3 to 0.4, but is fairly flat thereafter. The current level of fishing mortality is therefore roughly twice what it should be to take the maximum yield per recruit and even a threefold reduction in fishing effort would, in the long-term and according to this model, be expected to leave yields at their present level. The effects of an increase in mesh size depend almost entirely on what is assumed about discard mortality. For example, if one assumes that all discarded undersized plaice survive, then increasing the mesh size will have virtually no effect on yield per recruit.

In conclusion, it seems unlikely that the total yield of plaice from the Irish Sea can be improved by management measures such as catch and effort restrictions or changes in mesh size. There is a case for studying discard rates, mortality of discarded fish and mortality due to shrimp fishing in order to evaluate possible improvements in recruitment. It is possible that, in the long term, catch rates on plaice could be increased by a factor of up to three by reducing fishing effort, i.e. the same total catch could be taken by one third of the present fishing effort.

The Bristol Channel plaice are in a similar state to those in the Irish Sea except that here the decline in total catch since 1968 has been far greater. One of the problems in discussing the trend in total catch arises from the erratic nature of the French catch, which during the period 1968-75 fluctuated from nil (three years) to 50% of the total international catch (two years). However, even if one excludes the French statistics altogether, there has been a decline of 60% over the period. It is not clear whether this decline is due to poor recruitment, changes in migration pattern or both, but the yield per recruit curve, which is similar to that for the Irish Sea, suggests that there would be very little improvement in yield per recruit if fishing effort were reduced. Again, however, much higher catch rates could be expected at lower effort levels, according to this model.

Skates and rays

Skates and rays make up a far greater proportion of the total demersal fish catch in the Irish Sea than they do in the North Sea. In recent years they have averaged around 10% of the total demersal catch in both VIIa and VIII. Nevertheless, the trend in catch of skates and rays has been a slow steady decline since 1965 (Figure 2) and they constitute the only major demersal resource which is currently yielding below the 52-year average.

Two major problems in carrying out assessments of skates and rays are that they are difficult to age and that the catch consists of four species which are not recorded separately. The problem of ageing the fish can certainly be overcome (Holden and Vince 1973), but little research effort is currently being expended on them because of their low commercial importance. The species composition of the landings has been examined from time to time at Milford Haven and there was an appreciable change between 1961 and 1971 (Holden 1977). The proportions of R. clavata and R. montagui declined while those of R. brachyura and R. naevus increased. Since the species composition is different on different grounds throughout the Irish Sea this may be simply due to a change in the distribution of fishing effort. Figure 17 shows the numbers of each of the four main species caught per hour's fishing during two groundfish surveys in October and November 1976. The two areas in the north-east Irish Sea were covered by a small commercial vessel and the other three by RV CLIONE, so that catch rates are not strictly comparable, but the proportions of the different species should be accurate. R. clavata was the most abundant species off Conwy and in Cardigan Bay, where high catch rates were obtained. R. montagui was the most abundant species on the Tuskar grounds, but was caught in greater absolute numbers in Caernarvon Bay. All species were scarce between the Isle of Man and the Cumbrian coast. Cardigan Bay is one of the few areas where a directed fishery for rays exists, even though catches are mainly of the very spiky and commercially less attractive R. clavata. The amount of fishing in this area, at least by Milford trawlers, is to some extent dependent on weather conditions, since they will go there during spells of strong easterly winds.

The catch rate of skates and rays in the Irish Sea and Bristol Channel has fallen from close to 1.5 tonnes per 100 hours in 1954 to less than 0.5 tonnes per 100 hours in the years since 1969 (Figure 18). There is good evidence that, because of the direct relationship between number of recruits and stock size in

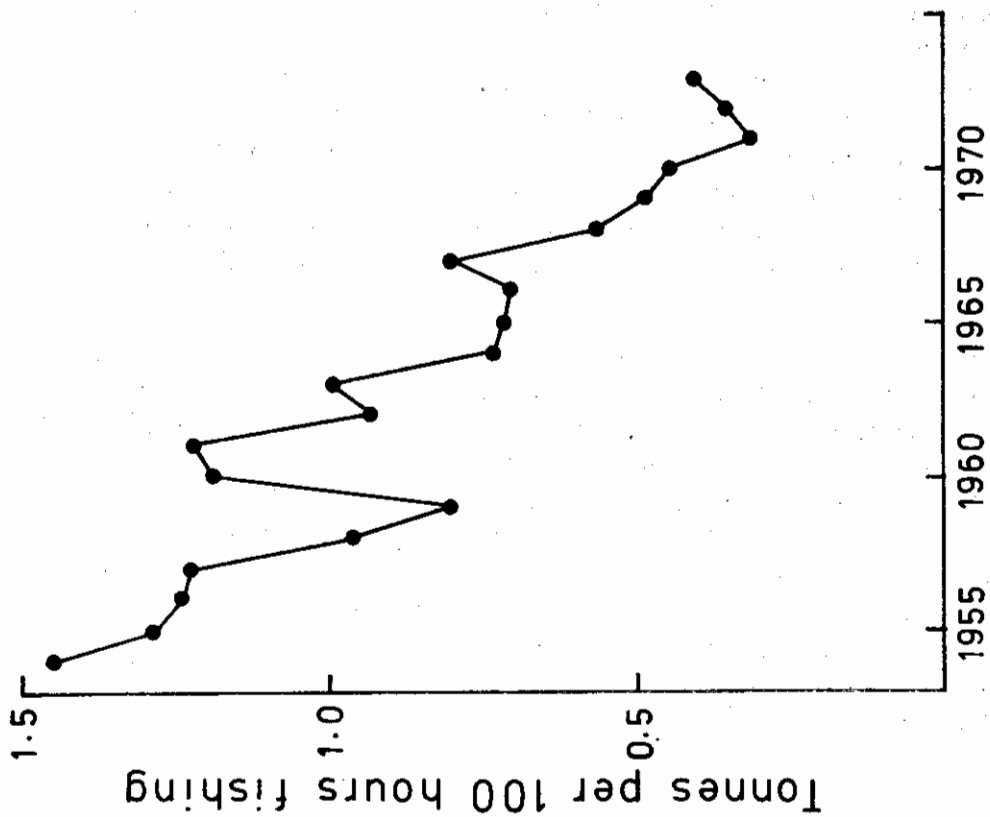


Figure 18 International catch per effort of skates and rays in ICES Divisions VIIa and VIII.

