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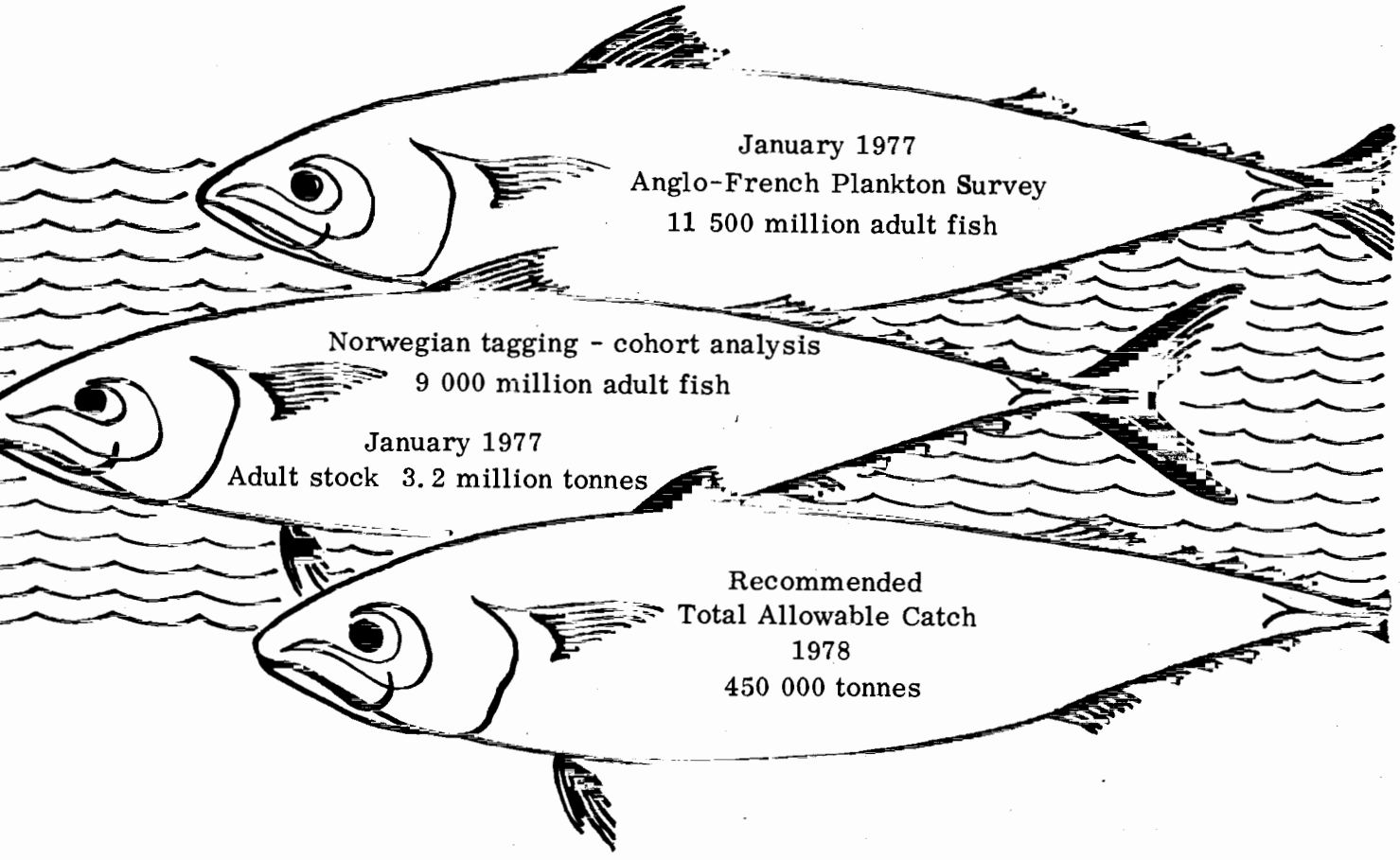
DIRECTORATE OF FISHERIES RESEARCH

MACKEREL
A problem in fish stock assessment



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MACKEREL - A PROBLEM IN FISH STOCK ASSESSMENT

by Stephen J. Lockwood

INTRODUCTION

The International Council for the Exploration of the Sea (ICES) first convened a Mackerel Working Group* in 1974 to assess the state of the stocks of mackerel (Scomber scombrus L.) in the North Sea and in the waters south and west of the British Isles. Since then the Group has recommended Total Allowable Catches (TACs) for the waters south and west of Britain, ranging from 182 000 tonnes in 1976 to 450 000 t in 1978 (Table 1). These very significant changes in advice given since 1974 by the ICES scientists have given rise to doubts about their credibility, not least in the eyes of those who rely heavily on the mackerel for their livelihood. For example, the recent (June 1978) change in advice for the 1978 TAC from 240 000 to 450 000 t caused concern among fishermen and has given rise to fears for the safety of the stock.

Table 1 The Total Allowable Catches (TACs) of mackerel recommended by, and the catches reported to, ICES for the North Sea and areas west of Britain since the Mackerel Working Group first met in 1974

	Year in which TACs were calculated			
	1975	1976	1977	1978
NORTH SEA AREA				
Recommended TAC for following year, t	249 000	155 000	190 000	145 000
Amended TAC for current year, t	-	-	220 000	145 000
Reported catch, t	297 724	314 358	269 336	-
WESTERN AREA				
Recommended TAC for following year, t	295 000	182 000	240 000	435 000
Amended TAC for current year, t	-	-	250 000	450 000
Reported catch, t	491 380	507 178	315 155	-

*Since 1974 all Mackerel Working Groups have included scientists from Denmark, England, France, the Netherlands, Norway and Scotland. Prior to 1977 the USSR was represented as have been Canada, Ireland, Poland and the USA at some meetings.

This Laboratory Leaflet traces the short history of the ICES Mackerel Working Group, the problems it has encountered in assessing the stock, and how these problems have been tackled in order that fishermen and others interested in the mackerel fishery may have a better understanding of the reasons behind the changes in advice.

THE RECENT HISTORY OF THE EUROPEAN MACKEREL FISHERIES

In European waters there have been two distinct mackerel fisheries, the North Sea fishery, and the fishery west of Britain. Prior to the mid-1960s they were both relatively stable in terms of total international landings although, historically, the North Sea fishery was always more important with landings of 60 000-100 000 t, up to three times higher than those in the west. Most of this fish was caught by continental vessels for sale in Europe. During the 1960s this stable picture changed. First of all there were changes in the North Sea fishery and then a little later in the western fishery.

After 1964 the North Sea landings increased very rapidly from 200 000 t in 1965 to almost 1 million t in 1967 (Figure 1). This dramatic rise was entirely due to the expansion and increased efficiency of the Norwegian purse-seine fleet catching fish for reduction to meal and oil. It was more than the stock could support and landings began to fall as

