HELGOLÄNDER MEERESUNTERSUCHUNGEN
Helgoländer Meeresunters. 33, 687–699 (1980)

Fisheries management and conservation in the Irish Sea

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ABSTRACT: The Irish Sea ia a relatively small, enclosed sea area which is subject to a wide range of human uses including navigation, oil terminals, dumping of sewage and industrial sludge, cooling for nuclear power stations, gravel extraction, gas and oil prospecting and fishing. Commercial fishing is affected by the other uses and at the same time it provides a means of monitoring their effects on a part of the ecosystem. Regular samples taken from fish markets provide a long series of age-composition data of the main commercial species – cod, whiting, plaice and sole – from which population changes can be assessed. More recently groundfish trawl surveys have been carried out to provide more detailed information on the distribution of all demersal fish species seasonally and in relation to area, depth and sediment type. Advice on the management of commercial fish species is prepared by a working group of the International Council for the Exploration of the Sea (ICES), and is based mainly on analytical single-species models. There are obvious shortcomings of such models in an area of mixed fishery and high diversity such as the Irish Sea. The objectives adopted in these models and in fisheries management generally are examined critically in relation to the possible aims of conservation.

INTRODUCTION

The Irish Sea (ICES Division VIIa, see Fig, 1) has an area of approximately 45 000 km^2 and is a relatively enclosed sea which is subject to a wide range of human uses. Its maximum depth, in the North Channel, is over 200 m but most of the area is less than 50 m deep. In terms of annual fish yield it is one of the least productive areas around the British Isles (Brander, 1977) and this may be linked to the apparently short and late production cycle (Colebrook, 1979) which may in turn be due to strong tidal mixing and low solar radiation during the spring months (Dickson & Reid, in preparation).

In several respects the Irish Sea is the most polluted sea area around the British Isles. The levels of zinc, copper, reactive mercury and manganese are all higher than those in the North Sea or English Channel (Sheets 50 and 51 of Lee & Ramster, 1979). This is due partly to high natural levels and runoff from old mine workings, but mainly to industrial inputs and sludge dumping, the scale of which is documented by the Department of the Environment (1978) and by Murray & Norton (1979). The major discharge of radioactive waste in the UK takes place at Windscale in Cumbria and levels of caesium-137 in the Irish Sea are up to three orders of magnitude higher than those in the North Sea (Mitchell, 1977).

Other activities affecting life in the sea are: navigation by oil tankers, cargo vessels and ferries – the scale of which can be judged from sheet 7 of Lee & Ramster (1979); oil terminals – there are major terminals at Milford Haven and Anglesey; gravel extraction

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by dredgers – mainly in Liverpool Bay (sheet 23 of Lee & Ramster, 1979); oil and gas prospecting – again mainly in Liverpool Bay at present.

All of these have caused concern about the state of the marine environment both because of the danger to life in the sea and, in the case of pollutants, because of the danger of return pathways to man. Monitoring programmes have been established, particularly with the latter in mind (Mitchell, 1977; Murray, 1979; Portmann, 1979). The direct effect of pollutants on life in the sea is very difficult to establish, particularly outside the littoral, since so little is known about natural population levels and their fluctuations. Even where lethal effects are not observed there may be less easily detectable sublethal ones, although the distinction is not a particularly important one in terms of population dynamics, since in either case a change is brought about in one or more of the population parameters (growth, mortality, net reproduction, migration).

It has been suggested that toxic wastes, particularly PCBs, may have been a contributory factor in the increased incidence of epidermal lesions in the flatfish populations of the North East Irish Sea in 1971 (Perkins et al., 1972). Shelton & Wilson (1973) collected further data on epidermal lesions and concluded that "... of all the environmental variables which can be invoked to explain these results, pollution is the least likely." Sindermann (1977) quotes only the earlier of these studies and adds, erroneously, that "Fin damage, unknown before 1970 (in the Irish Sea), was observed in plaice and dab."

The role of pollution studies is well known, but in addressing the problem of protecting life in the sea it seems strange that the need for studies of fisheries is sometimes questioned. There are at least two reasons for this state of affairs which have recently come to the author's notice. One is that fisheries biologists are regarded as having the interests of the fishing industry rather than those of the marine ecosystem at heart and the other is the idea that fisheries statistics are subject to too many uncertainties to be of any use in monitoring population changes due to pollution.