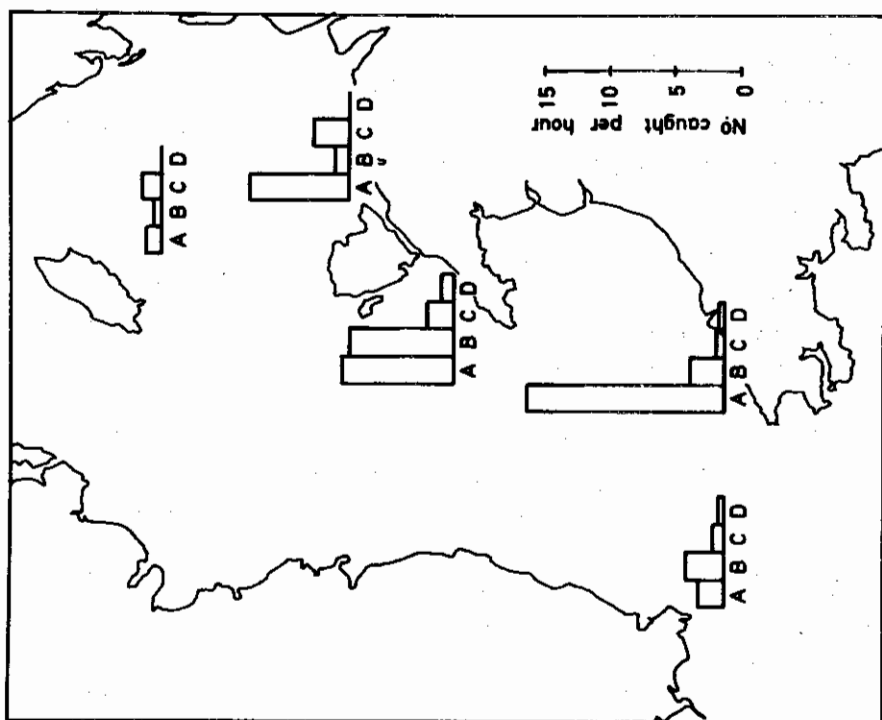


Figure 17 Catch rates of Rajidae on ground-fish surveys in October and November 1976.

- A. R. clavata,
- B. R. montagui,
- C. R. brachyura,
- D. R. naevus.

these species, the ability of these stocks to replace themselves has been damaged. Holden (*op. cit.*) states that ". . . . it seems very probable that these stocks of rays have not been replacing themselves for 15-20 years now. . . .". This is apparently the first demersal stock in the area whose recruitment has been affected by the current high levels of fishing effort and which must therefore be regarded as in danger of extermination or reduction to very low levels. The general question of whether, because of their different reproductive biology, sustainable fisheries for elasmobranch species are possible, has been considered by Holden (1974). In the context of mixed fisheries in the Irish Sea, the special regulation which they may require certainly poses a number of difficulties.

To begin with, the mesh size which would be needed in order to increase the size at first capture to correspond to a minimum marketable size, is very much bigger than is needed for the teleost fish in the area. Even though there are certain main areas in which rays predominate, the fisheries are genuinely mixed and a regime of closed areas or closed seasons would probably create some hardship. In the end it may be impossible to retain a sustainable fishery for rays in a mixed fishery situation, unless the overall level of fishing effort is reduced by at least 30%, i. e. to around the level which it was at in 1965. If prevention of the extermination of a commercially important species is to be one of the first objectives of a management regime, then skates and rays will have to be considered.

Herring

There are two stocks of herring indigenous to the Irish Sea: the Manx stock which spawns along the south and southern part of the east coasts of the Isle of Man between July and August, and the Mourne stock which spawns off the Co. Down coast between October and December. In addition, a variable number of herring larvae drift into the Irish Sea from the Celtic Sea (Dunmore) stock. As 1- and 2-ring immatures these mix with the local fish which are caught in spring between the Isle of Man and the Irish coast. The size of this influx seems to be determined by residual water movements, since it correlates closely with prevailing wind (Ozcan 1974).

The total international catches of herring in Division VIIa have increased enormously since 1964 and, although the vast bulk are still taken by UK and Irish vessels, there has been some participation by French and Dutch during the 1970s. The trend in international catch since 1964 is shown in Figure 19, and during that period the relative proportions of Manx and Mourne herrings have been 75% Manx, 25% Mourne. The present catches of around 20 000 tonnes of Manx herring are well over twice the average catch since 1948. It would appear that there has been a huge increase in stock size since 1963 due to a series of very good year-classes. In 1963 the number of fish in the stock was estimated to be 24 million fish, whereas in 1969 it was 206 million fish (Ozcan, *op. cit.*). There has also been a slight increase in growth rate over the period which further raises the stock biomass. The Mourne stock has also shown increased catches since 1968, but on both stocks there is now clear evidence that fishing mortality has become too high and that spawning stock size is being reduced too quickly. This is particularly so with the Mourne stock, which is