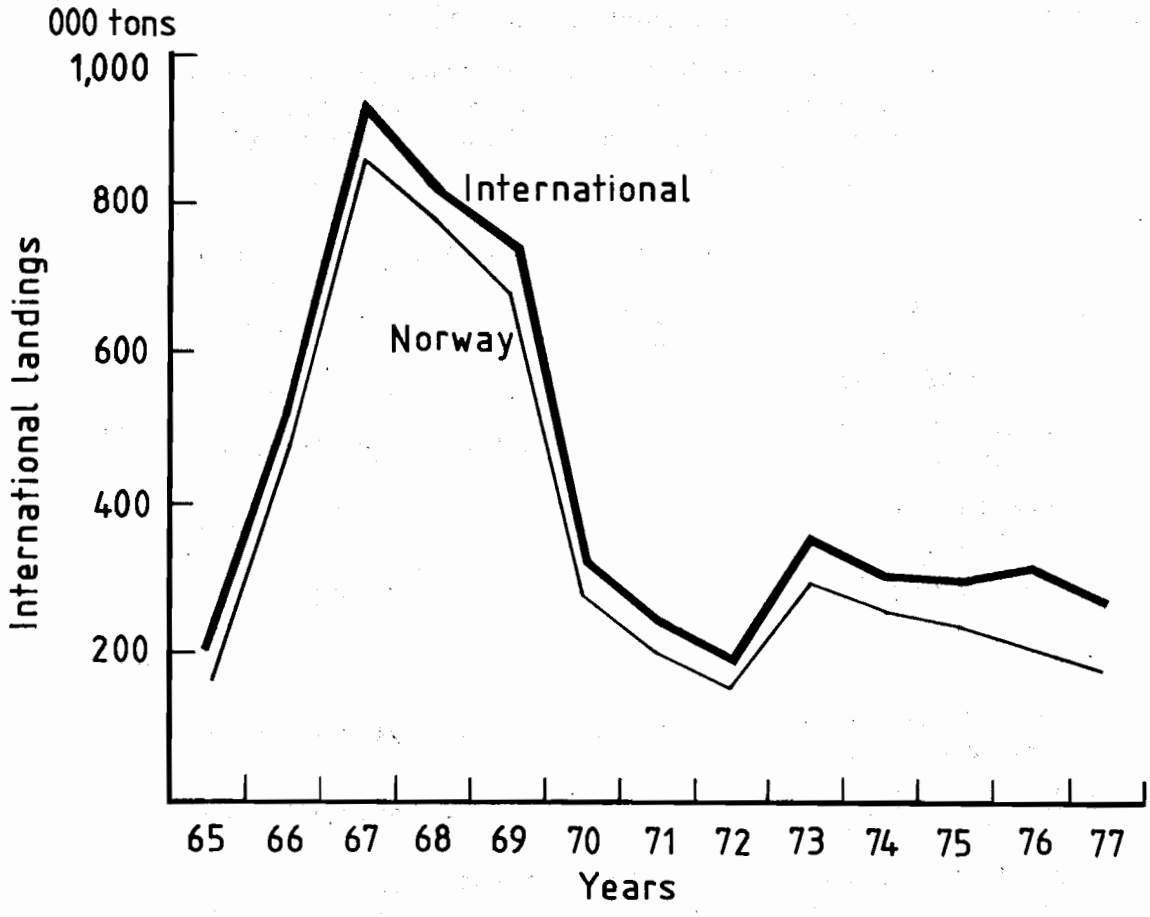


Figure 1 The total international and the Norwegian national catches in the North Sea since the expansion of the Norwegian industrial fishery.

fast as they had risen. In 1970 the Norwegian government implemented a quota restriction on their own fleet which took over 85% of the total international North Sea catch from 1966 to 1974. In 1971 the Norwegian government introduced further controls on the industrial fishery, limiting it to the summer and autumn and restricting the industrial landings of fish under 30 cm long to amounts less than 20% by weight of a boat's catch. These Norwegian controls were later adopted by the North East Atlantic Fisheries Commission (NEAFC) as NEAFC recommendations. At the same time as these fishery controls were being introduced the Institute of Marine Research, Bergen began a major mackerel stock assessment programme.

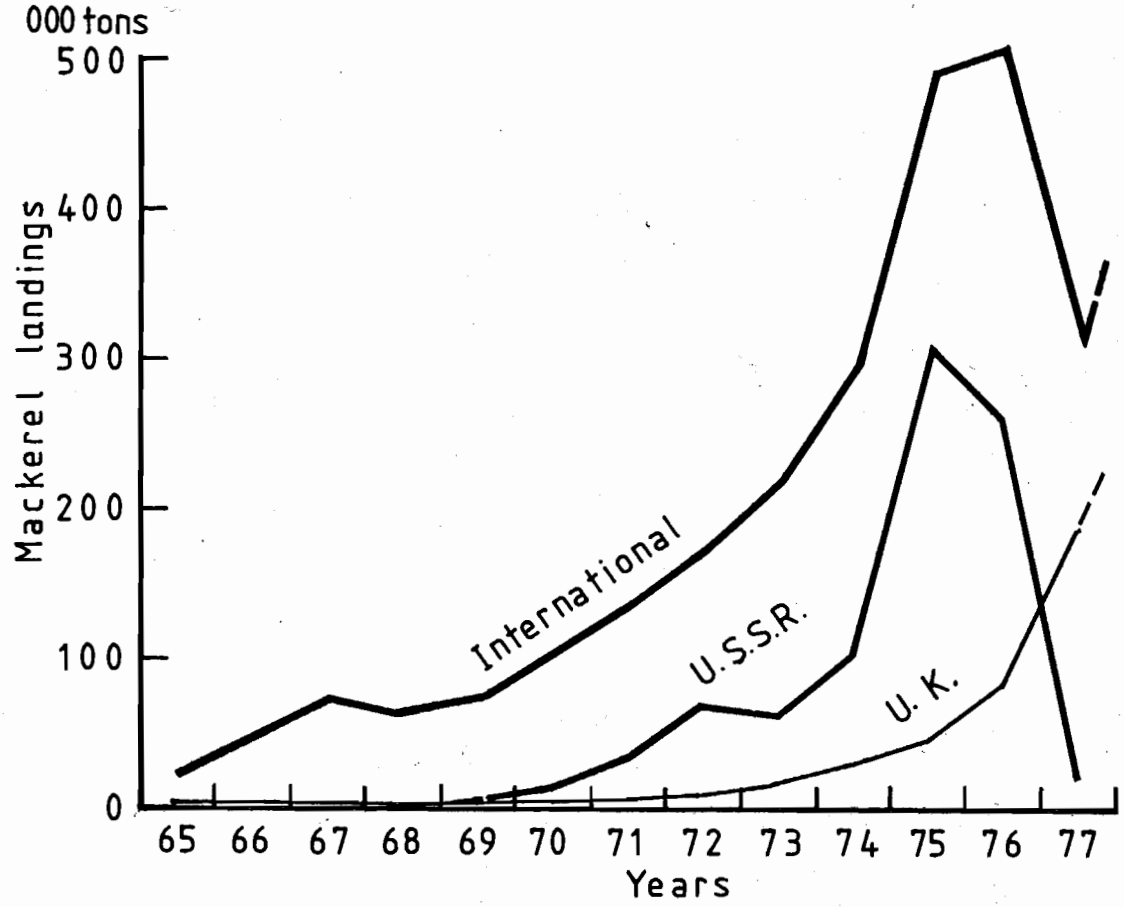


Figure 2 The total international, Soviet and UK mackerel catch from the areas south and west of Britain, 1965-77.

While the North Sea mackerel fishery was going through this dramatic period of rise and fall the western fishery was beginning to show signs of an increase. From 1965 to 1976 there was a continuous steady rise in landings. To start with this was probably no more than one of the periodic increases which had occurred during the previous 40-50 years, but in 1968 Soviet vessels began fishing for pelagic species west of Britain. Their mackerel catches increased rapidly so that by 1971 they were catching as much as France or Spain and by 1975 they were taking over half the total international landings (Figures 2 and 3). In 1976 the USSR catch fell a little and during 1977 Soviet fishing activities ceased as they were excluded from the waters of EEC member states. This resulted in a drop in the total international landings, compared with the previous two years.

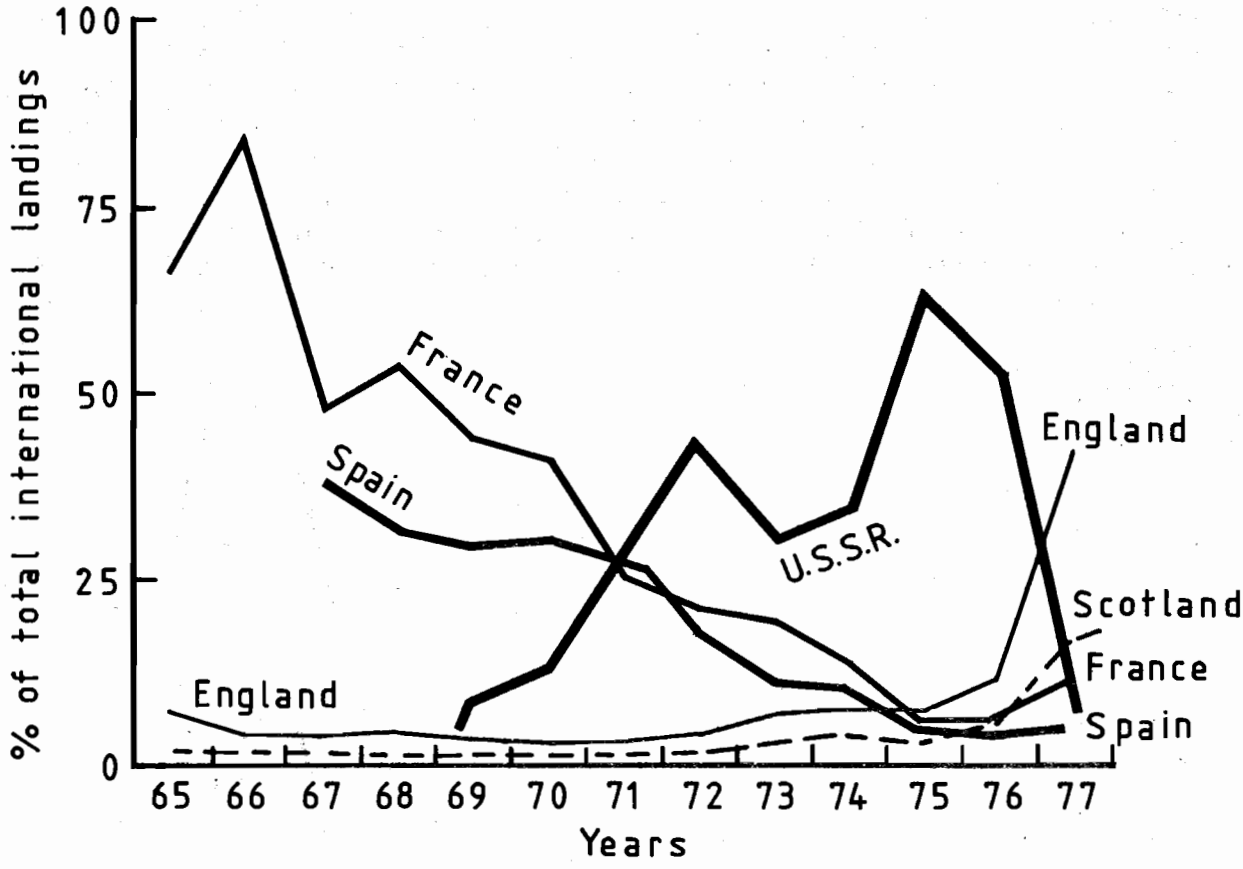


Figure 3 The mackerel catches taken by the leading mackerel fishing nations in the areas south and west of Britain shown as a percentage of the total international catch.