This paper seeks to examine the validity of these criticisms and to show that fishing has had a very great effect on Irish Sea fish populations. Studies of the fisheries are therefore essential when considering the aims of marine conservation in the area and are also necessary when drawing conclusions about the possible effects of pollutants.

STUDIES OF COMMERCIAL FISHERIES

Records of catches of commercial fish species and studies of their population dynamics go back over several decades, putting them among the most closely monitored natural animal populations. The study of commercial fisheries provides the foundation for management of fishing activity to maintain yields and it may also provide a means of monitoring the effects of other human activities on a major component of the marine ecosystem. Fishing itself can be shown to have a very great effect on the exploited populations and three kinds of study will be described to give an idea of their scale and resolution: (a) a straightforward description of the long-term catch trends and an examination of the historic catch and effort data for demersal species to produce a yield curve; (b) the analytical assessment of the state of the stocks of single species, incorporating growth, mortality and recruitment; (c) an analysis of part of a series of groundfish surveys in the North East Irish Sea.

LONG-TERM CATCH TRENDS AND TOTAL DEMERSAL SURPLUS PRODUCTION

Statistics of annual landings of fish and shellfish by country have been recorded in the Bulletin Statistique of the International Council for the Exploration of the Sea (ICES) since 1909. Throughout most of this period landings were reported for the Irish Sea and Bristol Channel combined (ICES Divisions VIIa and VIIf, see Fig. 1) and it has therefore been necessary to keep them combined in examining the long-term catch trends and in calculating total demersal production. The 1977 Bulletin records landings of 30 demersal fish species, 5 pelagic fish species and 15 shellfish species from the Irish Sea. The countries taking part in the fishery are UK, Ireland, France, Belgium and the Netherlands. The principal demersal species are cod, whiting, plaice, sole and the ray species. Herring make up the bulk of the pelagic catch and the main shellfish species are Norway lobster, queen scallops, scallops and mussels. In 1977 international landings of demersal fish in ICES Division VIIa totalled about 34 000 tonnes, pelagic fish about 22 000 tonnes and shellfish about 21 000 tonnes. The high proportion of shellfish, over 27 % of the total

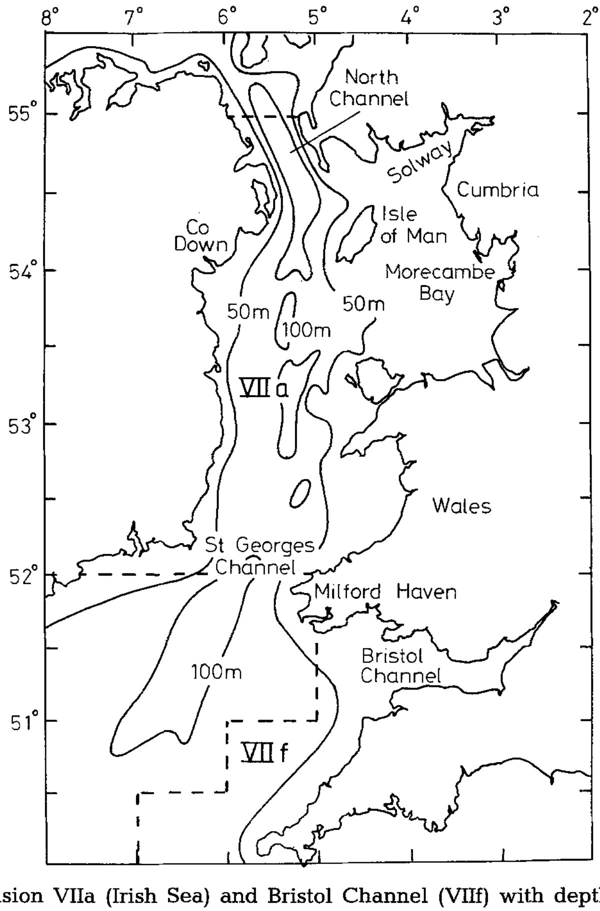

Fig. 1. ICES Division VIIa (Irish Sea) and Bristol Channel (VIIf) with depth contours and place names used in the text

weight landed, is a noteworthy feature of the Irish Sea fisheries, particularly since several of the species are of high value.