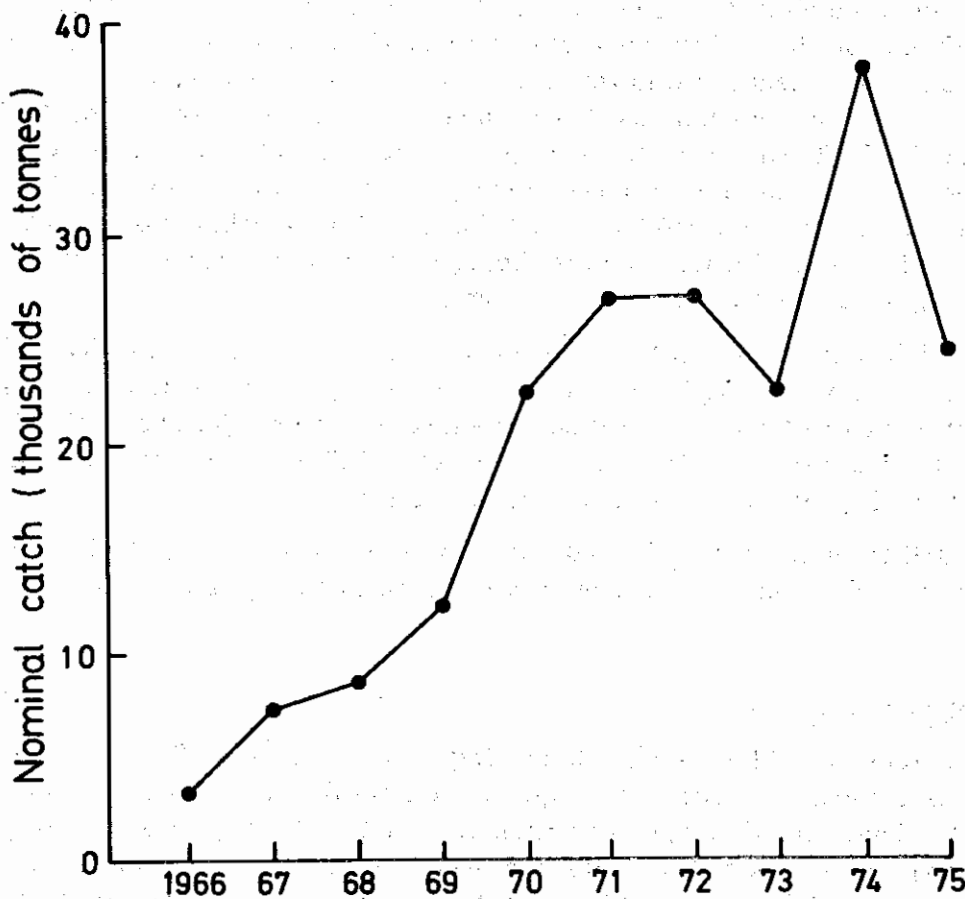


Figure 19 Total international catch of Irish Sea herring, 1966-75.

now exploited for a much greater part of the year and which has also until recently been exploited by an industrial fishery.

The huge increase in fishing effort from 1970 onwards was brought about because catch rates were high and because the traditional fishing areas in the North Sea were overfished. Virtually all the fishing for Manx herring takes place between 6 and 12 miles from the Isle of Man and the main participants are Scottish and Northern Irish inshore trawlers. In 1974 three freezer trawlers also took part but 94% of the catch was taken by inshore trawlers (< 80 ft). Most of the fishing occurs in September, and since 1973 there has been a prohibition on herring fishing within 12 miles of the Isle of Man from 1 October-17 November. There have also been short seasonal closures and other restrictions on the Mourne fishery. Since 1974 there has been some herring fishing throughout the year and this has meant that fishing mortality has remained high in spite of the seasonal closures. From January to May catches are chiefly taken west of the Isle of Man on a mixture of Mourne and Manx stocks. The number of trawlers generally increases rapidly throughout July and August and by the beginning of September most are fishing on the spawning grounds to the east of the island. After 1 October, when fishing is prohibited within 12 miles of the island, small numbers of catches are made outside 12 miles. The areas outside 12 miles are the only ones where foreign trawlers can fish and this accounts for the very low level of foreign effort. Landings continue from the Kilkeel grounds throughout November and December.

Because the closed season was insufficient to reduce fishing effort on its own, a catch quota for UK vessels was introduced in 1975. For 1976 the recommendation by UK scientists was that it should be 12 000 tonnes, made up of 9 000 tonnes of Manx herring and 3 000 tonnes of Mourne. In the event the Total Allowable Catch (TAC) for Manx herring was set at 12 000 tonnes, but was in fact exceeded. The catch of Mourne herring is not known at present. The recommendation made for 1977 was that the TAC for the whole north Irish Sea area should be 13 000 tonnes, the aim being to build up the spawning stock sizes and give higher catch rates in the long term.

The difficulty with this type of year-to-year regulation stems from the fact that recruitment is highly variable and a large part of the catch consists of recruiting year-classes. Pre-recruit surveys are only just beginning in the area (Molloy and Corten 1975, Wood and Howlett 1976) and it will take some years before they become a reliable predictive tool.

A further measure which would help to maintain spawning stock size and catch rate would be the introduction of a minimum landing size of 20 cm.

Nephrops and other shellfish

The total weight of shellfish landings from the Irish Sea and Bristol Channel is comparable with the weight of demersal and pelagic fish landings (Table 2). They include large quantities of valuable Norway lobsters (Nephrops norvegicus), scallops and lobsters and make up the major part of the earnings of the Northern Irish, Manx and Scottish fleets. The earnings of Welsh inshore fishermen come to a great extent from lobsters, while along the Lancashire coast there are extensive shrimp fisheries.

There are two main ways in which the exploitation of shellfish resources affects the overall management of Irish Sea and Bristol Channel fisheries. The first is that small-mesh nets are used for catching Nephrops and shrimps and this results in very heavy mortality on young roundfish and flatfish. The second is that even where shellfish stocks do not provide the main livelihood for a fleet they often form a valuable alternative resource at certain times of year. Assessments of shellfish stocks are generally less advanced than those for fish species because many problems still exist over determining age structures, growth rate and abundance.

The quantity of juvenile flatfish caught in the shrimp fisheries along the English coast is unknown and so also is the effect on flatfish recruitment. The shrimps themselves have been the subject of some recent studies (Driver 1976) and it has been found that there is a very close relationship between the catch rate of brown shrimps at Lytham St Annes in any one year and the mean sunspot number in the previous year. Since the sunspot numbers can be predicted fairly accurately for years ahead, this provides a means of predicting future shrimp catch rates, which are expected to show their next peak in the early 1980s. The mechanism whereby this relationship might be established is unknown, but may involve changes in water temperature.

A great deal more work is also needed on the population dynamics of the major molluscan resources, particularly scallops and queen scallops, before they can be incorporated in an overall management strategy for the Irish Sea.

A recent assessment of the Irish Sea Nephrops stocks (Brander 1975) allows some conclusions to be drawn about the effects of existing mesh regulations and of proposed changes in them.

A Nephrops trawl with a 40 mm cod-end will generally catch about 25% more marketable (> 30 mm carapace length) prawns than one with a 70 mm cod-end, but there is some doubt about the way in which mesh selection operates. If the selection characteristics are of the type described by Brander (*op. cit.*, Figure 2), i.e. the 40 mm mesh retains all prawns above 24 mm and the 70 mm mesh all those above 44 mm, then the yield per recruit will be greater by using the 70 mm mesh, because the age of first capture is increased (Figure 20). Even if this type of mesh selection does not take place, there is still a case for raising the mesh size to 70 mm, because this would reduce the fishing mortality from its present value of close to 0.8 (Hillis 1975; assuming $M = 0.2$) some way towards the value of 0.2 needed for MYR (see Figure 21).