Over the ten year period 1968-77 UK landings increased from 3 300 t to over 180 000 t, most of the catch being taken from the inshore waters off Cornwall. The landings began to increase from the time that the winter hand-line fishery became established in the mid-1960s, but it was not until 1975-76 when vessels from other parts of the UK, notably, distant-water trawlers and purse-seiners, began to participate in this winter fishery that the UK fishery began to be of any significance internationally (Figure 3). In 1977 it rose to the point where the UK landings exceeded half the international total.

As yet, unlike the North Sea fishery, there have been no substantiated indications that the western mackerel is being overexploited. With the decline of the North Sea mackerel stock in mind, the ICES Mackerel Working Group first met in 1974 to assess the western mackerel fishery, to ensure that this stock would be maintained at a safe level, and to review the state of the North Sea stock.

THE WORKING GROUP ASSESSMENTS

The mackerel stocks

The first problem facing the Working Group was to decide how the mackerel were to be grouped for the purposes of stock assessment. After reviewing all the available information it concluded that there were two main stocks which should be assessed

separately. The first of these was the North Sea stock which overwinters along the edge of the continental shelf off south-west Norway and spawns in the central and northern North Sea. The other was the 'Western' stock which overwinters along the edge of the continental shelf in the Bay of Biscay and Celtic Sea and close inshore off Cornwall (Figure 4A). This stock spawns principally in the Bay of Biscay and Celtic Sea area but part of it spawns west of Ireland, in the English Channel and southern North Sea (Figure 4B). During their annual migrations, as indicated by the arrows in Figure 4A, the two stocks mix in the central North Sea and more importantly to the north of Scotland around Shetland. The importance of the latter region stems from the fact that the Norwegian purse-seine fishery has been prosecuted there (Figure 4C) most vigorously in recent years, and the mixing of the two stocks there has presented a major problem in the actual assessments.

The North Sea stock assessment

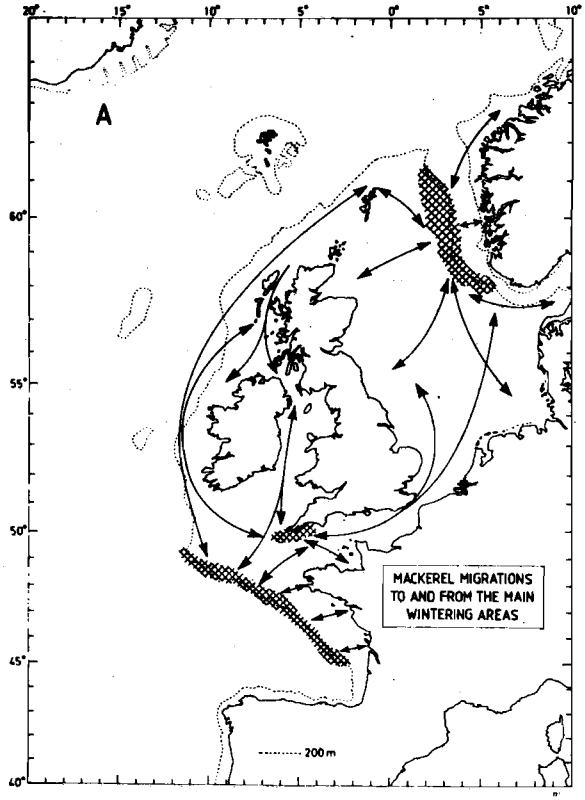
Most fish stocks are now assessed by a procedure known as cohort analysis. This method of assessment requires that not only the total quantity of fish caught each year is known but also the number of fish at each age in the catch. This latter piece of information is obtained relatively easily by national catch sampling programmes run by the fisheries research organizations. (These programmes are currently run by nations which account for over 70% of the total mackerel catch in both the North Sea and western area.) It is also necessary to know the natural mortality rate of the population, i.e. the proportion of the population which dies each year for reasons other than fishing. Finally, in order to start the assessment it is necessary to know either the total number of fish at each age in the free population in the year preceding the assessment year or the fishing mortality rate in a particular year, i.e. the proportion of the total population at each age removed by fishing.

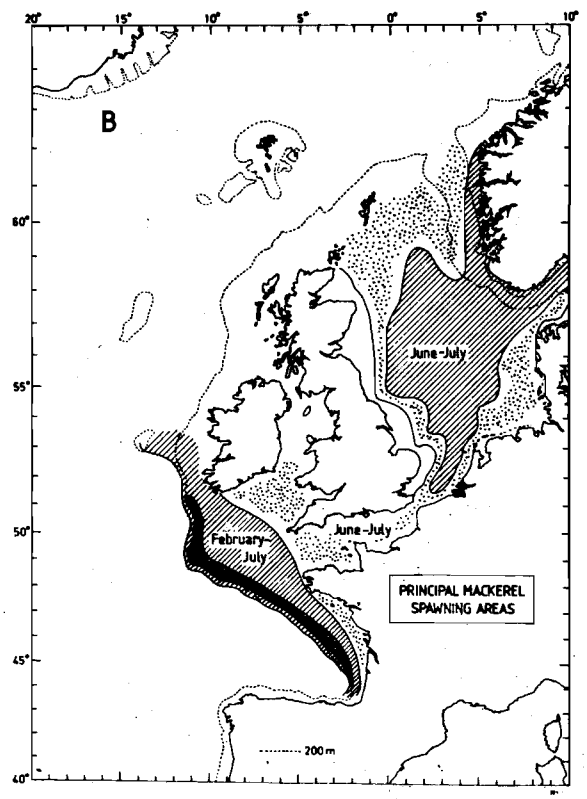
Under ideal circumstances the information on the numbers of fish at each age in the total international catch should be available for as many years as there are ages in the population. In making its assessment the Mackerel Working Group uses up to nine age groups, 0-7 and older than 7. In the late 1960s when the Norwegian scientists began their national effort to assess the North Sea stock they did not have sufficient data, but as they caught 80-90% of the international total they were in a position to collect it. To obtain the necessary age data they took samples of fish from the commercial landings, and they also began a tagging experiment to estimate the stock size and mortality rate.

Estimation of population size by tagging is based on a relationship known as the Petersen Index. In its simplest possible form this relationship says that, all things being equal, the number of tagged fish released into a population form a ratio with the population which is equal to the ratio of tagged fish recaptured to the commercial catch, i.e.

$$\frac{\text{Population size}}{\text{Number of tagged fish released}} = \frac{\text{Size of catch}}{\text{Number of tagged fish recaptured}}$$

The number of tags recaptured from a given release batch will decrease with time due to fishing and natural mortality. The rate at which they decrease is equal to the proportion of the population dying. If the tagged fish released and recaptured are divided into their appropriate age groups the abundance and mortality rates of individual year-classes can be estimated.





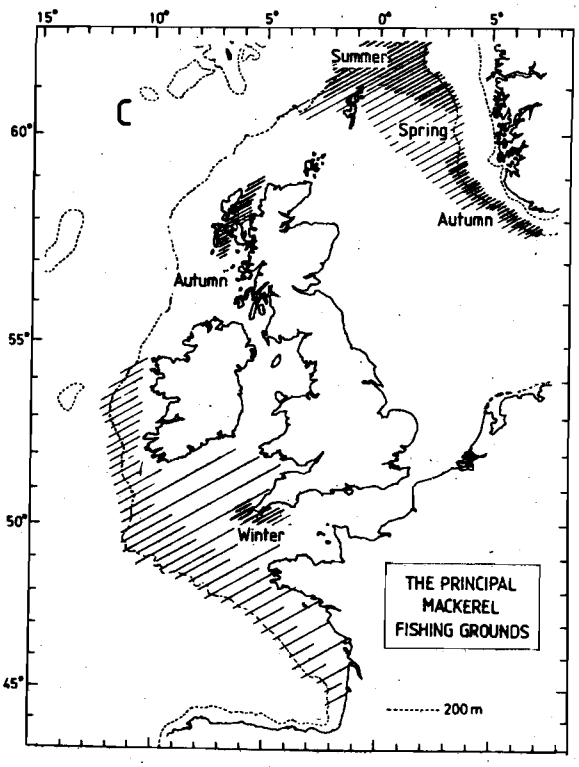


Figure 4

A. The main mackerel overwintering grounds and the annual migration paths to and from the spawning and feeding grounds.

B. The mackerel spawning grounds. Spawning occurs to some extent in all shelf waters around the British Isles, but the main areas are in the central-northern North Sea and the western Celtic Sea.