Figure 2 shows the trends in total demersal, total pelagic and shellfish landings from Divisions VIIa plus VIIf since 1922. Shellfish landings prior to 1950 were small and have not been included because the units are incompatible. All three categories have shown great increases over the period, but the reasons for the increase are varied. Pelagic landings rose sharply from 1970 onwards due partly to good herring recruitment in the Irish Sea and increased exploitation of the Celtic Sea stock, but mainly because catches of mackerel from the Westerly stock around Cornwall are sometimes taken in Division VIIf. There is no indication that pelagic catches in Division VIIa could be maintained above 20 000 tonnes on a sustained basis. Fishing on the Mourne herring stock has been banned and the Manx stock could easily follow the same downward path if tight controls are not enforced.

The increased shellfish landings are probably due to increased fishing effort on them as the market for shellfish has improved. Fishing effort on *Nephrops* is too high (Brander, 1977), but the mesh size has recently been increased and the stocks seem to stand up to the fishing pressure remarkably well.

The demersal landings have risen considerably too over the past thirty years and reached by far the highest level of the century in 1973, since when there has been a slight decline. On their own these statistics cannot be taken as an indication of population size since the fluctuations in catch may be a result of varying fishing intensity rather than population changes. Statistics of fishing effort (fishing intensity = fishing effort/area) are less complete than those of international catch and there are

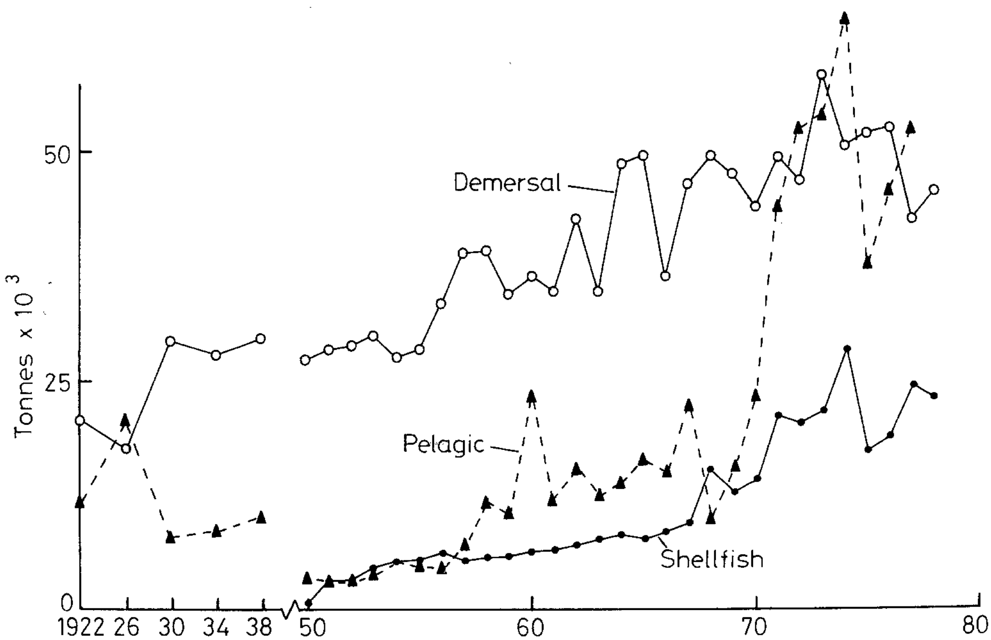

Fig. 2. Total international landings of demersal and pelagic fish and shellfish from ICES Divisions VIIa + VIIf. (Source: ICES Bulletin Statistique 1922–1978)

difficulties in defining the units of effort and in standardising them between different countries and methods of fishing. Nevertheless, an index of the fishing effort on demersal fish has been produced for the period since 1954, which is derived from English, Welsh and Belgian trawl data, corrected for increases in horsepower (Brander, 1977). The rising trend in the total international fishing effort thus derived is shown in Figure 3 which also shows the resulting decline in total demersal catch per effort. Catch per effort is taken as an indicator of available stock biomass and from these figures it therefore appears that the total demersal fish biomass in the Irish Sea and Bristol Channel has fallen to little more than a third of its 1954 level as a result of fishing. Before going on to look further into these figures it is perhaps worth giving more detail about fishing intensity and its distribution. A rough calculation indicates that the total area swept by trawls in 1978 was about 147 000 km^2 which is about 2½ times the total area of Divisions VIIa and VIIf. Since fishing effort is not evenly distributed this means that popular grounds and tows may have been trawled over many more times than this, whereas large areas are not fished at all.

The distribution of international fishing effort within the Irish Sea can only be given approximately because not all countries collect the information, but Figure 4 shows the English, Welsh and Belgian contributions in 1976, with most fishing taking place in the Eastern Irish Sea. The remaining countries, Eire, Northern Ireland and France fish mainly in the central and western parts, particularly in the areas west and southwest of the Isle of Man.

