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International Council for the Exploration of the Sea

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REPORT OF THE MACKEREL WORKING GROUP

Copenhagen, 1-9 March 1988

*General Secretary
ICES
Palægade 2-4
DK-1261 Copenhagen K
DENMARK

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1 INTRODUCTION

1.1 Terms of Reference

At the 75th Statutory Meeting in Santander, it was decided (C.Res. 1987/2:3:3) that the Mackerel Working Group (Chairman: Mr S.A. Iversen) should meet at ICES Headquarters from 1-9 March 1988 to:

a) assess the status of and provide catch options for 1989 within safe biological limits for the mackerel stocks and management units in Sub-areas II-VII and Divisions VIIIa,b;

b) update the quantitative description of the distribution and relative abundance of juvenile mackerel by season and by as fine an area breakdown as possible, and re-evaluate possible management measures to limit the catches of juvenile mackerel;

c) consider appropriate management units in light of recent developments in the migratory pattern of mackerel;

d) provide quarterly catch-at-age and catch and stock mean weight-at-age data and information on the relative distribution at different ages by quarter for North Sea mackerel for 1987 as input for the multispecies VPA, and provide information on the likely level of Western stock mackerel which are seasonally present in the North Sea.

In a letter from the Chairman of ACFM (3 February 1988), the Working Group was also asked to:

a) review the assessment for the Western stock of mackerel in the light of the latest scientific data on egg mortality, atresia, and spawning outside the standard egg survey area and the consequence of these factors upon estimates of the spawning stock biomass;

b) comment on whether the mackerel stock in Divisions VIIIc and IX should continue to be considered by the Working Group on Pelagic Stocks in Divisions VIIIc and IX and Horse Mackerel, or whether it should be handled by the Mackerel Working Group.

1.2 Participation

The Working Group met in Copenhagen with the following participants:

E. Bakken	Norway
J. Dalskov	Denmark
W.A. Dawson	UK (England and Wales)
A. Eltink	Netherlands
P. Hopkins	UK (Scotland)
S.A. Iversen (Chairman)	Norway
N.A. Nielsen	Denmark
J.P. Molloy	Ireland

Dr E.D. Anderson, ICES Statistician, attended the second part of the meeting.

2 REVIEW OF WORKSHOP REPORTS

2.1 The Mackerel Egg and Recruitment Workshop Report

The Mackerel Egg and Recruitment Workshop was held 25-29 January 1988 in Aberdeen to:

a) coordinate the timing and planning of the mackerel egg surveys to estimate the total egg production of mackerel and horse mackerel;

b) discuss problems in mackerel and horse mackerel fecundity estimation and review the basis for estimating spawning stock biomass from egg surveys;

c) evaluate the methodology and results of recruitment surveys for 0- and 1-group mackerel and horse mackerel.

The subject in the report of this meeting (Anon., 1988) is reviewed in Sections 2.1.1-2.1.7.

2.1.1 North Sea mackerel egg survey in 1988

The surveys in the North Sea have been carried out on a yearly basis during the period 1980-1984 and since then every second year. The last egg survey in the North Sea was carried out in 1986, which gave the lowest egg production ever estimated since these investigations started in 1980. The spawning stock was estimated at 45,000 t.

In 1988, the Netherlands, Denmark, and Norway will carry out egg surveys and cover the egg production of mackerel, horse mackerel and sole.

It is recommended that the participants in the North Sea survey meet in the last week of October 1988 at the Institute of Marine Research in Bergen to assess the results and write a final report.

The results should be made available to the ACFM meeting in November 1988.

2.1.2 Western mackerel egg survey in 1989

England, the Federal Republic of Germany, France, Ireland, the Netherlands, and Scotland will all participate. The Research Institute for Fish Science and Technology Basque Country (Spain) will participate subject to the availability of a survey vessel. It was agreed that the survey should cover spawning of both mackerel and horse mackerel and that estimates of egg production would be made for both species. To achieve this, the survey area would be extended north to 56^{0}N and south to 44^{0}30'N.

No changes were made to sampling gear, procedures, and sampling strategy, except that the high abundance rectangles, which are sampled 1-2 times as often, are now based on the egg abundance of both species.

A preliminary estimate of egg production of both species should be made available to the ACFM meeting in early November 1989.

2.1.3 Egg staging and egg mortality

It was recognized that there were no great problems in identifying stage 1 eggs. However, attempts to calculate mackerel egg mortality from earlier surveys had highlighted some difficulties with the later stages. It was decided that a further exchange of samples between all participants, to compare staging, would be beneficial and would be arranged.

2.1.4 Fecundity and atresia

As in previous years, fecundity estimates in 1986 were of potential fecundity rather than absolute fecundity. Potential fecundity is the maximum number of oocytes which might be spawned in the current season, with no allowance for resorption of developing oocytes (atresia). The estimation of potential fecundity assumes that the number of eggs destined to be spawned in a season is fixed and that these eggs are identifiable as developing oocytes in the ovary prior to the onset of spawning (determinate spawning). The size threshold at which 50% of the oocytes are developing is determined and all oocytes above this size are counted in ovaries from the appropriate maturity stage.

In converting estimates of total egg production to spawning stock size, estimates of absolute fecundity (the number of eggs actually liberated) are of critical importance. While it has been recognized for some time that mackerel have a protracted spawning season, it has also been assumed that they are determinate spawners. From histological work on the development of mackerel ovaries, two potential sources of systematic error have been identified, namely atresia and *de novo* recruitment of new oocytes from the resting stage during the period of spawning (indeterminate spawning).

The current method of calculating spawning stock biomass from egg production estimates assumes that mackerel are determinate spawners. An alternative method which does not make this assumption is the "batch fecundity method" which has been applied to a number of other stocks of pelagic fish (Lasker, 1985). It has been suggested that this method could be applied to the mackerel stock assessment (Priede and Laird, 1986; Alheit *et al.*, 1987).

The batch fecundity method avoids difficulties with estimation of total annual fecundity by basing the stock size calculation on samples taken during a short time span during the middle of the spawning season. Daily egg production is divided by mean daily female fecundity to give an "instantaneous" measure of biomass. Ideally, a measure of daily egg production is obtained in a single plankton survey. A random sample of fish is taken from the population and estimates are made of the proportion of fish spawning on that day together with batch fecundity in those that are spawning.

The main advantage of the batch fecundity method is that determinate fecundity is not assumed. Therefore, atresia and *de novo* vitellogenesis during the spawning season which give rise to potential errors in the total fecundity method do not affect the precision of the biomass estimate.