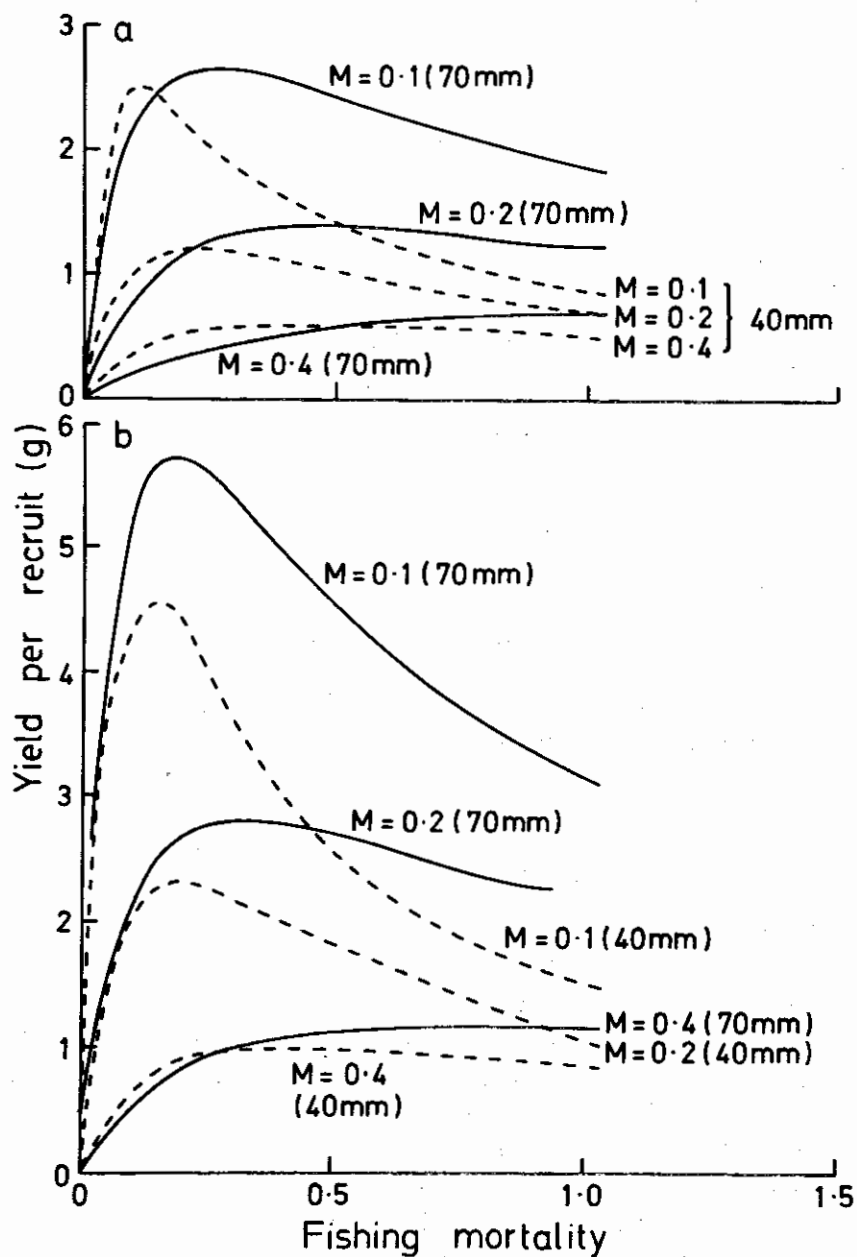


Figure 20 Yield curves for Nephrops with 40 and 70 mm uniform mesh size, (a) females, (b) males.

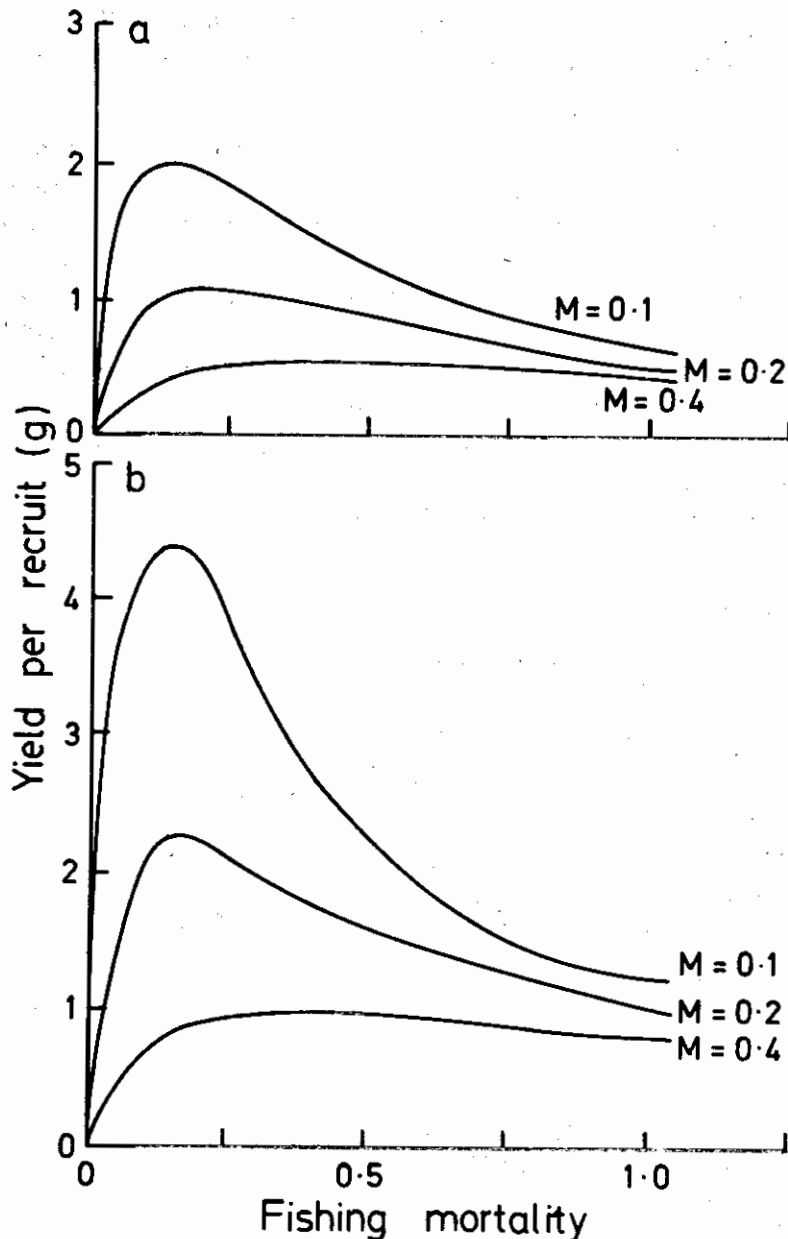


Figure 21 Yield curves for *Nephrops*, no selection operating, (a) females, (b) males.