C. The main mackerel fisheries. The Norwegian fisheries are concentrated in the northern North Sea while the UK fisheries are in the Minch, west of Scotland, and off Cornwall.

The Norwegian scientists' tagging programme was initiated in 1969, since when they have tagged and released 5 000-10 000 fish each year: these fish are caught by hook and line each August off south-west Norway, small metal tags are inserted into the body cavity (Figure 5) and the fish are released. Subsequently a high proportion of those fish which survive the capture-tagging-release procedure have been recaptured by the Norwegian purse-seiners operating around Shetland in the late summer and a few by UK vessels landing fish for reduction during the English winter fishery off Cornwall. The tags are recovered by magnets in the fish meal plants.

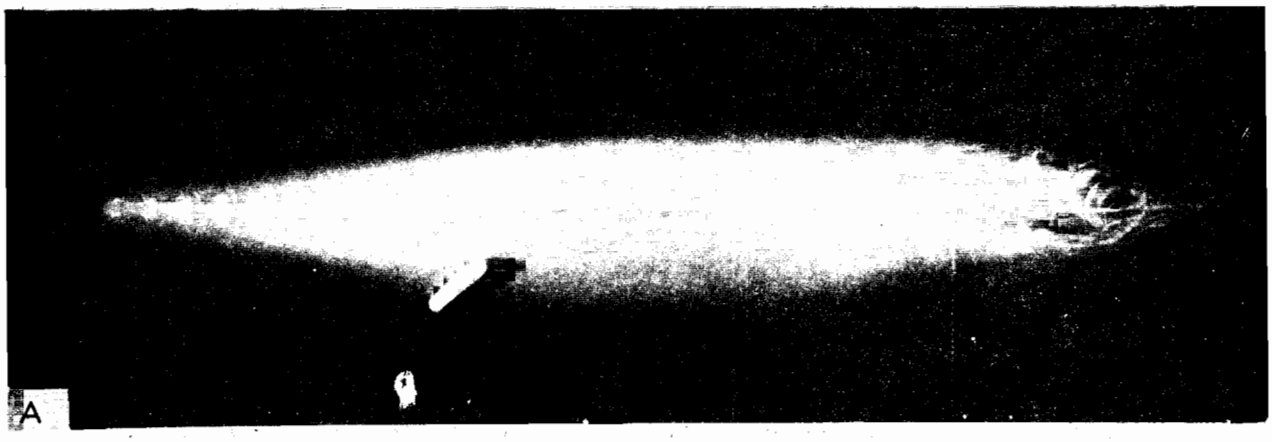
Within a year or so of starting the tagging programme the first estimate of population size and mortality estimates were made and these confirmed that the North Sea stock was in a depleted state. At the same time the 1969 year-class, i.e. the fish spawned in 1969, was found to be very abundant. It appeared that the combined effect of the Norwegian fishery controls and the increased abundance of young fish would be sufficient to stabilize the stock.

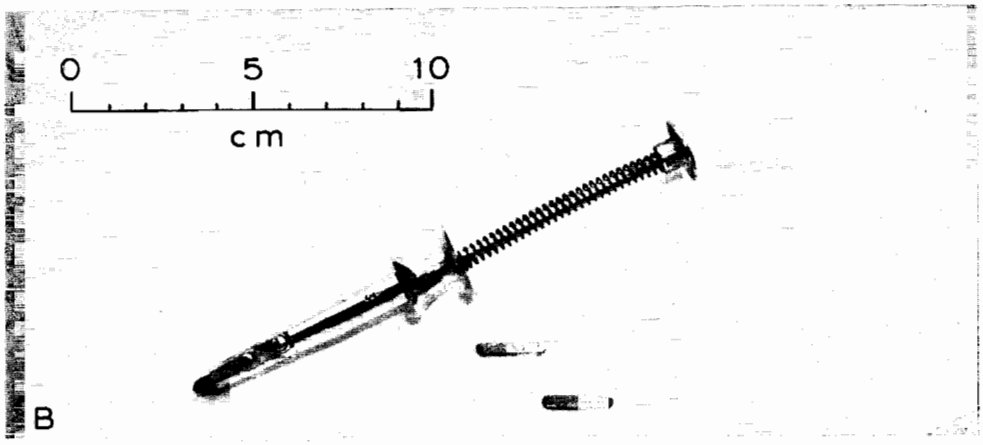
Since 1974 the Norwegian tagging data have been made available to the ICES Mackerel Working Group and they are still used as the basis for making the assessments of the North Sea stock. Each year, as more tagged fish are released and the archive of historical catch by age group data increases, the assessment is refined. As these tagged fish are also recovered in the Shetland area, estimates of the mixing rate of North Sea and Western stocks could be made. At the 1978 meeting of the Working Group it was realized that previous estimates of the numbers of fish surviving the tagging process had been too high and the estimates of the mixing ratios of North Sea and western fish at Shetland were wrong. The results of these errors had been to overestimate the size of the stock. It has also become increasingly clear that the numbers of young fish joining the fishery each year since 1970, except 1973, were often lower than might reasonably be expected. This means that not only is the stock smaller than previously estimated but also that it has been receiving insufficient numbers of young fish to allow it to rebuild. Under these circumstances the Working Group had no alternative but to recommend a severe cutback in the TAC for 1978 over that previously recommended and to add the warning that, if the level of recruitment did not improve or if the recommended TAC was exceeded, it would be necessary subsequently to impose a zero TAC. Such a draconian measure is not only harmful to the fishing industry but it also increases considerably the problems of assessing the stock in future years.

The Western stock assessment

The variation in the levels of TACs for the Western stock of mackerel recommended by the Working Group over the past four years is indicative of the problems facing the Group when making the assessment. At its first meeting in 1974 there were even less data available than there were for the North Sea stock.

Due to the relatively low importance of this fishery prior to the early 1970s very little research effort had been deployed upon the stock. The Fisheries Laboratory, Lowestoft had monitored certain biological aspects of the stock for several years but at a fairly low level. The most important aspect of this work was the tagging with external tags (Figure 5) which provided a great deal of information on the annual migration patterns of mackerel. Originally these studies, like the fishery, were concentrated in the summer months. Since the mid-1960s when overwintering shoals became established and fished in Cornish coastal waters, the emphasis of the work has shifted to the winter





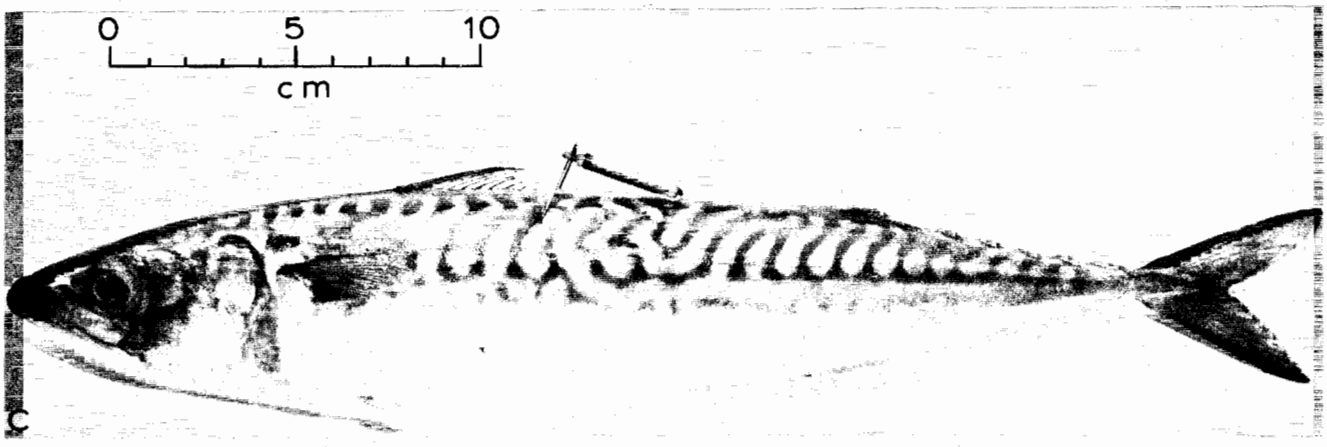


Figure 5 Tagged mackerel.
A. X-ray photograph of an internal tag in the body cavity.
B. An internal tag and the tagging gun used to insert the tag through the wall of the body cavity.
C. An externally tagged mackerel.
(All to the same scale.)

months. This has included further tagging experiments, and since 1972 the Lowestoft laboratory has made acoustic surveys of that part of the Western stock which overwinters off Cornwall. In January 1974 it put its mackerel monitoring programme on to an equal footing with more important species, such as cod and plaice, even though the English landings in 1973 were still only 13 000 t. Since then the research effort has increased steadily, not only at the Lowestoft laboratory but also at laboratories in other countries which have an interest in this stock.