Disadvantages of the method are:

a) It is presumed that the entire spawning stock is represented in the spawning area when the sample is taken. There is evidence in the Western mackerel stock that larger fish spawn earlier in the season than smaller fish (Dawson, 1986a; Eltink, 1987). It would, therefore, be necessary to sample the spawning population on more than one occasion.

b) There is no evidence of a diurnal cycle as in the anchovy. This can pose problems for sampling of the spawning population.

The evidence for and against the concepts of determinate or indeterminate spawning in mackerel were discussed and the Workshop could not reach a decision as to which was the correct interpretation of the available evidence. Although the total fecundity method will be retained in 1989, it was decided to make an estimate of daily egg production and attempt to implement the batch fecundity method in a pilot study.

The Workshop concluded that fecundity could be reduced through atresia. Disagreement centered on whether development of new eggs could occur to realize higher fecundity than indicated by the prespawning standing stock of oocytes. Analysis of batch fecundity and batch intervals in mackerel might help to resolve this difficulty.

Preliminary estimates of atresia were made in 1986 using stereological techniques. It was noted that there were relatively high levels in spent fish, but no correction was made for this in the final fecundity estimate. The meeting recommended a sampling programme to obtain estimates of atresia in 1988 and 1989.

The spawning stock estimates from the Western egg surveys were compared to those derived from a number of VPAs, with input F values in 1986 ranging from half to double those used by the 1987 Mackerel Working Group. It was found that, for 1977, the VPAs converged to agree reasonably closely with each other and with the 1977 egg survey estimates of SSB despite the potential sources of error in the latter. There is, therefore, no evidence to suggest that the egg survey estimates are seriously biased.

Usually, the Skagerrak has not been included in the North Sea surveys. Earlier studies have indicated that the egg production in this area might contribute about 5% of the total production (Iversen, 1977). The western part of the Skagerrak will be checked once during the peak of the spawning season.

2.1.5 Consequences of different factors upon estimates of the spawning stock biomass

Factors that would cause an underestimation of the spawning stock are:

1) Egg mortality: Earlier estimates of egg mortality were not applied for any egg survey, because there are still problems in staging the older eggs (Anon., 1987b, Section 9.2) which could bias the mortality estimate. Another comparison of the staging of eggs between participants is necessary.

2) Atresia will cause an underestimation of the spawning stock when mackerel are assumed to be determinate spawners.

3) Spawning to the north of the standard egg survey area is estimated to be only 4-5% to the north of the standard area. In June 1988, during an English survey on the western English Channel, the egg production to the east of the standard survey area will be quantified to get an indication of the underestimation of the spawning stock by not fully covering this area. The standard egg survey area is thought to cover the spawning area to the west and the south.

The factor that could cause an overestimation of the spawning stock is the de novo recruitment of oocytes during spawning, which will cause an underestimation of fecundity.

The Mackerel Working Group concluded that it was impossible to quantify the influence of these factors. Therefore, no attempts were made to calculate the fecundity and the total egg production.

The Workshop recommends, therefore, that the current method used for the previous surveys should continue to be used, and that research be continued to evaluate the magnitude of any likely errors.

2.1.6 Maturity

A new maturity key was presented and this was considered an improvement on the Macer key, which is presently in use; this new key needs further refinement to fully meet the particular requirements. It is recommended that the improved new key be circulated to all field workers for comment and revision. If the new key receives general acceptance, it is proposed that a manual with photographs be prepared for use by all ICES countries.

Until now, maturity ogives by age were estimated from the number of immature and mature fish from both the juvenile and the spawning area (Lockwood et al., 1981; Anon., 1985a). These were estimated without weighting the samples from both areas according to the relative abundance of the immature fish of a particular age group in the juvenile area and the mature fish of that group in the spawning area. This weighting could not be applied and its absence could, therefore, cause a severe bias. A method of estimating the percentage spawning fish by age group based on L_1 measurements, which is independent of this weighting, was presented at the Workshop. Preliminary results of this method, which was carried out only on otoliths of the 1981 year class of mackerel (626 otoliths), indicated that about 35% of this year class at age 2 was actually spawning [c.f. 60% according to the maturity ogive presently in use (Anon., 1987a)]. Further work is necessary to check the validity of this method.

2.1.7 Recruitment surveys

North Sea area

The Workshop recommended that juvenile mackerel abundance indices should continue to be calculated from the IYFS data and considered a new standard sampling area for this purpose.

Western area

Although it is possible to combine the results from different series of surveys, the changing migratory behaviour of mackerel makes it difficult to analyze the data in this way. In recent years, the distribution of juvenile mackerel has changed considerably and this makes it difficult to use a time series of data from any one series of surveys in isolation. The Workshop felt that the results from the surveys could be greatly improved if the surveys were combined as a single survey with standardized fishing gear, fishing method, survey area, and time.

The Workshop agreed that consistent sampling of juvenile mackerel could best be achieved by a standard bottom trawl and that the GOV trawl would be the most practical to use.

The Workshop recommended:

1) that all historical data available on the distribution and abundance of juvenile Western mackerel be written up jointly by representatives of countries participating in these surveys,

2) a manual of standard survey procedure be prepared for future surveys similar to that used for the North Sea International Young Fish Survey,

3) if standardization of fishing gears is not possible, the different gears used should be calibrated by overlapping the area coverage of different countries.

2.2 The Age Determination Workshop Report

The results of the otolith exchange in 1985 indicated an unacceptable low level of agreement of ages for fish older than 10 years (Dawson, 1986b). Therefore, an Age Determination Workshop was convened at Lowestoft during June 1987 to attempt to resolve these differences. The objectives of the Workshop were to:

i) assess the consistency of age determination of older mackerel by otolith readers for the main countries exploiting mackerel in the Northeast Atlantic, and in the event of an unacceptable level of disagreement in the age determination of older mackerel, attempt to identify the source of differences and agree on a standard method of interpretion;

ii) recommend whether or not the upper limit of the age range used in mackerel assessments should be extended from 10 to 15 years.

Seven otolith readers from seven countries participated in the otolith exchange and five of these readers were able to attend the Workshop. The Workshop was able to agree on the best way of otolith preparation and examination.

The first sample of otoliths selected for comparative age determination was a subsample of the otoliths used in an earlier otolith exchange and consisted of fish covering the full range of ages.

There was a fairly good degree of consistency between the two sets of age determinations with 59% of readings in agreement on both occasions and 89% were within ± one year.

After noting the age determinations for the first sample, the Workshop participants then discussed age determinations from a sample of seven recaptured tagged fish. The period of liberty provided an absolute minimum age for each fish, and it was agreed that these otoliths had been particularly valuable in providing some help in age determination validation for older fish. The participants went on to discuss disagreements in interpretation of the first sample and were able to resolve most of their differences. The Workshop considered that the detailed discussion of the first sample plus the information provided by the tagged fish otoliths could be expected to improve the consistency of interpretation between and within readers.