THE TOTAL DEMERSAL PRODUCTION MODEL

The figures of total fish catch which have been quoted so far, e.g. Figure 2, do not give a reliable guide to the changes in abundance of the stock because the catches may have resulted from different amounts of fishing. As an index of stock abundance the catch rate or catch per unit effort is more useful. The first step in looking at demersal fish production in relation to fishing effort is to standardize the unit of fishing effort in order to allow for changes in fishing power between the fleets of different countries and for changes over the years due to increases in engine power and improved fishing and navigational methods. The object of standardizing the recorded statistics of fishing effort (i.e. fishing inputs) is to make them more closely proportional to fishing mortality. Standardized estimates of fishing effort are also needed to relate the level of

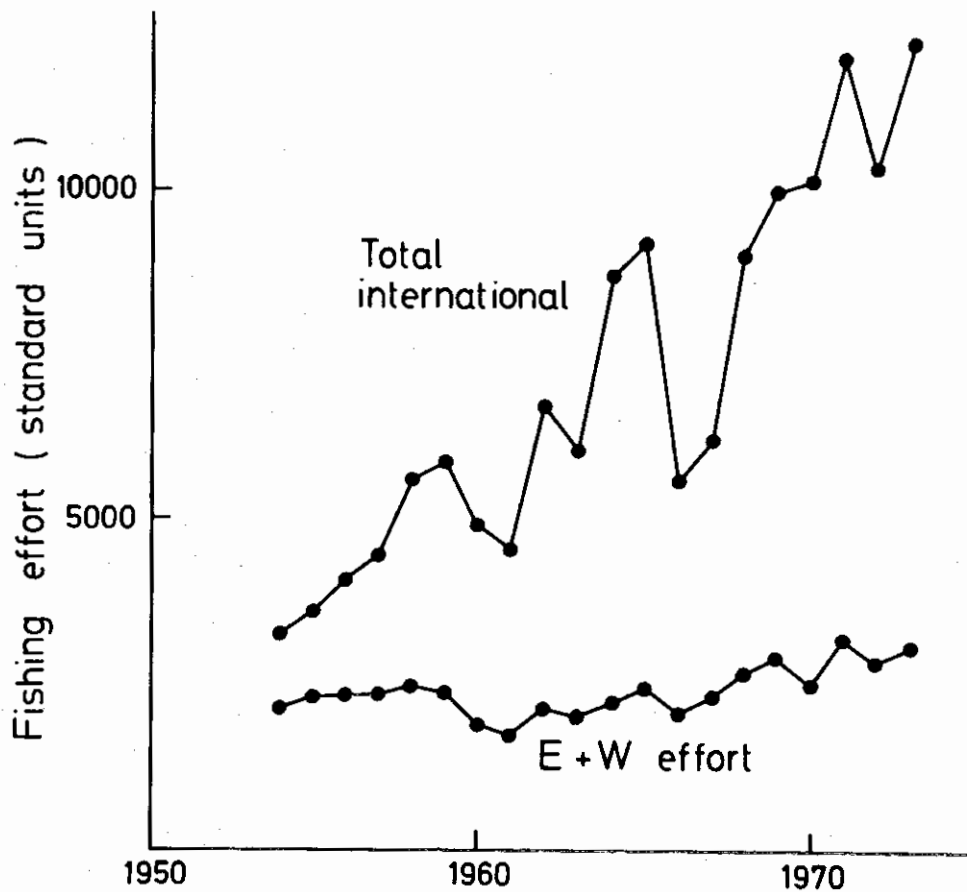


Figure 22 International fishing effort corrected for trends in fishing power.

production (e. g. tonnes produced per year) to the rate of removal by fishing.

The method of calculating standardized figures for total international fishing effort is given in Appendix A and the results are shown in Figure 22. The figures are derived from Belgian and English and Welsh motor trawl statistics. Figure 22 shows that total international fishing effort has increased by a factor of four during the period 1954-73, albeit starting from a rather low level. As the general production model which will be used needs data on yields at different effort levels it is fortunate that such a wide range of effort occurs, but, at the same time, the fact that there is an increasing trend means that the assumption of a steady state in the model is violated. The effect of this violation is not likely to be serious because the method of averaging fishing effort over a three-year period compensates for it (Gulland 1961).

Applying a model of this kind to total demersal biomass means that one is assuming that the net production of the individual species is linked in such a way that (a) the mean total demersal biomass at equilibrium depends on the overall level of fishing effort and (b) the equilibrium yield (i. e. annual net production) is determined by the mean total demersal biomass and the fishing effort applied to it. The 'carrying capacity' of the environment - in this case the Irish Sea - for each species is partly dependent on the level of biomass of the other species present, because they interact with each other. Whether this overall 'carrying capacity' is limited by food or some other factor is of no concern at present.

Nothing can be concluded from this model about the changes in biomass of individual species which might result from the different levels of fishing effort, because the model does not incorporate the ability of vessels to concentrate on particular species. The relative catchability of different species is assumed to remain constant as far as the total effort is concerned. Fox (1974) examines the effect of relaxing this assumption.

For the years 1956-73 the observed relationship between total demersal catch per effort and the running three-year mean of fishing effort is concave upward and the natural logarithm of catch per effort was therefore taken before fitting a straight line by geometric mean regression (Fox 1970, Ricker 1975). Figure 8 shows the regression with approximate 95% confidence limits on the distribution of the points. The correlation coefficient is -0.93 , which is highly significant even allowing for the use of the running three-yearly mean. Thus, over the wide range of effort which has occurred, there seems to be a remarkably consistent relationship between fishing effort and total demersal biomass. At least within this effort range there is a firm basis for predicting the steady-state catch rate which would result from different levels of fishing. The result of transforming this line, including the extrapolated parts, into a steady-state yield curve is shown in Figure 9. The confidence limits are the same as those shown in the previous figure and the reason why different yearly values lie outside them is because the denominator of cpe is the annual value, not the three-yearly mean.

The yield curve predicts that any further sustained increase in fishing effort would result in a decline in yield although initially a sudden increase would probably result in very high catches. In order to test whether a similar decline would be predicted using only data for the period 1963-73, during which the massive increase in total demersal catch in the Irish Sea and North Sea took place the model was recalculated using data for just those years. The results are so close to those for 1956-73 that the new lines could hardly be plotted in Figures 8 and 9 without cluttering them.