This increased research effort has included a second Norwegian tagging programme. Each May since 1970, 4 000-7 000 mackerel have been caught, tagged with internal tags and released to the south-west and west of Ireland. The tag returns have not been used in making stock assessments as they are not representative of the entire Western stock, but they have confirmed the pattern of migration described by the earlier English tagging results. In addition to this Norwegian tagging experiment the French reviewed their plankton survey data (mackerel eggs are planktonic) collected from the Bay of Biscay between 1964 and 1973. The results showed that the major western mackerel spawning grounds extend much further south than previously thought.

The commercial catch data available to the Working Group have suffered from the same shortcomings as the North Sea data; there was not a continuous historical set of catch-by-age-group data nor were any reliable estimates of fishing mortality or population size available. In the absence of suitable data which would allow the use of conventional assessment techniques the Working Group had to improvise by applying North Sea observations to the Western stock.

In 1975 an estimate of stock size was made by extrapolation from the North Sea tagging experiment. When the North Sea fishery is concentrated in the north-east North Sea (north of 57°30'N and east of 2°E) the Norwegian scientists obtain one tag return rate (tags per thousand tonnes of fish processed) and when the fishery is concentrated around Shetland they record a different, lower, return rate. This reduced return rate is due to Western stock fish mixing with North Sea fish around Shetland thereby 'diluting' the concentration of tagged fish in the population. The difference in return rates gave a mixing ratio which indicated that the Western stock was about 2.5 times the size of the North Sea stock. The Working Group recognized the tenuous nature of this method but, in the absence of any other data, it provided the best information available and the Group advised a TAC for 1976 of 295 000 t for the western area as a precaution against overexploitation.

In 1976, when a few more data were available, a new method of running a cohort analysis with limited data was devised. Due to the above-average abundance of the 1969 year-class in the North Sea it was possible to estimate the total number of fish, the mortality rate and the mixing ratio for this specific age group relatively easily. This provided a reference point from which to estimate the abundance and mortality rate of Western stock fish of the same age group (1969 year-class) in the Shetland fishery. From this the number of fish of the other ages in the Western stock was estimated from their abundance, relative to the 1969 year-class, in the commercial catches. This method still relied on the tagging data from the Shetland fishery but the more detailed analysis was judged to be better than the previous year's simple extrapolation. The TAC for the western area in 1977 calculated by this process was 182 000 t, little more than half the previous year's 'precautionary' TAC. The difference between the two recommendations indicated that the data available were still far from ideal and that more were required.

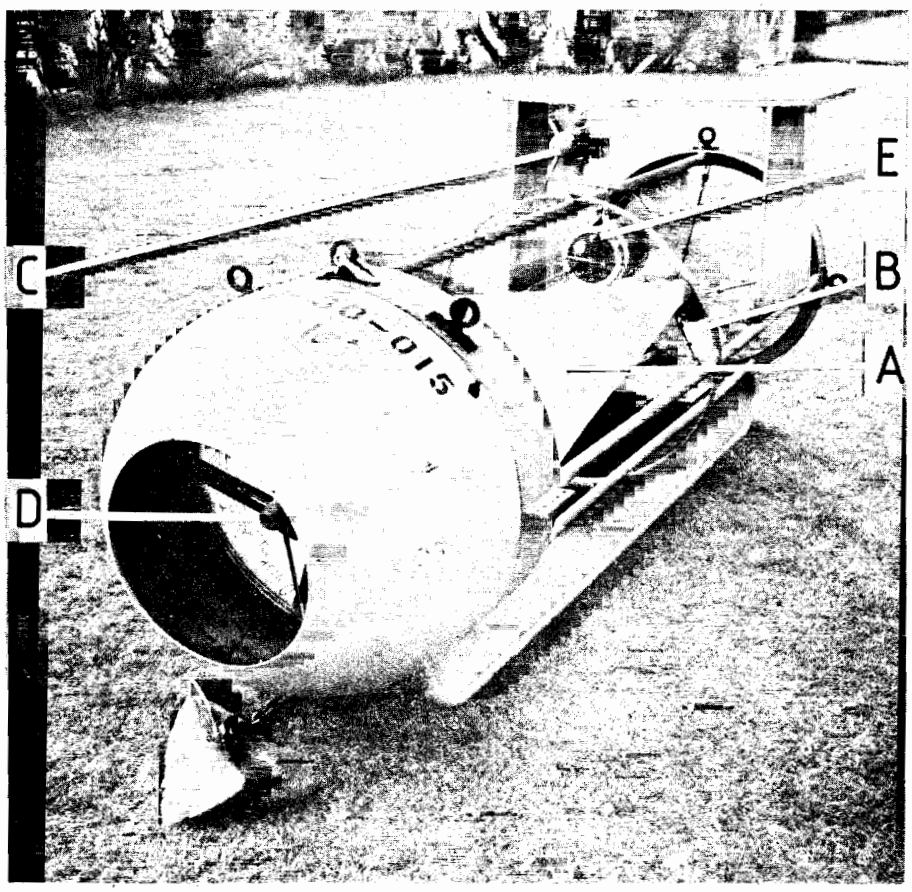


Figure 6 A Lowestoft pattern high-speed plankton sampler. In use the sampler is encased in a protective fibre glass tube. This has been removed to show the main filtering net, A, and the collecting bag, B. The volume of water filtered is measured by the external, C, and internal, D, flowmeters. The depth of the sampler is measured by a pressure sensor, E.

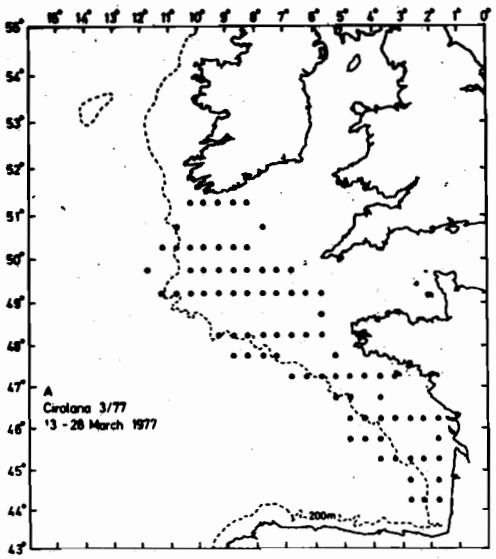
The Norwegian scientists were persisting with their tagging experiments and scientists at the Fisheries Laboratory, Lowestoft continued with their acoustics programme, but something else was also needed. The latter therefore decided that a plankton survey should be mounted in order to assess the abundance of mackerel eggs and so estimate the size of the spawning stock. This survey was carried out in 1977 with help from the Institut Scientifique et Technique des Pêches Maritimes (ISTPM), Nantes in France. The samples were collected during the spring and early summer; their analysis, and the estimate of stock size derived from them was completed by the end of the year. As this survey had not even commenced when the Mackerel Working Group met in February 1977 it persisted with the method used in 1976 as the best option from an unsatisfactory set of alternatives; it estimated that in 1977 there was a spawning stock of 4 200 million fish. At its 1978 meeting the Group were able to use both a cohort analysis and the results of the plankton survey to estimate the stock size.

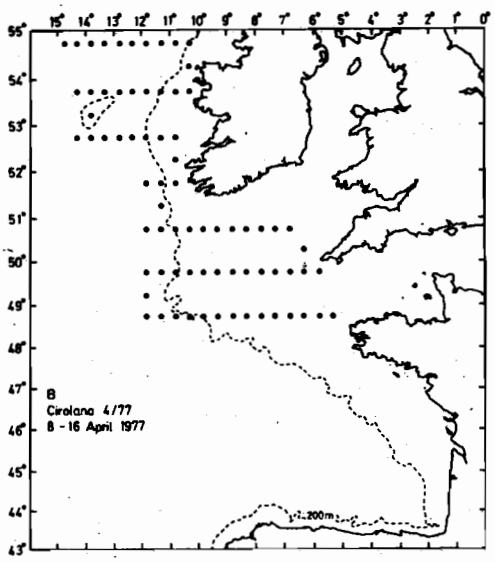
Before commencing the surveys all the available data and information on mackerel spawning in European waters were reviewed by the Lowestoft laboratory. From this information it was decided to survey the Bay of Biscay, the Celtic Sea and the area west of Ireland in each month from March to July 1977. The area to be surveyed was divided into rectangles $\frac{1}{2}^{o}$ of latitude by $\frac{1}{2}^{o}$ of longitude and samples were collected from the centres of the rectangles.