The expected improvement was verified when participants looked at a second sample containing predominantly older otoliths than the first. There was a greater consistency between readers over the greater part of the sample, and wide ranges in the determined ages were restricted mainly to the oldest fish (15+).

The full analysis of the results of the Age Determination Workshop is available in an EEC report.

The Workshop concluded that if the age range used in assessments was extended to cover age groups 0-14 and 15+, the reliability of the age composition data should be as good as or better than was previously available with the more restricted age range.

The Workshop recommended:

i) Ages should be determined up to age 15 and recorded as age groups 0 - 14, with all older fish aggregated as a 15+ group.

ii) The report should be brought to the attention of ICES.

The Working Group considered that the report of the age determination was a valuable document. It, therefore, endorsed its contents and decided that, in future assessments, the catch-in-numbers-at-age data should be extended to include a 15+ group.

3 STOCK DISTRIBUTION AND MIXING

3.1 Distribution of Mackerel Fisheries in 1987

As for 1986 (Anon., 1987a), the officially reported distribution of catches could not be taken as a fully reliable guide to where mackerel were actually caught in all areas and seasons. An attempt was made by the Working Group to map the catches using information from unoffical sources, but it was not possible to express the catch distribution in precise quantitative terms. For some less important national fisheries, no information was available on catch location and season. The quarterly distribution of the fisheries in 1987, as estimated by the Group, is shown in Figures 3.1a-d.

Besides the uncertainties related to misreporting, it should also be noted that the relative magnitude of catches in each location and season depends to a large extent on management controls. The distribution of the fisheries as given here will, however, in broad terms reflect the migration and availability of mackerel corresponding to that illustrated in Figure 3.2.

In the first quarter (Figure 3.1a), catches were taken all along the edge of the continental shelf to the west of the British Isles, off Ireland, and in the western Channel. The fishing area was much the same as in 1986, but the quantity caught in Division VIa was doubled (Tables 4.3 and 4.4). Most of the catch was taken in a trawl fishery by vessels from Ireland and the Netherlands.

During the first quarter, the mackerel migrate from north to south through Divisions VIa and VIIb,c to the main spawning area. This migration is reflected in the fishery by a general shift from north to south during the months December-March.

In the second quarter (Figure 3.1b), catches in the Western area were all taken south of Ireland in the spawning area. The fishing area was the same as in the previous years, but the quantity taken in 1987 was smaller. It is possible that the trawler fleet in 1987 reduced mackerel fishing and instead fished horse mackerel in order to preserve the available mackerel quota. The only other mackerel fishery in the second quarter took place off the coast of southwest Norway. A small quantity was taken, mainly by drift nets and as by-catch in trawl fisheries.

In the third quarter (Figure 3.1c), the major fishery took place in the eastern part of Division IVa as well as in the adjacent part of Division IIa. The fishing area and the quantity were the same as that of 1986. Most of the catches were taken by purse seine, and Norway accounted for a major part. Catches were also taken in the Skagerrak by various gears, and the total catch in Division IIIa doubled compared to 1986 (Table 4.4). Small catches were recorded in the southern North Sea. This was mackerel taken as by-catch in trawl fisheries.

In the fourth quarter of 1987 (Figure 3.1d), the fishery shifted westwards. Although there are uncertainties about the exact fishing locations, it seems that a large part of the catches were taken around the Shetlands. The actual fishery probably took place somewhat further east than in the previous year. The total quantity taken in 1987 in Divisions IIa, IVa, and VIa was the same as in 1986. Both purse seiners and trawlers from most mackerel fishing nations participated in the fishery, but catches by UK (Scotland), Norway, and Ireland accounted for about half the total. In addition to the Shetland area fishery, smaller quantities were taken off northwest Ireland, Cornwall, and southwest Norway.

During the fourth quarter, the major fishery shifted from east towards west and southwest through the northern part of Division IVa. This fishery exploited mackerel which were migrating from the main summer feeding areas to the winter area west of the British Isles.

3.2 Review of Information on the Adult Stocks

A meeting of a Norwegian-EEC Joint Scientific Group on Migration and Area Distribution of Mackerel (Western Stock) took place in Bergen in November 1987. The Group was asked to collect and up-date the most relevant information on stock and catch distribution, particularly for the most recent years, specified on seasons and year classes. Relevant data for the North Sea stock was also considered. The report of the Group (Anon., 1987c) was available to the Mackerel Working Group, and as it contains information of general interest, the Working Group felt it should be published by ICES.

The report describes the spawning areas, the distribution of various age groups, and the migration pattern. Available data from commercial catches indicate that the distribution of juvenile mackerel has changed in recent years. From 1982 onwards, juvenile mackerel have formed a higher proportion of the total catch in Division VIa. For most recent years, there is also evidence of considerable quantities of juvenile mackerel in the eastern North Sea (Divisions IVa,b) in the late summer. Since the relevant age groups do not appear to be present throughout the year, it may indicate that a high proportion of these are immigrants from the Western stock. Irish egg surveys carried out in 1986 and 1987 (Molloy and Barnwall, 1988) have indicated a spawning biomass of 80,000-100,000 t in Division VIa. This is about double the last estimate of the spawning population of the North Sea stock.

Shifts in the seasonal distribution of adult Western mackerel during the 1970s and 1980s were also noted. Most of the information was obtained from the fisheries. In recent years, the main winter fishery, October-January, has shifted northwards away from Divisions VIId-e and is now located mainly in the northern part of Division VIa. There are also indications of a further shift towards the northern North Sea. Considerable catches, however, are taken in January in the southern part of Division VIa and the northern part of Division VIIb. These catches are, however, believed to be taken from shoals which have already moved southwards, having overwintered in the northern part of Division VIa. The fishery in summer also provides evidence for changes in distribution. In the most recent years, mackerel have occurred further south and east in Division IIa as well as in the adjacent northern part of Division IVa.

Western stock mackerel are probably distributed over a wider area of Division IVa during late summer and then move westwards across the northern North Sea on the return migration to the overwintering area west of Shetlands. The amount of time spent on the over-wintering area appears to vary because some shoals have already moved as far south as 54^0N by mid-January. The migrations to and from the feeding grounds and the actual distribution of the shoals during the main feeding times seem to vary substantially from year to year. The migrations may be influenced by the total size of the stock, environmental factors, location of the over-wintering quarters, or a combination of all three.