A MANAGEMENT REGIME FOR THE IRISH SEA

The management of fisheries in the north-east Atlantic has been undergoing rapid changes, but it is now possible to discern in broad terms the type of management structure which will emerge. The major developments in modelling the dynamics of exploited fish populations took place during the 1950s and, based on these developments, regulations on mesh size and minimum landing size of commercially important species were introduced. These regulations were intended to raise the age at first capture in order to maximize the yield per recruit at the current level of fishing effort. Since little was, or is, known about the causes of fluctuations in recruitment and since the absolute size of the stocks could not be estimated easily at that time, it was rarely possible to derive the yield curve itself, but only the yield per recruit curve. The maximum yield per recruit position could, in theory, be maintained by adjusting the age of first capture (via the mesh size) to the current level of fishing (i. e. the fishing mortality), but in practice such adjustments were a crude instrument of management because different species require different mesh sizes and because mesh size could not be changed to take account of year-to-year changes in fishing.

As the amount of fishing effort rose it became clear that some limitation would have to be imposed on the resultant fishing mortality and that this could be done most easily by means of catch quotas on individual species. These were first introduced for demersal species in the north-east Atlantic in 1974 and have been up-dated annually since then. As well as the practical difficulties of enforcement, a major shortcoming of annual catch quotas (or effort restriction) is that they may reduce the catch but leave the cost of taking that catch virtually unchanged. The rather haphazard laying up of vessels at certain times of year, because quotas have run out or because a closed season exists, is an economically inefficient form of management. It can also cause great bitterness if other countries are still able to fish because their quota is not full. In order to reduce costs and prevent haphazard laying up of vessels, the total catching capacity of the international fleets would have to be reduced over a period of time but, with the difficulties which have existed in obtaining year-to-year agreement on TAC, the idea of long-term planning of fleet sizes has been unthinkable internationally and futile unilaterally. The advantage of the recent actions on exclusive fishing limits, which bring the resources under limited ownership, is that it becomes possible to think about a strategy for fleet size with some assurance that it will succeed. Some conclusions may be drawn about the constraints imposed on such a strategic plan by the nature of fish stocks in the Irish Sea and Bristol Channel.

There are two principal features of the living resources of the Irish Sea which have a profound influence on the industry which exploits them. The first is that production of fish per unit area is low and, since the total area is small, the total yield from the area is also low. This fact has protected the area from large incursions by mobile fleets, because catch rates were too low to be commercially attractive. The last few years have seen the failure of this protection for two stocks, namely the sole and the herring. Although the reasons for the low productivity are unknown, it seems unlikely that total yield will ever be much greater than at present. At the same time the total fishing effort needed to take this yield is less than operates in the area at present.

The second feature of biological production is that the catch consists of a large number of species and very few fishing enterprises are able to sustain themselves only or mainly on one of these. In some cases a vessel will direct its activity at one species for certain periods of the year, switching from cod and whiting in the spring to sole and plaice in the summer and then possibly to queen scallops or herring later in the year. In other cases mixed catches are taken throughout the year, but either way the vessels need to be flexible in their use of gear and methods of work.

If one of the first aims of a management strategy is to safeguard the interests of fishing fleets which are entirely reliant on the Bristol Channel and Irish Sea for their livelihood, whether they are local or not, then attention must be focussed on the activities of mobile fleets fishing selectively or seasonally for particular species. The seasonal sole and herring fisheries are the only ones attracting large amounts of mobile effort at present, but they are quite different cases. The herring fishery exploits a stock which is not a part of the year-round mixed catch in the area. The main local fleet exploiting the herring is the Northern Irish trawler fleet and, with the present stock levels, some mobile effort is undoubtedly needed to take advantage of the resource which is

available. The sole stock, on the other hand, is a major component of the mixed catch in the area and if mobile beam trawl effort is allowed to exploit it selectively at certain times of the year, this may reduce the profitability of the remainder of the fishery and thus prevent the full potential, in terms of maximum yield of all species, from being realized.

The problem of balancing the fishing mortality which is directed at different species is an extremely involved one and it poses quite clearly the contradictions which are inherent in trying to apply single species maximization criteria to mixed fisheries. For example, with the present balance of fishing mortality the skate and ray stocks are in danger of serious depletion but the sole stocks are probably closer to MSY than any other. Complaints about overfishing, however, are directed mainly at the sole stock. The criteria adopted for managing the fishery will have to be very much more flexible than those used at present in setting TACs. To begin with it may be necessary to acknowledge that skates and rays will have to undergo further depletion, since they are largely an unavoidable by-catch.

Another facet of the special mixed fishery situation which exists in the Irish Sea is the importance of shellfish, particularly Nephrops. Fishing effort directed principally at Nephrops and using small-mesh nets has resulted in excessively high mortality on juvenile whiting and cod, as well as having created an enforcement problem. Similarly the small-mesh fisheries for shrimps have caused high mortalities on flatfish.

The ways in which exploitation pattern and level of fishing mortality should be adjusted for individual species were outlined on pages 16-33. It is not possible at this point to investigate the interactions between the regulatory actions which might be instituted for all these species. The effect of trying to manage the mixed fisheries in the area only by setting TACs on each species separately would be to increase the costs and uncertainties of the industry still further and to bring the regulatory system into even greater disrepute. I believe the situation can be improved by concentrating on the problem of obtaining some agreement on the long-term size and structure of the fishing fleets which work in the area and in the meantime relaxing the attempts at single species regulation. Some suggestions about a scientific approach to this problem are contained in Appendix C. The fisheries of the Irish Sea and Bristol Channel are not grossly overexploited and the changes in fishing activity needed to ensure their continued productivity are urgent but probably not drastic. Past management measures such as mesh regulation, closed seasons and catch quotas have played their part in maintaining the stocks and will continue to do so, but they are not enough to ensure the continued productivity of the area and the prosperity of those who fish it.

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APPENDIX A CALCULATION OF STANDARDIZED FISHING EFFORT STATISTICS

Only two series of data on nominal fishing effort are sufficiently complete to be used in calculating effort statistics for VIIa and VIII. These are the Belgian and the English and Welsh otter trawl data which between them account for about 20-30% of the total demersal catch and go back to 1954. The tables in the Bulletin Statistique changed in 1961 and this has meant leaving out the Belgian fishing effort prior to then because the equivalent total demersal catch was not known. Both series have been corrected for trends in fishing power by using all the available data (shown in Figure A1) to get some idea of the trend in horse-power and calculating a fishing power correction from this. The Belgian correction factor was calculated by using the relationships for sole and plaice given by Zijlstra and de Veen (1963) for Dutch otter trawlers; the English and Welsh factor was calculated using a relationship established by Houghton (pers. comm.). These show that between 1954 and 1975 Belgian fishing power increased by 70% and English and Welsh fishing power by 30%.