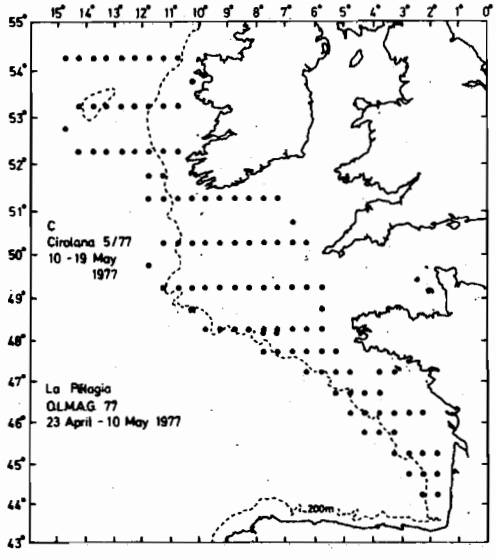
Each sample was collected with a Lowestoft pattern high-speed plankton sampler, 0.76 m in diameter and 2.4 m in length (Figure 6). The sampler was towed at a speed of 5 knots from the surface to the sea bed or a maximum depth of 100 m and back to the surface. Each sample took approximately 40 minutes to collect during which time the plankton, including the mackerel eggs, was filtered from well over 500 t of water. Once the sampler was back aboard the ship the sample was removed from the net and stored. Due to time lost to bad weather the entire area was surveyed only once within one cruise by a single ship, viz in July (Figure 7), and once by using two ships in succession, viz in April-May, otherwise only the Celtic Sea was surveyed on every cruise.

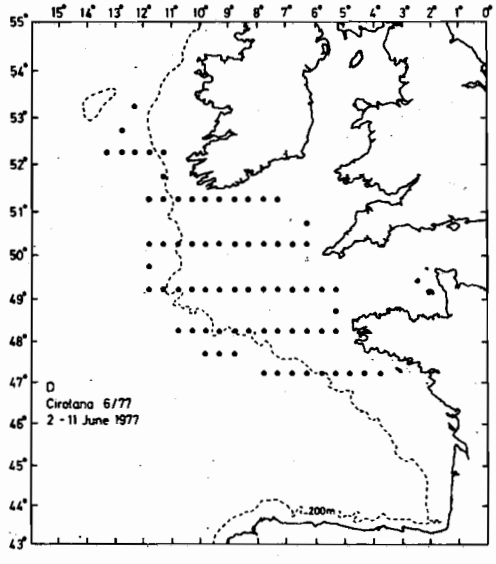
Once the samples were returned to the laboratory the mackerel eggs were picked out, examined, allocated to one of six development stages (Figure 8), and the number in each stage in each sample noted. The numbers of eggs in each sample were then raised to an estimate of the numbers spawned per square metre per day. This calculation was made possible by measuring with flowmeters (Figure 6) the quantity of water filtered when each sample was collected, and by knowing the rate at which mackerel eggs develop. Prior to the survey the development rate for mackerel eggs from European waters had not been measured. It had been measured for the same species off America in the 1930s but it was necessary to be certain that the correct development rate for the north-east Atlantic was used, so it was studied and recorded on the 1977 survey cruises (Figure 9).

Once the numbers of eggs spawned per square metre each day on each survey was estimated the results were plotted on to charts of the survey area and contours drawn (Figure 10) to establish the extent of the spawning ground. From the observations for each sampling position a mean daily egg production rate (eggs/m^2/day) was calculated for each survey. This mean value was multiplied by the size of the area in which eggs were found, during that survey, to obtain an estimate of the total egg production per day. At all times the data were only applied to the area surveyed, thus in March no allowance was made for spawning west of Ireland, and similarly in May and June no allowance was made for the Bay of Biscay. This policy for making no adjustments to the estimates for areas not surveyed was intended to increase the probability that the final stock size estimate was on the low, i.e. safe, side.









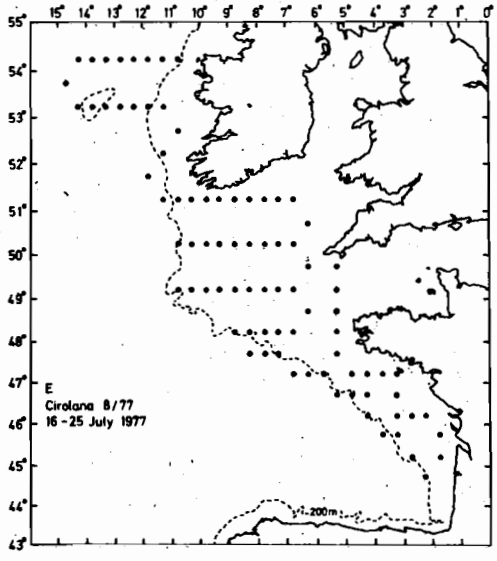


Figure 7 The positions of samples collected during the plankton surveys in 1977.

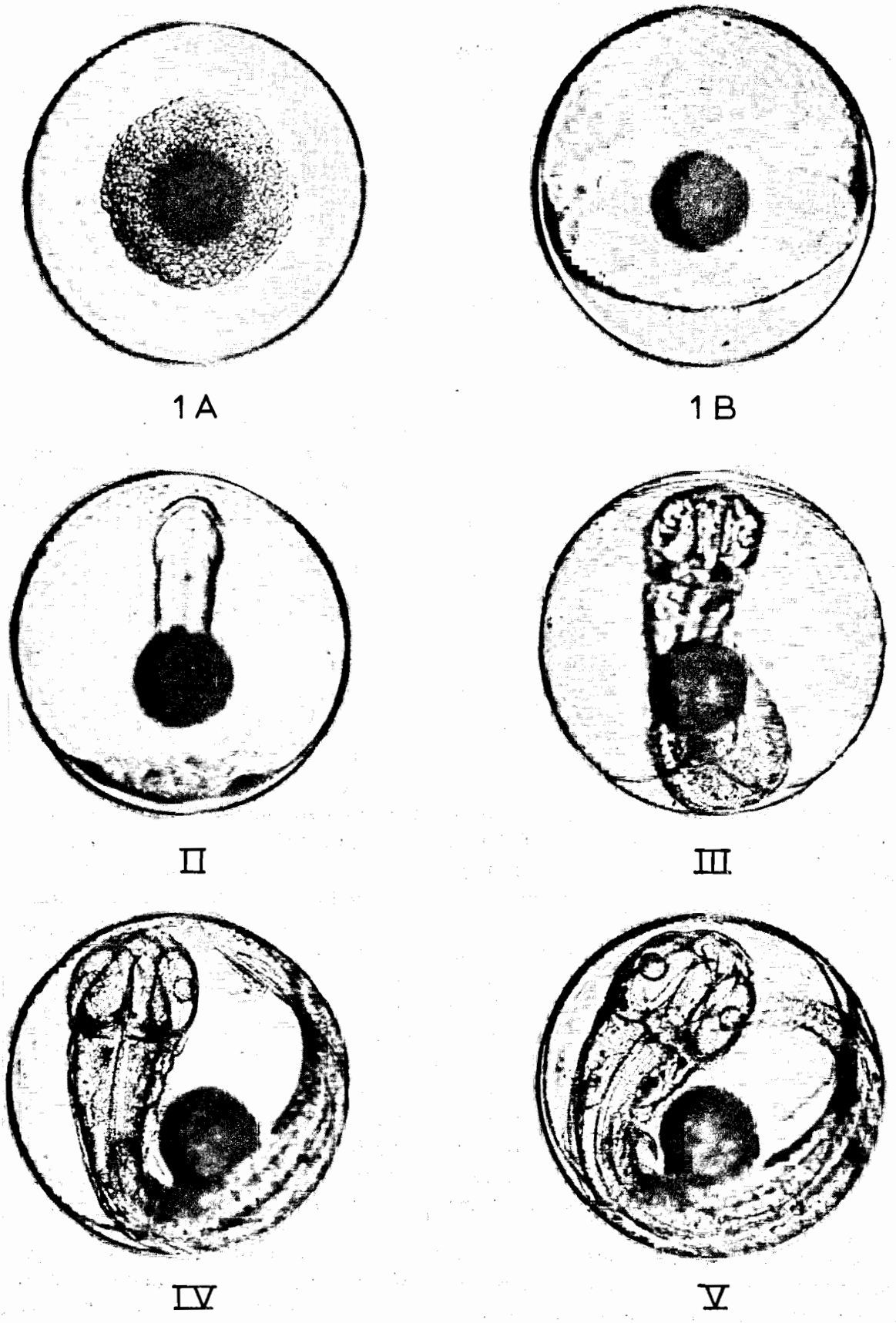


Figure 8 Mackerel eggs at the end of six readily identifiable development stages: IA, an apparently undifferentiated mass of cells; 1B, the first signs of differentiation; II, the early embryo; III and IV, the developing embryo with eyes, heart muscle structure and fins showing; V, the developed larval fish about to hatch.