A yield curve for the demersal species can be derived from Figure 3 using the methods described by Brander (1977) and Anonymous (1978, 1979), and this is shown in Figure 5. Bearing in mind the limitations of the method, it provides some useful first approximations. The maximum sustainable yield (MSY) from the demersal fishery of VIIa and VIIf is just under 50 000 tonnes (nominal weight) and the biomass of demersal fish (of catchable size) at MSY is about 100 000 tonnes, since fishing is removing about half of the biomass each year. In the absence of fishing the biomass would be around

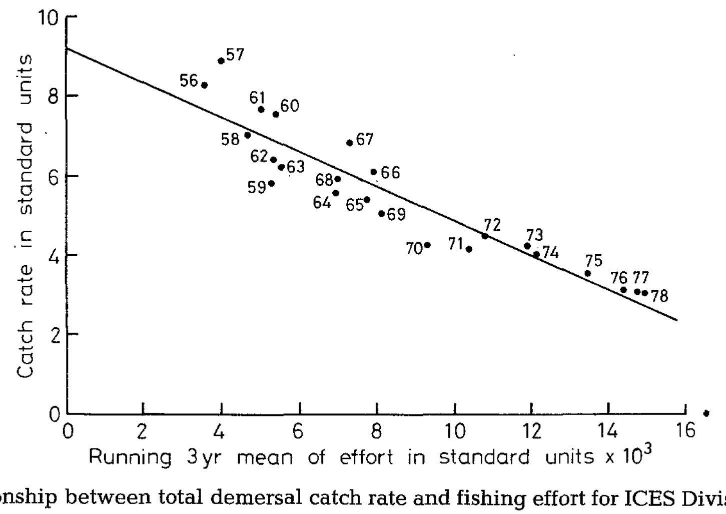

Fig. 3. Relationship between total demersal catch rate and fishing effort for ICES Divisions VIIa + VIIf