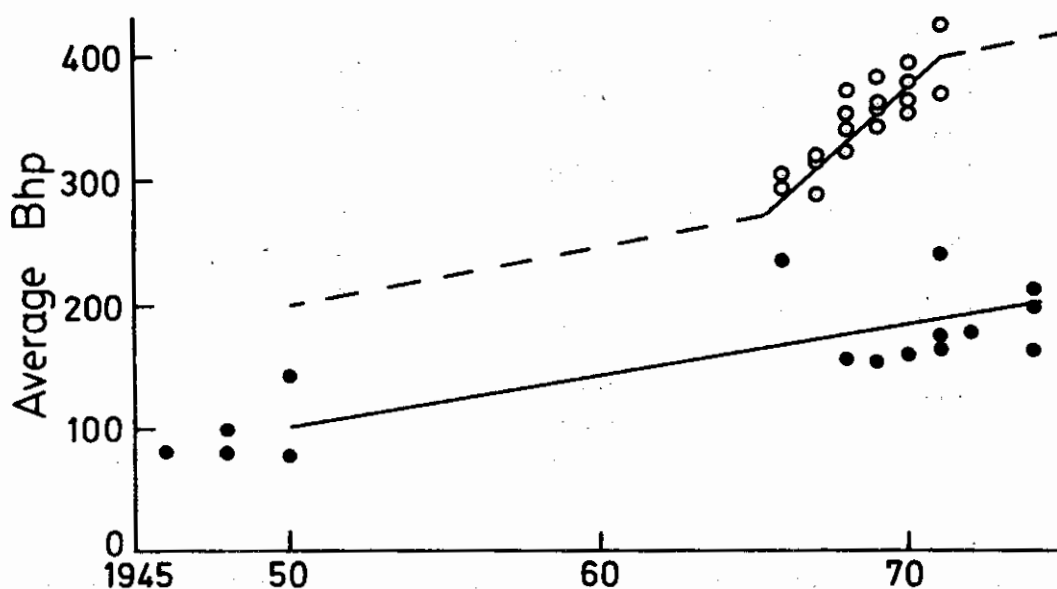


Figure A1 The trend in horse-power for Belgian otter and beam trawlers O---O and for English and Welsh otter trawlers ●—●.

English and Welsh steam trawler hours were converted to motor trawler hours by multiplying by 1.2, a factor derived by equating catch rates for the two methods of propulsion over the period 1949-57. Belgian nominal effort is first corrected for fishing power and then converted into English and Welsh equivalent units by multiplying by 0.8561, the ratio of the total demersal catch rates during the period 1961-73. Finally, the total international effort is estimated by raising the corrected effort by Belgian and English and Welsh otter trawlers to the total international demersal catch. The results are presented in Table A1 (and were plotted in Figure 22 in the body of the report) in units of 100 h fishing by 1954 English and Welsh otter trawlers. This is referred to throughout as the standard unit.

Table A1 International and English and Welsh fishing effort in Divisions VIIa and VIII. Units are 100 h fishing by a 1954 English and Welsh motor trawler and the figures are calculated from English and Welsh and Belgian statistics, corrected for trends in fishing power

	International effort	English + Welsh effort	Catch per effort of total demersal
1954	3 206	2 133	8.6
1955	3 513	2 252	8.0
1956	4 046	2 310	8.2
1957	4 423	2 375	8.8
1958	5 572	2 434	7.0
1959	5 887	2 364	5.8
1960	4 882	1 852	7.5
1961	4 560	1 705	7.6
1962	6 743	2 126	6.4
1963	5 595	2 059	6.2
1964	8 706	2 216	5.6
1965	9 195	2 391	5.4
1966	5 612	2 052	6.1
1967	6 201	2 292	6.8
1968	9 114	2 659	5.9
1969	10 035	2 892	5.1
1970	10 165	2 427	4.3
1971	12 042	3 108	4.2
1972	10 377	2 837	4.5
1973	12 269	3 021	4.3

With some fluctuations, which may (particularly in 1966 and 1967) be due to erratic reporting of the French catch, the total fishing effort in VIIa and VIII has risen rapidly since 1954. English and Welsh effort has been rising very much more slowly since reaching in 1961 what was probably its lowest point this century (apart from the War years). Most of this increase can be attributed to increased fishing power rather than an increase in overall fleet size.

APPENDIX B THE EFFECT OF DIFFERENT FISHING MORTALITIES ON THE VARIABILITY OF SOLE CATCHES

It has been argued that one of the benefits of reducing fishing mortality is that the size of the stock is thereby increased and that the variability in the catch from year to year due to fluctuating recruitment is damped. The extreme case would be if all fish were caught as soon as they recruited, in which case the variability in catch would equal the variability in recruitment. If it is proposed to reduce fishing mortality below the level needed for maximum sustainable yield in order to reduce the fluctuations in catch, then there must be some consideration of the trade-off between loss of catch and reduced variability in catch. For example, is it preferable to have an average catch of 1 000 tonnes with fluctuations between 750 and 1 250 or an average 950 tonnes with fluctuations between 900 and 1 000?

In order to try to quantify the relationship between variability in recruitment, fishing mortality and yield, a simple numerical model has been devised which resembles the fisheries dynamics of the North Sea sole.

Recruitment is generated by random numbers and has the following characteristics: the probability of the number of two-year-old recruits being between 20 and 160 million is 0.9 and the probability of their being between 160 and 500 million is 0.1. No account is taken of stock level or of any possible seriality in the amount of recruits (there is evidence for some stocks that the variability in recruitment increases as stock size is reduced and this would make the variability in catch at high fishing mortality greater).

Natural mortality was set at 0.1 and the growth characteristics and exploitation pattern are those of the female North Sea sole. The simulation was run for 100 years using several values of fishing mortality and the same series of recruitments.

Figure B1 shows the resultant mean yield, the maximum and minimum level of yield in any one year, and an interval of one standard deviation on either side of the mean. The mean yield is exactly the same as the steady-state yield curve obtained by multiplying the yield per recruit curve by the average mortality for the 100-year period.