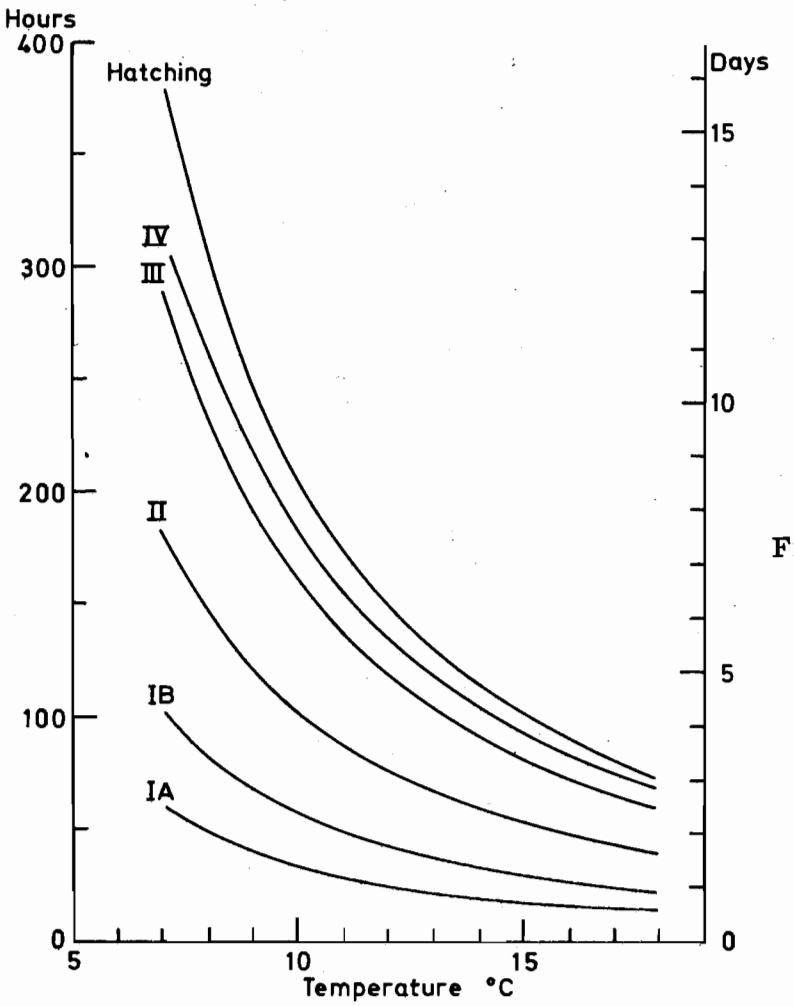


Figure 9 The time taken for mackerel eggs to reach the six development stages shown in Figure 8 over the range of temperatures at which they can develop.

Once the totals for number of eggs produced per day each month were estimated they were plotted against the mean date of the survey to which they apply. As each month's production value is an estimate and not a certainty, 95% confidence limits, an estimate of error, were calculated for each production estimate (Figure 11). (These mean that if 100 ships had collected a similar series of samples to those collected, the results from 95 of them would have fallen within the limits shown.) By joining the production estimates for each survey by straight lines and measuring the area beneath the line so completed, i.e. summing all the daily egg production estimates for the duration of the spawning season, the total number of fertile eggs spawned was estimated. This estimate too has 95% confidence limits, the values of which fall between the highest and lowest confidence limit values for the individual survey estimates. The final estimate of the number of eggs spawned was 1 980 000 000 000 000 (+30% or -20%), i.e. one million, nine hundred and eighty thousand billion eggs (following the convention 1 billion = 1 thousand million), with the possibility that there may have been 30% more or 20% less than this. This estimate is only one step towards knowing the size of the spawning stock.

Next the number of eggs was converted to the number of mature female fish in the population by estimating the number of eggs each one spawns, i.e. its fecundity. If the sex ratio is known the number of females can then be raised to obtain the total stock size.

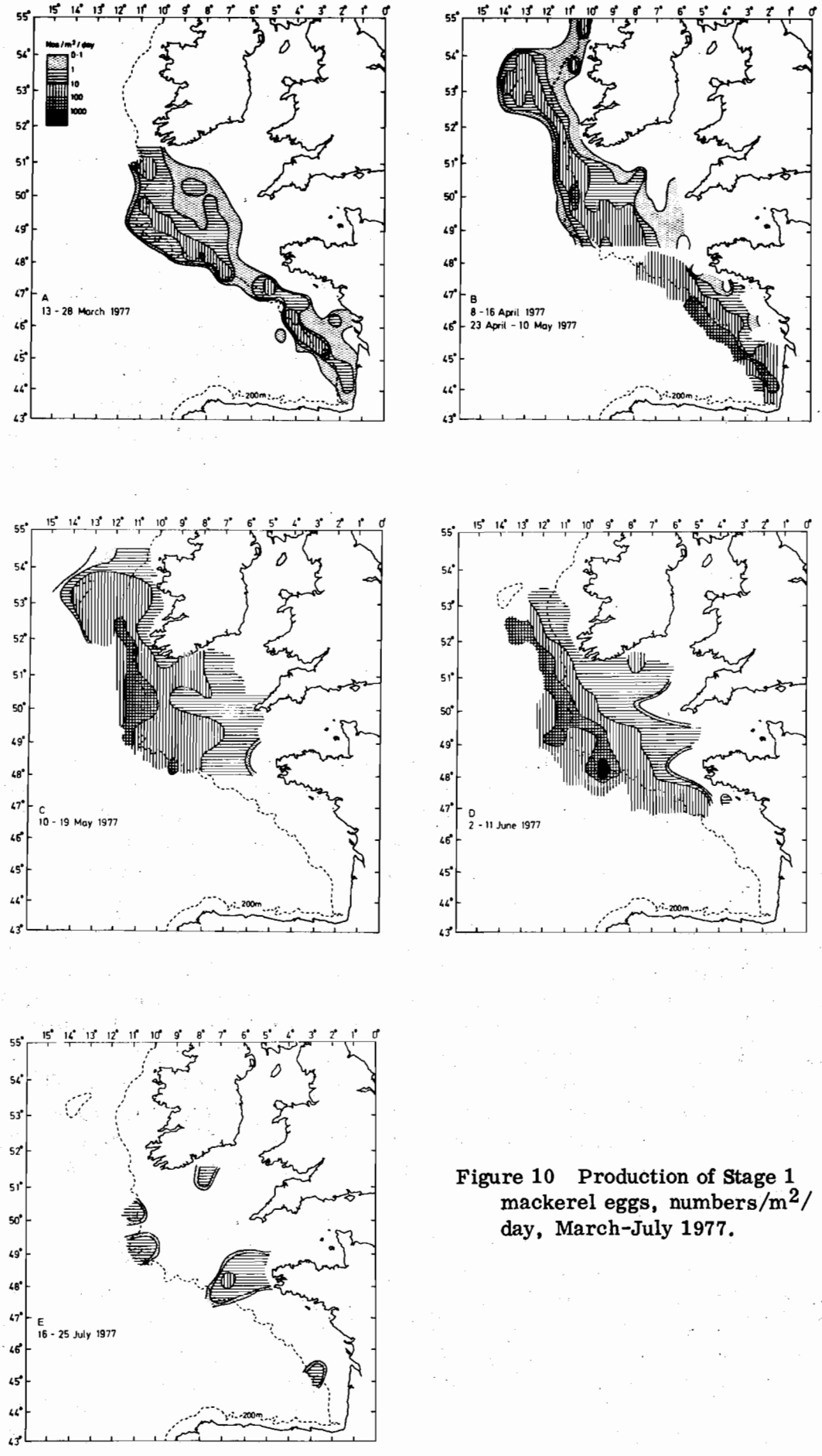


Figure 10 Production of Stage 1 mackerel eggs, numbers/m^2/ day, March-July 1977.