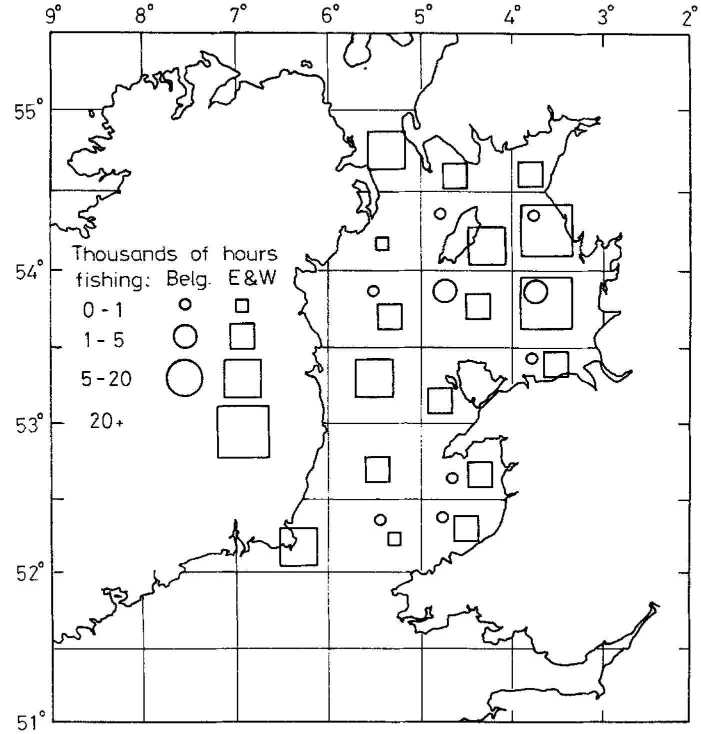

Fig. 4. Distribution of Belgian, English and Welsh fishing effort in 1976

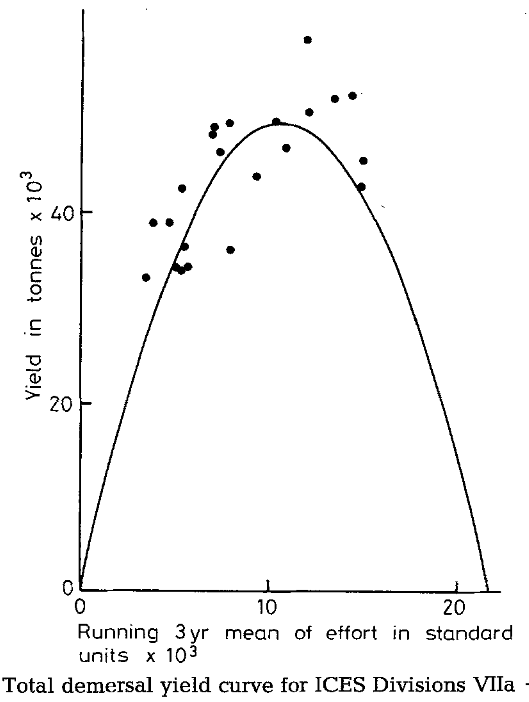

Fig. 5. Total demersal yield curve for ICES Divisions VIIa + VIIf

200 000 tonnes. The current level of fishing is greater than that needed to take the MSY and demersal stock biomass, as indicated by catch per effort, is just over a third of the virgin stock biomass. The model is little more than a summary of the changes which have taken place in the demersal stocks over the last thirty years, but it does fit the data well and is consistent with the more detailed single species analytical models. As such it forms part of the management case for restraining and reducing the international fishing effort.

SINGLE SPECIES ANALYTICAL MODELS OF FISH POPULATIONS

Whereas the total demersal model allowed only rather broad generalisations about the current state of Irish Sea fish stocks, the single species models are based on quarterly or annual age compositions of the landings obtained from routine sampling on fish markets and on large numbers of age determinations from otoliths. For cod, plaice, sole and whiting we know the age structure of the landings for a number of years and are able to reconstruct the age structure of the populations using virtual population analysis (Pope, 1972).

Thus we have information on the rates of growth, mortality and recruitment for these species extending back over 10 to 15 years and updated annually by a working group of ICES (Anonymous, 1979). With the exception of fishing mortality, the changes which have taken place in these rates are for the most part small and without trend. For example, Figure 6 shows the deviation in plaice growth about the long-term mean for the period 1964–78. Recruitment too has a random scatter (Fig. 7) in spite of a marked decline in the stock biomass of cod, plaice and sole. On the other hand fishing mortality has increased steadily on plaice and cod, as one would expect from the trend in total international effort (Fig. 3). Sole, which is taken mainly in a directed seasonal fishery, has not apparently been subjected to increased fishing mortality and the whiting assessment is complicated by high mortality in small mesh fisheries for *Nephrops* and industrial species.

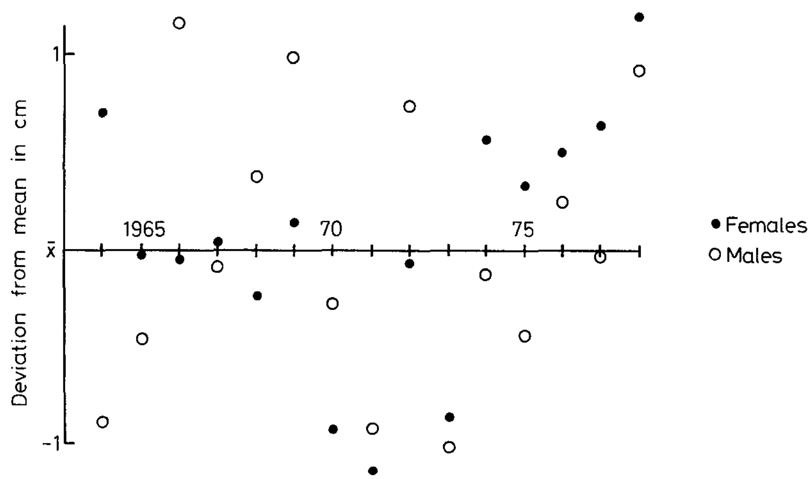

Fig. 6. Deviation in mean length of plaice (ages 3–5) from the long-term mean (based on Fleetwood market samples of trawl landings from ICES Division VIIa)