It is evident from tagging experiments that mackerel occurring southwest of Ireland in May migrate to the Norwegian Sea (Division IIa), to the northern part of the North Sea (Division IVa) and, on occasions, even into the central North Sea (Division IVb) in the summer period.

The very low size of the North Sea stock and the mixing with mackerel from the Western stock at certain times of the year makes it difficult to determine the distribution and migration of the North Sea mackerel. At present, this is not known with any precision outside the spawning season. It is likely that North Sea mackerel now overwinter in the area to the west of the Shetlands, although scattered observations demonstrate that mackerel are present in the Norwegian Trench during winter.

The Working Group reviewed the Scientific Group's report and available additional information which are presented here in Figure 3.2 in a schematic outline of the current distribution and migrations of the two mackerel stocks. It should be emphasized that the figure in some parts is speculative and not based on quantitative information. It may, however, serve the purpose of illustrating general features relevant to discussions on allocation of catches to stocks (Section 3.8) and management considerations (Section 6).

Reference is also made to an illustration of seasonal migration of mackerel into the North Sea from Western areas given in the 1986 Working Group report (Anon., 1986, Figure 1).

3.3 Juvenile Distribution

In 1985, the Mackerel Working Group discussed the apparent changes in the distribution of juvenile Western mackerel that had taken place since about 1981 (Anon., 1985b). These changes were illustrated by comparing the annual ratios of the catches of Western stock juveniles (1- and 2-year-olds) from Division VIa to total catches of Western stock juveniles in all areas with the ratios of total catches of all ages of the Western stock in Division VIa to the total catch of the Western stock in all areas. After 1981, there was a tendency for the catches of both juveniles and adults to increase proportionately in Division VIa. This ratio could not be calculated on the same area basis in 1987, however. Therefore, it was impossible to separate the catches of the Western stock in Divisions IIa and IVa. If the ratio is calculated from the catches in the northern area, however, the proportion of juveniles in the north remains high.

To investigate the distribution of each year class in more detail, the distribution of catches made by research vessels is shown in Figures 3.3-3.9. The abundance indices were derived from research vessel trawl surveys by England (first and fourth quarters, 1984-1988), Ireland (fourth quarter, 1985-1987), Netherlands (first and fourth quarters, 1984-1988), Scotland (first and fourth quarters, 1985-1988), Federal Republic of Germany (first quarter, 1985-1988), Norway (first quarter 1985-1988), and Denmark (first quarter, 1985-1988).

The occurrence of the 1985, 1986, and 1987 year classes expressed as a percentage (number) of the catches taken in the commercial fishery in each ICES division in 1987 is shown in Figure 3.10. The most noticable difference in 1987 is the lack of abundance of the 2-year-olds (1985 year class) in the catches compared with the 2-year-olds present in 1986 (1984 year class). In its terms of reference, the Working Group was asked to give the distribution and relative abundance of juvenile mackerel by season by as fine an area breakdown as possible. Therefore, the occurrence of the 1985, 1986, and 1987 year classes is also expressed in the same way in more detail by rectangles in Figures 3.11a-l.

3.4 The 1987 Year Class

Research vessel surveys during the fourth quarter of 1987 were undertaken by Ireland, Scotland, the Netherlands, and England and covered most of the Western area. These surveys gave a good indication of the distribution and abundance of the 1987 year class in Division VIa and Sub-area VII. The IYFS in February 1988 provided additional information of the distribution and abundance of the 1987 year class in the North Sea. The highest concentrations were once again found in the Western area, mainly in the Celtic Sea (Divisions VIIb,j, and h). In the North Sea, the highest concentration occurred in the Norwegian deeps between the Shetland Islands and Norway (Figure 3.3).

The 1987 year class was present in the catches in the fourth quarter in Division VIIe only (Figure 3.10).

3.5 The 1986 Year Class

The revised distribution of the 1986 year class during the period October 1986 - March 1987 is presented in Figure 3.4 and includes additional information that was not available to the Working Group in 1987. Large concentrations were found off the Cornish Peninsula (Division VIIe) and close to the shelf edge in the Celtic Sea (Division VIIj). In the North Sea, a single, very large concentration was found in the Norwegian deeps between the Shetland Islands and Norway (Figure 3.4).

The distribution of the 1986 year class in the fourth quarter of 1987 in the Western area from research vessel surveys is illustrated in Figure 3.5. No large concentrations were found, however, but they were abundant once again in Divisions VIIj and e.

The 1986 year class was present in the catches in some areas for all quarters of the year. However, although they were present in large numbers in the third quarter in Division IIIa (21%), they only comprised 1% of the total catch (t) during the main fishery in Divisions IVa and VIa during the fourth quarter (Figure 3.10).

3.6 The 1985 Year Class

Additional information on the distribution of the 1985 year class was made available to the Working Group for both the periods October 1985 - April 1986 and October 1986 - March 1987. The distribution of the 1985 year class for each period is shown in Figures 3.6 and 3.7, respectively. The 1987 Working Group observed the highest concentrations to be in the area south of Ireland between October 1985 and April 1986, while one year later, the only high concentration was found southwest of England. The additional data did not show any other areas of high concentrations for the 1985 year class as "1/2" groups.

The distribution of the 1985 year class was also reflected in the same way in the catches in the first quarter of 1987 when very large numbers were present in the catches off southwest England. Some were present in most areas in the second and third quarters, particularly in the spawning areas, but only comprised 7% of the total catch in Divisions IVa and VIa in the fourth quarter (Figure 3.10).

3.7 The 1984 Year Class

Additional data were also provided on the distribution and abundance of the 1984 year class. These data showed the 1984 year class to be even more abundant than previously thought for both the period October 1984 - March 1985 (Figure 3.8) and October 1985 - March 1986 (Figure 3.9).

3.8 Allocation of Catches to Stocks

In the years prior to 1986, Norwegian tagging data were used to estimate the rate of mixing between Western and North Sea mackerel. The proportion of mackerel from the North Sea stock taken in Division IIa in 1985 was calculated to have been 0.05, and this proportion was applied to catches in number of fish older than 3 years. Similar figures for catches in 1984 and 1983 were 0.10 and 0.06, respectively.

Tagging data were also used to estimate stock proportions in catches taken in Division IVa, but tag numbers were smaller and considered less reliable. For 1985, the same proportion as that used for Division IIa catches (0.05) was applied to catches taken in Division IVa north of 59°N. Fish of age 1 and 2 were assumed to be entirely of the North Sea stock. For the 1984 catches, the Working Group decided to apply a proportion of 0.10 North Sea stock to catches taken in Division IVa north of 59°N. For 1983, all catches in Division IVa were assumed to be 100% North Sea stock.