Comparing, say, an F of 0.6 with an F of 0.3, the yield remains the same, but the fluctuation between maximum and minimum annual catch is reduced by 25% at the lower level. If, for example, a processing plant was set up to deal with the average level of catch then it would have to deal with 50% more than that roughly once in every 9 years if F is 0.6 and in every 17 years if F is 0.3. Since the distribution of annual yield is not normal, the standard deviation is not a very useful statistic.

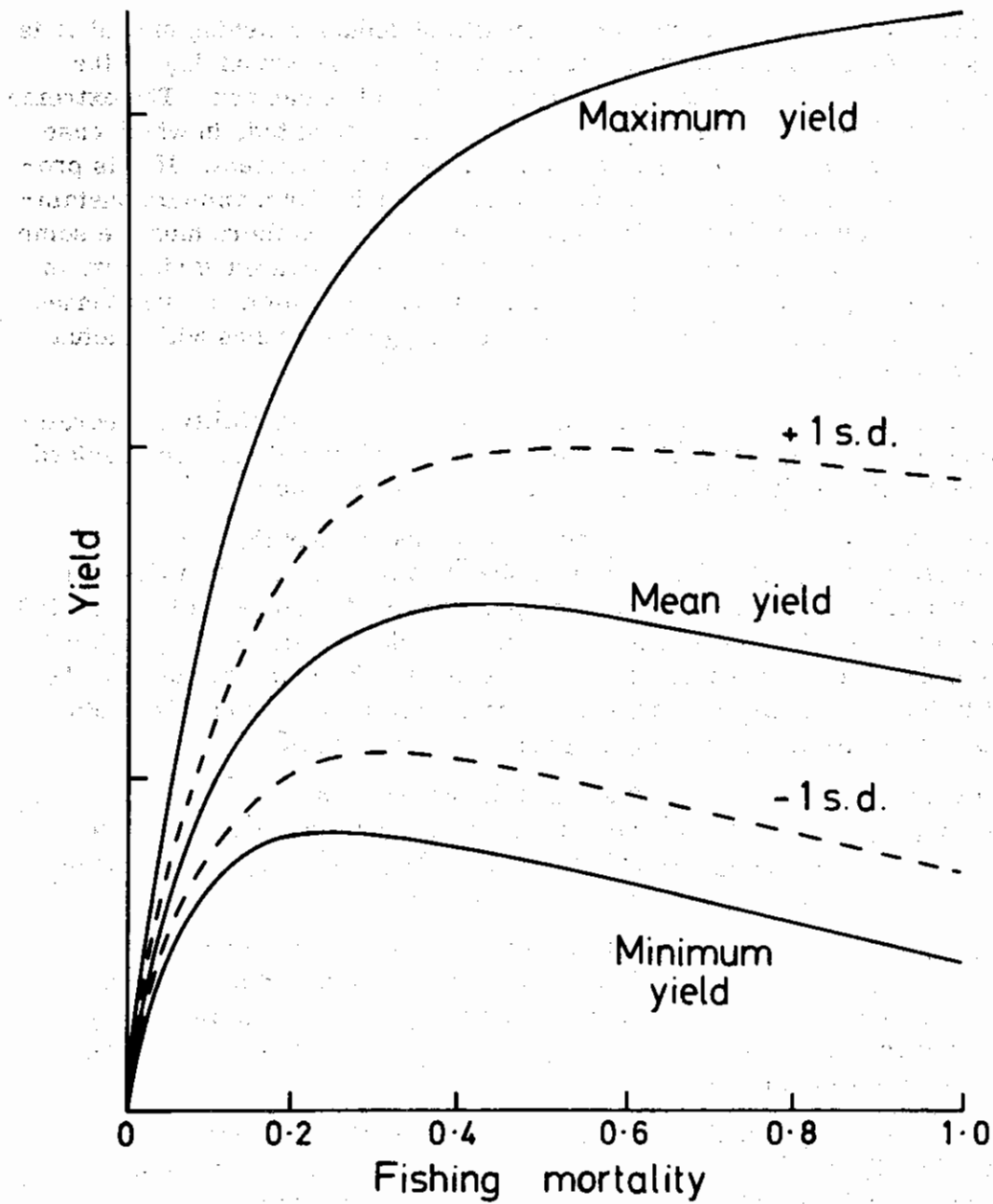


Figure B1 Simulated yield curve for a sole stock, showing the effect of fishing mortality on the variability of yield.

APPENDIX C A SUGGESTED CHANGE IN THE SCIENTIFIC AND TECHNICAL ADVICE ON MANAGEMENT

The difficulty in changing from the present single species approach to a mixed species, area-based assessment is that there is no consensus among fisheries biologists about how the problem should be tackled. The methods used by the present ICES Working Groups have evolved over a number of years and have become a matter of routine. The 'objectives' in setting TACs are clearly defined in terms of yield per recruit theory and, although misgivings are sometimes expressed about the accuracy and precision of estimated quotas, their relevance to the management of mixed fisheries as a whole is rarely questioned. Social and economic factors, although not considered explicitly, nevertheless play a major part in determining what work is done and what management options are feasible. Particular species are selected for attention by Working Groups because of their economic importance. Sole and plaice, the only two demersal species under quota in Divisions VIIa and VIII, were initially regulated in order to prevent diversion of fishing effort from the North Sea. Together they make up only 15% of the total demersal catch in VIIa and VIII and no conclusions about the overall management of fisheries in the area can be drawn from only two assessments, especially since they point in opposite directions. The fishing mortality on sole is close to optimal for conditional MYR, but is too high by 100% on plaice. A general pattern does begin to emerge when all the available assessments are looked at together, as has been done in this paper. Various more sophisticated production models could also be attempted. As well as studying the effect of different kinds and levels of fishing effort on the mixture of species, such models might go some way towards explaining the difference in productivity between the Irish Sea and the North Sea and also the causes of the great increase in catch since the early 1960s.

An international Working Group could look at these problems for the area, with two main aims:

1. To make recommendations about the size and structure of fishing fleet which should be encouraged to develop in the long term.
2. To study ways in which adjustments to present fishing activity can be made in the interim period (say five years) in order to increase or maintain yields and to minimize disruption and uncertainty.

Such a Group might begin by documenting the statistics of catch, fishing activity (including fishing effort, fishing power and relative catchability of different species), species biomass and relative value of different species. If one of the aims is to adjust the amount and type of fishing effort to the available resources then economic criteria need to be included explicitly even if they do not play a major role in the assessments. Attempts to avoid this by setting maximum weight of total fish production as the objective are short-sighted; one is thereby merely assuming equal value for all species. The management measures proposed should also take account of the effects on harvesting costs, since these should normally be kept low.

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