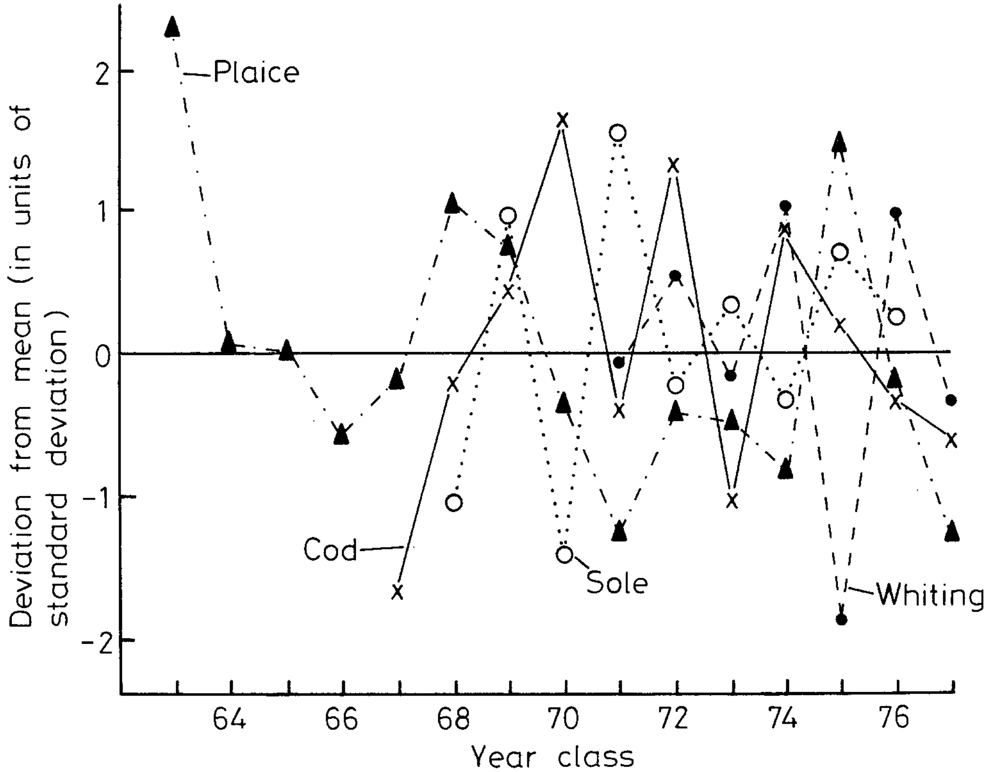

Fig. 7. Deviations in annual recruitment of plaice, sole, whiting and cod from the geometric long-term mean for ICES Division VIIa (data from Anonymous, 1979)

The current fishing mortality rates mean that fishing removes a large proportion of the adult populations of fish from the Irish Sea each year; the proportion ranging from about 25 % for sole to 65 % for cod. As a result of the single species analytical models, which are in good agreement with the total demersal model, a total allowable catch (TAC) is set each year in order to prevent fishing effort from rising further and indeed to reduce it to a level close to that giving the maximum sustainable yield (MSY). The practical and institutional difficulties in enforcing these TACs are still considerable, but in principle they should serve to protect the four species for which they are set. The effect of these TACs on other species is difficult to forecast since they may either result in a general decrease in fishing effort in the area or in diversion of effort onto unprotected species, such as occurred in the North West Atlantic in the early 1970s. Even if fishing effort does decline this may not be sufficient to protect commercial species such as rays which, because of their low fecundity, are particularly sensitive to fishing pressure. One species, the common skate *Raia batis*, has already become extremely rare if not extinct in the Irish Sea, probably as a result of fishing. In 1902 Herdman & Dawson wrote of its occurrence in the Irish Sea: "abundant in all parts, and taken by line and by trawling all the year round on nearly all our fishing grounds. The young are frequently taken in shrimp nets in shallow water." Not a single specimen has been taken in several hundred research trawl hauls over the past decade and only occasional fish appear in commercial landings from the North Channel. Its disappearance seems to have been unnoticed or at least unrecorded, and it is doubtful whether a management policy to protect it from fishing could have been devised in any case. The same is probably true for the other ray species and this is a clear example of the limitations of the protection afforded by fisheries management.

A shortcoming of the analytical models based on commercial market sampling is that for most purposes it is impossible to work on a finer scale than the whole area (in this case Division VIIa) by quarters of the year. In the case of plaice and cod it is known that there are different spawning areas and consistent growth rate differences between the eastern and western Irish Sea, but because it is impossible to divide the total catch between these areas the assessment cannot be split. When more detailed information on a particular small area is needed, it is usually necessary to use special research surveys and the kind of information which can be obtained with these is described in the next section.

RESEARCH SURVEYS OF FISH POPULATIONS

A series of groundfish trawl surveys in the North East Irish Sea has been carried out over the last 5 years. The surveys take place every 4 months using a small (16.7 m length) chartered fishing vessel. Details of the method and some of the results are given by Brander & Wallace (1976). The advantages of this kind of survey are that fishing positions can be selected and methods kept standard; small mesh covers are used and all fish whether commercial or not are recorded; supplementary biological information on feeding, condition, etc. can be collected.