For catches taken in Division VIa north of 58°N in the periods January-March and October-December, an average stock proportion of 0.07 North Sea mackerel was estimated in 1985. However, a rounded value of 0.10 was applied, as in the previous four years.

Catches taken in 1986 in Divisions IIa, IVa, and VIa were not split on the basis of tagging data. Instead, the Working Group used three sources of information to calculate the catch of North Sea mackerel in number by age for the various divisions: 1) the estimate of the relative proportion of the two stocks present in the North Sea by quarter and age group, 2) an estimate of the number of 1-year-old fish in 1984 and 1985 in each of the two stocks, and 3) the age distribution of the North Sea spawning stock in 1986. The calculation method and the results are given in last year's report (Anon., 1987a, Section 4.4 and Table 4.2).

The Working Group reviewed this procedure and found it unsuitable to be used for splitting the 1987 catches, the main reason being that no estimate of the North Sea stock could be made for 1987 since no egg survey had been carried out. In addition, it is still not known whether the 1984 year class recruits to the North Sea or the Western stock.

The Group also considered using tagging data to split the 1987 catches. The data were, however, found to be unreliable because very few returned tags could be related to fishing area with any certainty due to misreporting of a substantial part of the catches. Also, this method would require estimates of stock sizes, and the calculated stock proportions would be rather dependent on the relative stock sizes which, to a large extent, would be determined by the assumed size of the North Sea stock.

For these reasons, the Working Group decided to allocate the 1987 catches to stocks by assuming that the proportion of North Sea mackerel taken in all areas except Divisions IVb,c and IIIa were insignificant and had only little influence on the assessment of the Western stock. Catches from Divisions IVb,c, VIc, and IIIa were assumed to be all North Sea fish as in previous years.

A table showing the estimated catches which have been allocated to each stock has not been included in recent Working Group reports. These estimated catches are, therefore, shown in Table 3.1 for the period 1976-1987. The catches are the same as those on which the stock VPAs are based, i.e., in the Western stock VPA up to 1987, the North Sea stock VPA up to 1985, and the combined stock VPA which was carried out by the 1986 Working Group.

4 NORTH SEA AND NORWEGIAN SEA AREAS

4.1 The Fishery in 1987

Nominal national catches in the North Sea, Skagerrak and Kattegat (Sub-area IV and Division IIIa) are given in Table 4.1 and catches in the Norwegian Sea and off the Faroes (Divisions IIa and Vb) in Table 4.2. Major fisheries took place in bordering areas between Sub-area IV and Division IIa and between Sub-area IV and Division VIa. Misreporting is known to have occurred and the catches by area, as given in Tables 4.1 and 4.2, are erroneous.

The total nominal catch in 1987 in the two reporting areas (Tables 4.1 and 4.2) increased by 31,600 t compared to 1986. The fisheries took place during the period July - November as in earlier years. In 1987, fishing in the northern part of Division IVa accounted for the major proportion of the total. This was caused by the distribution of the mackerel and by provisions in the fisheries regulations allowing transfers of catch quotas from Division IIa to Division IVa north of 59°N.

Table 4.3 gives the estimated catch by quarter for the various sub-areas and divisions. The estimates were made on the basis of information on the fisheries provided by Working Group members. An allocation of catches between Divisions IIa and IVa could not be made due to the problems of misreporting by area. Table 4.3 formed the basis for calculations of catch in number by age (see below). The catches in the same areas for 1986 are shown in Table 4.4 for comparison.

In previous years, discarding of mackerel at sea was considered minimal in the fisheries in the North Sea. Information on the fisheries in 1987, however, indicates that discarding occurred. This seems related to a high proportion of small fish being caught in some areas and to the development of fish processing onboard the fishing vessels. No estimates of discard rates were available, and the Working Group was unable to assess the quantity of discarded mackerel. The reported catches should, however, be considered as a minimum.

Reports from the fishery in Division IIIa indicate that mackerel in 1987 occurred further south than in previous years, with catches being taken both in the southern Kattegat and even in neighbouring parts of the Baltic.

4.2 Assessment of the North Sea Stock

4.2.1 Catch in numbers in 1987

The catch in number at age for Divisions IIa + IVa + Vb, IIIa, and IVb + IVc is shown in Table 4.5.

Division IIIa

The Swedish data were allocated to quarters and age groups by quarters using the combined Norwegian and Danish data.

Divisions IIa + IVa + Vb

The catches by England and Wales, the USSR, the German Democratic Republic, and Sweden were available by quarters. These catches were allocated to age groups according to data from Norway, Denmark, Scotland, and the Netherlands.

Divisions IVb + IVc

Sampling data were available for the Dutch, Danish, and Scottish catches. The French and English catches were allocated to age groups using the combined Dutch, Scottish, and Danish data.

4.2.2 Revision of the 1986 catch-in-numbers data

The corrections in catches for 1986 are minor; therefore, no corrections in catch in numbers per age group were made.

4.2.3 Weight at age and maturity

Mean weights at age in the catches by quarter in 1987 were provided by Denmark and Norway for Division IIIa and by Denmark, the Netherlands, and Scotland for Divisions IVb,c. Weighted (by number) mean catch weights at age were calculated for Divisions IVb,c and IIIa by quarter and for the whole year.

The calculated sum of products (SOP) for these divisions was rather similar to the reported catches in 1987.

Last year, the Working Group changed the weights at age in the stock at spawning time for 1986 in the WEST file (Anon., 1987a). This was because data from the spawning survey in 1986 differed somewhat from those usually used by the Working Group. In 1987, there were data from Norwegian commercial catches in Divisions IVa SE, IVb, and IIIa from the second quarter and from survey vessel data ("Eldjarn") from Division IVb (27 June - 12 July 1987). In addition, there were samples from the Danish fishery in the second quarter in Division IVb. The smoothed average weights for the different age groups are given below together with the weights in the WEST files for the years 1969-1985.

Age	WEST file		
	1969-1985	1986	1987
1	180	200	145
2	275	300	250
3	330	340	320
4	415	380	400
5	460	415	435
6	495	460	470
7	525	500	500
8	550	540	535
9	565	580	565
10	590	620	590
11	610	665	620
12	630	700	650
13	645	745	675
14	650	780	700
15	675	825	730

Data obtained during the egg surveys in 1986 demonstrated that only 3% of the 2-year-old fish were mature. This was in contrast to the 37% used in the previous years. Little data were available for the 1985 year class in 1987, but it seemed that a larger proportion of the 2-year-olds were mature in 1987 than in 1986. Therefore, the maturity ogive used in the years prior to 1986 was also suggested for 1987.