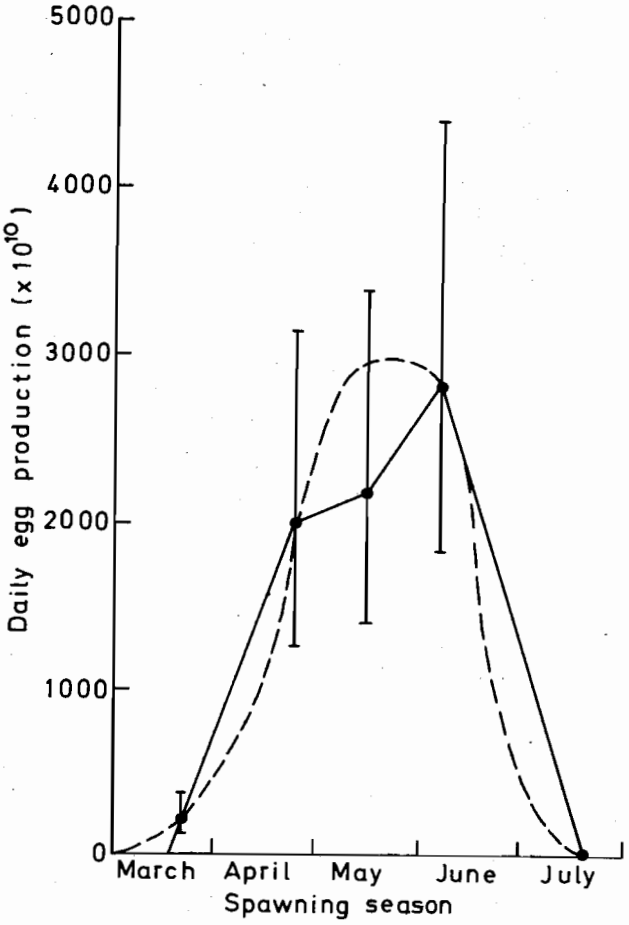


Figure 11 The Western mackerel stock daily egg production curve, March-July 1977. The 95% confidence limits about each cruise estimate are shown. The broken line indicates the probable form of the season's egg production curve.

By collecting the roe from mature female fish before they spawn and counting the number of eggs that are being prepared for the current spawning season the relationship between fish size and the fecundity was established (Figure 12). This relationship was applied to the size frequency distribution in the commercial catches during the spawning season from Biscay, the Celtic Sea and the area west of Ireland to obtain a mean fecundity estimate of 282 530 eggs per fish.

From the estimated number of fertile eggs spawned and the mean fecundity, the total number of mature female fish was calculated to be 7 000 million. A sex ratio of 1 male to 1 female is the generally accepted norm and it is the ratio found in Scottish commercial landings. This ratio gives a stock size of 2 x 7 000 = 14 000 million mature fish. However, during the spawning season the sex ratio in the English commercial landings from the western English Channel is only 0.64 males per female. This ratio gives a more conservative raising factor of only 1.64 instead of 2 as used above. This value of 1.64 was used to estimate the total number of mature fish in the spawning population as 11 493 million fish. This was the estimated 1977 spawning stock size presented to the ICES Mackerel Working Group in February 1978.

At its meeting in 1977 the Working Group had estimated by cohort analysis that there were 4 200 million mature fish in the population. The estimate based on the egg survey indicated a population nearly three times as large as previously estimated. All the available data, landing statistics, age distributions, tagging returns and the plankton survey, were then subjected to a most critical examination in a very real effort to establish the truth. One result was the discovery that there had been a fault in the treatment of the tagging data which affected the estimates of numbers surviving the tagging process

and of mixing ratios at Shetland. Once these estimates had been revised two new cohort analyses were made, the first showed that North Sea stock assessments prior to 1978 were too optimistic and the second that those for the Western stock were too pessimistic. The result of the new cohort analysis of the Western stock estimated that in 1977 there were 9 000 million mature fish in the Western stock. A similar stock size estimate is derived by taking the lower 95% confidence level of the egg production estimate, i.e. 1 980 000 000 000 000 less 20% eggs, which are the product of 9 200 million mature mackerel. The Working Group agreed to proceed with caution and base further calculations on this lower spawning stock size estimate, which is equivalent to 3.2 million tonnes.

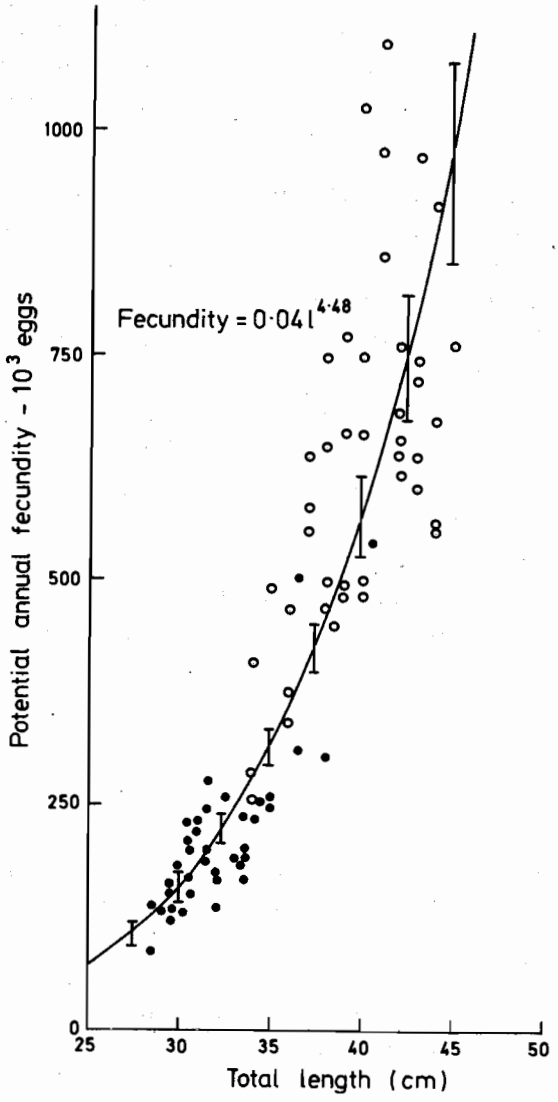


Figure 12 The fecundity of mackerel from the Western stock. Confidence limits of ± 2 standard errors about the regression line are shown. The open circles show the estimates for fish from the western Celtic Sea, the closed circles are for fish from Cornish waters.

THE RECOMMENDED TACs FOR 1978 AND 1979

From the stock size estimate to the TACs for 1978 and 1979 was a relatively straightforward procedure, but it is worth emphasizing here that when estimating the stock size the Working Group took the conservative option at all stages. Throughout the collection and analysis of the plankton samples no corrections were made to raise estimates to cover unsampled areas; a sex ratio of only 0.64 males per female was used in preference to the more usual ratio of 1 to 1 and the TAC was calculated from a minimum stock size estimate.

From the revised stock size estimate for 1977 the ICES Working Group calculated that the fishing mortality during 1977 had been about 10% per year. At previous meetings of the Group an acceptable level of fishing mortality was considered to be about 18-20% per year, but continuing with its decision to advance cautiously with the new increased stock size estimate it decided to limit the fishing mortality to 15% when calculating TACs for 1978 and 1979. This is equivalent to a total international catch from the Bay of Biscay and waters west of Britain of 450 000 t in 1978 and 435 000 t in 1979.

This new recommendation is almost double the value recommended in 1977 for 1978 but it is hoped that this account of how the revised 1978 TAC was reached will allay the doubts which have been expressed about its validity. At all times all the scientists of the ICES Mackerel Working Group have proceeded with caution, and wherever there has been reasonable doubt, or a choice between apparently equally valid options, the more conservative option has been taken.

Even now the Working Group is far from complacent about the quantity and quality of the data available to it. Its report for 1978 specified three major areas in which the data could be improved. It asked the member countries of ICES to do all that they can both to improve the accuracy of their catch data, and the research organizations to do all that they can to improve the quality of the basic biological data they collect from the commercial landings, and to continue or increase their programmes aimed at estimating stock size, whether by tagging, acoustic surveys or plankton surveys. In this connection the Fisheries Laboratory, Lowestoft is continuing with its acoustic surveys off Cornwall and will certainly participate in future plankton surveys like that carried out in 1977. Its market sampling programmes are constantly under review in order to ensure that the best possible information is being obtained from the commercial landings. These programmes provide the fundamental data for making stock assessments and it is here that the members of the fishing industry can give their assistance by ensuring that the information they give relating to their fishing activities, their catches and tagged fish returns is as accurate as possible.

INFORMATION SOURCES

In addition to original research data presented in this Laboratory Leaflet information was taken from ICES Mackerel Working Group reports and from a variety of other scientific publications which are listed below.

BOLSTER, G. C., 1974. The mackerel in British waters. pp. 101-116 In: Jones, F. R. H. (ed.), Sea Fisheries Research. London, Elek Science, 510 pp.

HAMRE, J., 1978. The effect of recent changes in the North Sea mackerel fishery on stock and yield. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 172, 197-210.

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