A major problem which has always confronted studies of fish populations is how to sample them and in particular whether the inherent variability in catches taken by gear such as trawls is so large as to obscure any fine differences in distribution. Our surveys have attempted to demonstrate consistent differences in fish distribution due to depth, distance from the coast, season and sediment type and in this they have met with some success.

As an example, the distribution of twelve species in relation to sediment and month is given in Table 1, which shows the geometric mean of the number per haul, the overall coefficient of variation, the proportion of the total sum of squares due to haul-to-haul (within stratum) variability and the significance levels for the effects of sediment type and month. The whole analysis was carried out on log transformed numbers per haul ($\log_e (1+N)$) because the frequency distributions are highly skewed. Even so, many of the coefficients of variation are above 100 % and, because this may lead to excessive numbers of significant F ratios in the analysis of variance, the month x sediment interaction term has been included in the "error" sum of squares and only the main effects have been tested.

In Table 1 the species have been grouped according to the sediment on which they occurred most abundantly and the 4 species which occur most commonly on muddy sand (dab, small plaice, sprat and flounder) all show significant differences in their distribution due to sediment type. Three of them (small plaice, sprat and flounder) also show significant seasonal differences. The sprat distribution is particularly interesting since it is a pelagic species, which might not be expected to be influenced by bottom type. The overall variability among the catches of sprat in the 30 hauls analysed is very high, as indicated by the coefficient of variation of 148 % for the transformed distribution, but the haul-to-haul variability within strata is low, accounting for only 17 % of the total sum of squares. As can be seen from the mean values, sprat are far more abundant over muddy sand than over the other sediments, a rather surprising result which is however confirmed by others studying the species elsewhere (Johnson, personal communication).

Of the other species only poor cod and pout whiting can be shown to be influenced by sediment type and only cod and whiting show statistically significant seasonal fluctuations.

Using information of this kind one can predict the species composition and abundance which might be expected in particular areas and seasons and hence detect significant deviations from expectation which might indicate some other factor at work. However, they are only the first step in understanding the structure of the fish community and their main use at present seems to lie in instilling caution when ascribing a cause to a particular decline or absence. For example, Corlett & O'Sullivan (1972) tentatively concluded on the basis of two trawl hauls that the slightly reduced number of species southeast of the Liverpool Bay sludge dumping area might be an indication of detrimental conditions, but our more detailed sampling in comparable depths and the same bottom type on areas 15 miles west of the dump site showed similar numbers of species to those near the dumping ground and comparable strata off the Isle of Man showed consistently lower numbers. In the latter case the reduced number of species may be due to greater tidal currents, but this factor is extremely difficult to include in the sampling design.

The problem of sampling fish populations in order to study the factors influencing their distribution and abundance is not an insuperable one, but the number of factors involved is large and therefore the unexplained residual variance is also likely to remain fairly big for most species. The analysis of variance described here may allow one to select species whose distribution appears to be well explained by the factors included and small plaice are a good example. A further analysis has looked at their numbers in relation to depth, distance from the coast, season and year, but keeping sediment type constant. Not surprisingly their distribution can be shown to depend significantly on all of these and one is left with a fairly clear picture of how their numbers would be expected to vary.

DISCUSSION

In commercial fisheries management the protection of life in the sea is not a matter of altruism, but of self interest, because by maintaining stocks the future livelihood of the fishing industry is protected. There is broad general agreement over the measures which are needed to do this, but great difficulties remain in implementing a regime which ensures that the long-term common benefit prevails over short-term individual advantage. To a fisherman any fish which he does not catch today is liable to be caught by someone else tomorrow and restraint is therefore a hard doctrine to accept. The institutional framework for carrying out the assessment, regulation and control in an equitable and effective manner is only in its infancy, but already the setting of annual catch quotas is becoming a regular procedure. There is every expectation that the danger to stocks in

Table 1. Analysis of variance of mean number of fish caught per one hour trawl haul