4.2.4 The state of the North Sea stock

Due to major uncertainties associated with allocating catches to stocks and estimates of recruitment, the Working Group in 1986 and 1987 (Anon., 1986, 1987a) decided not to proceed with an analytical assessment of the North Sea stock.

The situation is still the same with problems in allocating catches to stocks, and data are not available to quantify the recruitment of the 1984 and 1985 year classes to the North Sea spawning stock. However, the 1984 year class was observed in relatively large quantities in the catches, particularly in the third and fourth quarters in Divisions IVa and IIa (40-50%) and in the third quarter in Division IIIa (30%). It was also observed in similar quantities in a Norwegian survey in the North Sea and Skagerrak 24 June - 11 August 1987 (Iversen, 1988) and in a Danish survey in the eastern part of the North Sea and Skagerrak in August 1987 (Degnbol and Kirkegaard, 1988) (Figure 4.1). In the Danish survey, the 1985 and 1984 year classes were observed to be of equal strength, while in the Norwegian survey, the 1984 year class was observed to be stronger than the 1985 year class.

Samples from the Norwegian survey in Division IVb demonstrated that the 1984 year class was spent by the end of June. Of a total of 80 fish, only one was spawning, while all the others were spent. The spent fish might either have spawned in the North Sea or in the Western spawning area.

The last egg survey in the North Sea in 1986 gave the lowest egg production estimated since the investigations started in 1980. The spawning stock was then estimated at 45,000 t (Iversen *et al.*, 1987). Samples during the egg survey in 1986 demonstrated that the proportion of mature fish of the 1984 year class was very low, about 3%. This was much lower than the 37% used for 2-year-old fish in previous years (Anon., 1987a). In 1987, however, almost 100% of the 1984 year class investigated from the samples were mature.

Since no information about recruitment of the 1984 and 1985 year classes to the North Sea spawning stock was available and no egg survey was carried out in 1987, the Working Group considered it impossible to assess the North Sea stock until after the 1988 egg survey (see Section 2.1.1).

5 WESTERN AREA

5.1 The Fishery in 1987

The landings made by each country from the Western area (Sub-areas VI and VII and Divisions VIIIa,b) for the 10-year period 1978-1987 are shown in Table 5.1. The figures for 1987 are preliminary. Some slight revisions have been made to the 1986 catches, mainly due to the addition of some Northern Ireland data, and some changes have also been made to the amount of unallocated catches. The total revised 1986 catch has, however, been increased by less than 1%. The estimated catch taken from the areas for 1987 was about 209,000 t (Table 4.3), which is about 26% higher than that estimated for 1986 (Table 4.4). However, attention is drawn to the considerable misreporting of catches both in 1986 and 1987. It is estimated that over 117,000 t of the catches shown in Table 5.1 were in fact taken from the area east of 4°W. Although the amounts of misreported catches in 1987 were lower than those in 1986, they still present major problems for the Working Group. The total amount of "unallocated" catches which could not be attributed to specific countries decreased considerably compared to 1986 and represented about 6% of the total landings in 1987.

The main catches from the fishery were again taken by the UK (Scotland), Ireland, and the Netherlands. It must again be emphasized that these figures should be considered with caution because of the amount of misreported and unallocated catches. The reported Scottish catch, however, increased to about 180,000 t, which was slight lower than their highest reported catch in 1985 of 196,000 t. The reported Irish catch of 89,500 t was slightly higher than the 1986 catch. There has been a considerable decrease in the reported Dutch catch in recent years mainly because of a diversion in effort by the Dutch fleet both to horse mackerel and to mackerel in the Northwest Atlantic.

The total catch estimated by the Working Group to have been taken from Sub-areas VI and VII in 1986 and 1987 has been about 230,000-290,000 t. This is considerably less than the catches taken in previous years. This decline is partly due to 1) the shift which has taken place in the distribution of the stocks in the third and fourth quarters into Divisions IIa and IVa, 2) more effective management measures (e.g., the restrictions imposed by the box off Cornwall and the fact that the Irish fishery in 1987 was closed for the whole year except 6 weeks in January/February and 6 weeks in October/November), and 3) the decrease in effort by the Dutch fleet.

The reported catches taken by sub-area are shown in Table 5.2. This table shows the changing pattern of the fishery which has been caused by the shift in distribution of the shoals to the northern part of Sub-area VI and also shows the decrease which has taken place in the fishery off Cornwall due to the introduction of the "box" in that area. As shown in Table 5.2, considerable quantities of mackerel were reported as having been caught in Division VIa in both 1986 and 1987, when, in fact, they were taken in Division IVa. The catch figures shown in Table 5.2 are, therefore, misleading for 1986 and 1987 and do not demonstrate the continuous change which has taken place in the fishery in recent years to Divisions IVa and IIa.

The distribution of catches per quarter is shown in Table 4.3. In Sub-area VI, over 56% of the total catch was taken in the first quarter (mainly in the southern part of the area), while 43% was taken in the fourth quarter (mainly in the northern part of the area). In Sub-area VII, over 93% of the catch was taken in the first and second quarters.

5.2 Discarded Catches

There were no reports of discarded catches in 1987, although the Working Group believes that discarding may still take place, but to a limited extent. However, the problem may become apparent again, particularly if there is an influx of a number of good year classes into the fishery.

5.3 Assessment of the Western Stock

5.3.1 Catch in numbers in 1987

Division VIa

Sampling data for Division VIa were provided by Scotland, the Netherlands, and Ireland. Landings by the Federal Republic of Germany and the UK (England and Wales) were converted to numbers at age using the Dutch data. Landings by the Faroe Islands and Northern Ireland were raised using the combined sampling data.

A large part of the reported catch for Division VIa is thought to have been taken in Division IVa, particularly during the fourth quarter. The catches in numbers at age, after subtraction of rough estimates of the quantities misreported, are shown in Table 5.3.

Divisions VIIa-c

Sampling data were supplied by Ireland, the Netherlands, and the UK (England and Wales).

Divisions VIId-k

Sampling data were supplied by the Netherlands, the UK (England and Wales), and the Federal Republic of Germany. These were combined to raise the landings by France, Denmark, and Belgium to numbers at age.

Divisions VIIIa,b

Numbers-at-age data were not supplied for Divisions VIIIa,b. The annual age distribution for Divisions VIId-k was applied to convert catches to numbers at age.

Allocation of catch in numbers to stock

As described in Section 3.8, the catches in Divisions IVb,c and IIIa were considered as catches from the North Sea stock, which was also the usual procedure in previous years. In addition, North Sea mackerel are also captured in Divisions IVa, IIa, and VIa. Since the Working Group was not in a position to calculate this proportion, the catches of Western mackerel are, to some extent, overestimated. This overestimation is dependent on the size of the North Sea stock. The lesser the North Sea stock, the lesser the overestimation.