Species	Sediment (6 hauls)						Month (10 hauls)					
	Muddy sand	Sand	Mud, sand & gravel	Shelly sand	Lag gravel	Significance level	March	June	November	Significance level	Coefficient of variation	% of sum of squares within stratum
Dab *Limanda limanda*	134.5	67.1	60.4	4.4	99.7	*	101.0	68.8	16.5		51	9
Plaice *Pleuronectes platessa* (< 25 cm)	39.9	8.4	2.8	3.6	28.7	**	24.0	12.5	3.5	**	65	20
Sprat *Sprattus sprattus*	33.2	4.3	3.2	0.6	0.4	*	4.5	13.1	0.1	**	148	17
Flounder *Platichthys flesus*	4.4	2.0	1.0	1.4	0.6	**	5.8	1.4	0.1	**	114	16
Poor cod *Trisopterus minutus*	4.4	379.3	68.6	52.5	328.6	**	75.2	33.1	167.2		56	13
Plaice *Pleuronectes platessa* (> 25 cm)	13.4	29.7	18.1	3.9	25.9		13.3	16.0	16.4		50	12
Dragonet *Callionymus lyra*	0.3	5.1	11.7	1.4	1.9		3.9	3.7	1.2		104	6
Pout whiting *Trisopterus luscus*	3.2	38.6	5.5	54.8	13.7	*	10.4	25.8	15.6		69	26
Cod *Gadus morhua*	0.9	3.9	7.4	8.6	6.8		1.3	5.4	11.5	**	75	22
Lesser spotted dogfish *Scyliorhinus caniculus*	1.2	0.9	1.3	6.3	2.4		0.7	2.8	4.9		101	44
Whiting *Merlangius merlangus*	57.6	39.6	84.7	33.1	96.8		31.4	95.4	62.8	*	25	27
Thornback ray *Raia clavata*	3.2	2.4	3.1	1.3	9.5		3.0	3.7	3.2		68	40

* Significant ($p < 0.05$)
** Highly significant ($p < 0.01$)

the Irish Sea and elsewhere, which current excessive fishing pressure represents, will be curbed within the next few years. If this desirable state is achieved it will be a notable success for fisheries management, but will be regarded by most of those concerned about marine life as only the first step on a long road.

The objectives of fisheries management are limited to maintaining yields of commercial species and practical considerations mean that only a very few of these are properly studied and protected. The parallel with agriculture, which husbands a limited number of species to the detriment of many others is inescapable. One of the main aims of conservation is to maintain the diversity of species, but on land the conservation movement owes much of its force to aesthetic and amenity considerations, which may be hard to apply beyond littoral areas. As on land, there may be some conflict between the objectives of management to obtain a yield and those of general conservation, but studies of the fisheries will play a major part in identifying and resolving these and are in any case essential to an understanding of the marine ecosystem and of the dangers to it.

Turning to the question whether fisheries data such as those used in the analytical model could be used to detect changes due to pollution, the first point, which is obvious but needs to be made again, is that one certainly cannot interpret any changes in the marine ecosystem without taking account of the massive effects of fishing on fish populations and, directly or indirectly, on other life in the sea. For example, the increased incidence of lesions in Irish Sea flatfish reported by Perkins et al. (1972) might be explained by fishery induced stress, particularly since the incidence was higher among adult fish living in less polluted offshore areas than among young fish on inshore areas which are more polluted, but less heavily fished. There is no evidence that fishing changed at that time in a way which might have brought this about, but neither is there any direct evidence that pollutants did either. The effects of fishing are so great and widespread that it is indeed doubtful whether pollution induced changes in growth, natural mortality, recruitment or migration could be detected against them, unless the changes are particularly disastrous or persist for a long enough period.

CONCLUSIONS

(1) The Irish Sea is heavily polluted in several respects and is also subject to many other human activities including navigation, recreation, gravel, oil and gas prospecting and extraction and fishing. To date only fishing can be shown to have a widespread effect on the marine ecosystem; it removes over half of the adult populations of several commercial species each year.

(2) In general, the demersal fisheries are producing yields which are as high as or higher than ever before, but there is little doubt that most species are overfished. Fishing has probably led to the disappearance of *Raia batis* from the Irish Sea and other species of Raiidae are also in danger.

(3) The fisheries are beginning to be managed by catch quotas and other means, in order to produce high sustained yields, but it is doubtful whether such management will lead to the protection of more than a few commercial species. If a more comprehensive conservation policy is to be considered then the objectives need to be formulated to allow this.

(4) Studies of the fisheries can give information on long-term changes in population levels, on the growth, mortality and recruitment of fish populations and on their detailed distribution in relation to each other and to environmental factors. Such studies are essential in determining the possible causes of changes in the fish populations and form an important part of our understanding of the marine ecosystem.

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