Table 5.4 shows the catches in numbers by age groups, area, and stocks as applied by the Working Group.

Based on the recommendation of the Age Determination Workshop (Section 2.2), the Working Group decided to extend the age groups to 15+ in 1989.

5.3.2 Revision of the 1986 catch-in-numbers-at-age data

The revisions made to the 1986 catches by country increased the total catch by less than 1%. This was considered negligible and no revisions were made to the catches in numbers at age for 1986.

5.3.3 Mean weight at age

Mean weights at age in the catches by quarter in 1987 were provided by Scotland (Divisions VIa and IVa,b), England (Divisions VIId,e), Ireland (Divisions VIa and VIIb), the Federal Republic of Germany (Divisions VIIb,c and VIIg-k), and the Netherlands (Divisions IVa, VIa, VIIb, VIIc, VIIj, and VIIe). Weighted (by number) mean catch weight-at-age estimates were made by division by quarter and by division by year for catches from the Western area and the Western stock.

Mean weights at age (g) in the spawning stock at spawning time were estimated for 1987 by using samples from Dutch commercial freezer trawlers in Division VIIj in March, April, and May and are shown in the text table below (1-year-olds are rarely taken in samples; therefore, a constant weight of 0.070 was taken):

Age	1	2	3	4	5	6	7	8	9	10	11+
$\bar{W}$	70	139	233	268	363	371	392	402	459	483	507

5.3.4 Maturity at age

The necessity of an accurate estimation of the maturity at age is becoming more and more important in a declining stock where strong incoming year classes have a great influence on the size of the spawning stock biomass. However, the estimation of the maturity at age causes problems due to the unknown weighting of the samples from both juvenile and adult areas (see Section 2.1.6). A preliminary estimate of a method independent of this weighting indicated that 60% mature fish at age 2 might be too high and might be only about half of that. In last year's assessment (Anon., 1987a), 20% mature fish of the 1984 year class at age 2 was accepted, while for the other year classes at age 2, a percentage of 60% mature fish remained as was accepted before (Anon., 1985b). This change was based on a much lower number of 2-year-olds in the spawning areas than expected during the Western mackerel egg survey in 1986 and on a slower growth compared to the preceding 1985 year class at age 2. However, the 1984 year class does not show a significantly slower growth compared to the 1979, 1980, and 1981 year classes, which also indicates that 60% mature fish at age 2 might be too high for some years.

The Working Group decided to use 60% mature fish at age 2 in all years with the exception of 1986, when the percentage of mature fish at age 2 (1984 year class) was estimated to be 20%. A VPA was also run on the 1987 data with 20% mature fish at age 2 (1985 year class) to evaluate the effect on the SSB. The results are given in Section 5.4. The Working Group recommends that further studies be carried out to investigate this problem.

5.3.5 Fishing mortality and tuning of VPA

Spawning stock estimates from the egg surveys

The VPA was tuned to the estimates of spawning stock biomass from the egg surveys (1977, 1980, 1983, and 1986) using a least squares method. The egg survey estimates were calculated using a fecundity-weight regression to convert egg production estimates directly to spawning stock biomass estimates of females measured at stage 4 maturity. These biomass estimates were then adjusted to biomass during spawning using the relative weights of stage 4 females and spawning females over the years 1981-1987 (from Dutch commercial data in Division VIIj). The regression estimates that 1,457 eggs are produced per gram of female mackerel at maturity stage 4 (see Anon., 1987a, p. 3). The conversion to the biomass of fish at spawning time increased the regression estimate by 8%. The advantages of using the fecundity-weight regression are:

1) The biomass estimates are independent of the size composition of fish in samples taken at spawning time.

2) The estimates are independent of assumptions of the proportions mature at age.

The egg production estimates and resulting spawning stock biomass estimates are shown in Table 5.5. Also shown are the egg survey estimates of spawning stock biomass which have been used previously.

The spawning stock estimates from the egg surveys were converted to biomass estimates at 1 January to tune the VPA. This was done using Pope's cohort analysis formula:

$$\text{Biomass at 1 Jan} = \left[\left(\begin{array}{c}\text{Biomass}\\ \text{at}\\ \text{spawning}\end{array}\right) \times e^{\left(\frac{0.4}{2}M\right)} + \begin{array}{c}\text{Catch in the}\\ \text{first two}\\ \text{quarters}\end{array}\right] \times e^{\left(\frac{0.4}{2}M\right)}$$

which is an approximation which assumes that 0.4 of M is applicable before spawning and that the catch is taken midway between 1 January and spawning time.

Exploitation pattern on ages >2 in 1987

Separable VPA (SVPA) was used to derive the most appropriate exploitation pattern to determine levels of fishing mortality at age in the most recent years and for the oldest true age groups in earlier years. This was carried out using a data set on ages 0-10 for the years 1979-1987. In order to take into account the possibility of a change in exploitation pattern in recent years, the catch-in-numbers data were subjectively weighted according to the method of Stevens (1984). Maximum weighting (1.0) was assumed for the years 1982-1987 and minimum weighting (0.001) for the period 1979-1981. A terminal F reference age of 4 years and a terminal S of 1.0 at age 10 gave an exploitation pattern with a more or less constant exploitation on age groups 4-10. Since there was no concrete evidence to suggest how the older age groups are exploited relative to the reference age, a flat exploitation pattern was chosen as being the most reasonable, setting the relative F on ages 4-10 in the terminal year to 1.0. The relative F on 2- and 3-year-olds was then determined by SVPA (Table 5.7).

Exploitation pattern on 0- and 1-group in 1987

The above procedure enabled fishing mortality to be estimated for ages 2-11+. However, no external information was available to estimate fishing mortality on 0- and 1-group.

The recruitment survey data given in Sections 3.4-3.5 cannot be used as a basis for quantitative estimates. It was concluded that the very strong 1984 year class showed up in the surveys both as 0/1-group and 1/2-group. The 1985 year class was caught in a quantity similar to that of the 1984 year class as 0/1-group, but only traces of this year class as 1/2-group fish were seen in the surveys.

It is difficult to draw conclusions on the abundance of the 1986 and 1987 year classes until further information becomes available. Because of this, the Working Group assumed that these year classes are of average strength and, therefore, modified the terminal F on 0- and 1-group accordingly.

The assumption that the 1986 and 1987 year classes are of average strength implies that fishing mortality, especially on 1-group mackerel, has declined in 1986 and 1987. This trend in F seems reasonable because of a change in the main fishing areas to northwest of Ireland and Scotland. In 1986 and 1987, the Cornwall box was effective in reducing catches of juvenile mackerel since these were present in the box.

There seems to be evidence to support a reduced fishing mortality on juvenile mackerel although this reduction cannot be quantified. However, unknown quantities of juvenile mackerel discarded by the fleet and the processing vessels adds to the uncertainty concerning fishing mortality on juvenile mackerel.

The output of the VPA

The comparison of spawning stock biomasses from the VPA runs and the egg surveys is shown in Table 5.6. The sums of the residuals at various values of F are shown in Figure 5.1. The minimum sum of squared residuals occurs at about F = 0.265 if the 1980 egg survey estimate is included and at about F = 0.275 if it is excluded. The value of F at age 4 and older in 1987 was, therefore, taken to be 0.270.

The inputs and results of the VPA are shown in Tables 5.8-5.10.

5.4 Forecast for the Western Stock

The stock and catch predictions were based on the following assumptions and parameters summarized in Table 5.11:

a) The stock size in number at age on 1 January 1988 was taken from the VPA (Table 5.10).

b) The number of 1-group in 1987 and the number of 0-group in 1988-1990 were all set at the geometric mean for each age group calculated from the VPA estimates for the years 1972-1984.

c) The fishing pattern in 1988 and 1989 was assumed to be the same as that used in the VPA for 1987.

d) The maturity ogive was assumed the same in all years except in 1986 when 20% maturity was assumed for the 1984 year class.

e) The catch in 1988 was assumed to be 600,000 t. This assumption was based on the recorded catch of 615,000 t in 1987 as well as the sum of the various TAC agreements for 1988 involving the EEC, Norway, the Faroes, and the USSR which amounted to about 573,000 t.

f) The proportion of F effective during the period before spawning was set at 0.3 in accordance with recorded catch by quarter in 1987 (Table 4.3), while the proportion of M was set at 0.4 to cover the period January-May.

g) Only a small amount of the 1984 year class was assumed to spawn in the North Sea in 1987.

The predictions for stock and catch in 1989 and 1990 were calculated for F_{med} (Figure 6.2), $F_{0.1}$, $F_{89} = F_{87}$, and F_{high} in 1989 and before spawning in 1990. The results are given in Table 5.12. Short-term yield and spawning stock biomass in relation to F are also given in Figure 5.3.

The VPA indicates that the 1984 year class increased the spawning stock biomass from 1.6 million t in 1986 to 1.86 million t in 1987. If the proportion of mature 1985 year class as 2-year-old fish is changed to 20%, the spawning stock will be about 4% lower in 1987. With a catch of 600,000 t in 1988, the spawning stock will be reduced, and if fishing continues at the same catch level in 1989, the spawning stock will be further reduced. This is despite recruitment of the strong 1984 year class which might have sustained the increase in spawning stock biomass had the recommended TAC been observed in 1987. With the assumed high catch of 600,000 t in 1988, the spawning stock in 1989 can only be kept on the 1986 level of 1.6 million t if average fishing mortality in 1989 is set below 0.27, which is the estimate for 1987.

As explained above, the recruitment of the 1-group in 1987 was set at the geometric mean of that estimated for earlier years. If, however, the recruitment of the 1-group (1986 year class) in 1987 is assumed to be half this size, the predicted spawning stock biomasses in 1989 will be about 10% less than those given in Table 5.12.

6 MANAGEMENT CONSIDERATIONS

6.1 Catches and TAC

As described in Sections 4.1 and 5.1, the catch of mackerel in 1987 increased both in the North Sea-Norwegian Sea area and in the Western area. The catch was substantially higher than that recommended by ACFM.

At its November 1986 meeting, ACFM recommended that catches from the North Sea mackerel stock in 1987 be kept at the lowest practicable level. A preliminary TAC of 380,000 t was recommended for the Western areas including Divisions IIa and Vb. At its meeting in May 1987, ACFM found no reason to alter its earlier assessment and, therefore, reiterated its recommendation that the TAC in the Western areas (Sub-areas VI and VII and Divisions VIIIa,b, IIa, and Vb) should be 380,000 t in 1987.

On this basis, the recommended total catch of both stocks taken in all areas was about 380,000 t, while the actual catch in 1987 amounted to 628,500 t (Table 4.4).

The 1987 TACs set by the EEC, by the EEC and Norway, by the EEC and the Faroes, by Norway, and by Norway and the Faroes totalled about 550,000 t, which is about 50% above the recommended level.

ACFM has, on various occasions, pointed out that any TAC set for Western mackerel should apply to all areas in which they are caught, i.e., Divisions IIa, IVa, and Vb as well as Sub-areas VI, VII, and VIII. It seems, however, that the scheme of catch quotas in 1987 was insufficient in limiting catches over the total distribution area of Western mackerel. As a result, catches in 1987 greatly exceeded the recommended level.

As outlined in Section 3.1, changes in the distribution of the Western mackerel have been observed in recent years. Mackerel of this stock now occur in larger quantities in the northern part of the distribution area, and a major fishery has developed in the bordering area between Divisions IIa and IVa. An appropriate management system is now needed which records the whole fishery in Divisions IIa, IVa, and Vb.

In previous reports, the Working Group has advocated a total ban on the fishery for North Sea mackerel in order to protect the spawning stock. This protection of the very small stock was the only means which could be used to increase the probability of improved recruitment and thereby rebuild the North Sea stock.

Although the size of the North Sea stock is unknown (see Section 4.2.4), it has been assumed that the spawning stock is likely to remain low also in 1989. Only a major contribution by the 1984 year class can change the situation. This will not be known until after the 1988 egg survey. The results from this survey will be made available for the ACFM meeting in November 1988.

On the assumption of the North Sea stock remaining on a low level, the Working Group retains the view that fishing should not be allowed. This, however, creates problems since mackerel of this stock only occur completely separated from Western mackerel at the time of spawning. At other times, when important fisheries take place, the two stocks mix. The ratios of mixing by time and area in recent years cannot be determined with certainty, but the general distribution and migration pattern are outlined in Figure 3.2.

It is reasonable to asssume that mackerel occurring in Divisions IIIa, IVb, and IVc are predominantly North Sea stock at all times of the year. Mackerel in Division IVa can be of mixed origin, but Western mackerel dominate in the northern part during the July-October period.

Based on this, the Working Group recommends that fishing for mackerel be prohibited in Divisions IIIa, IVb, and IVc at any time of the year and in Division IVa from 1 January - 31 July. This might, however, leave a proportion of the North Sea stock vulnerable to fishing in the southern part of Division IVa.

The Western mackerel stock has a wide distribution and is fished over an extensive area at different times of the year. This is illustrated in Figures 3.1a-d and 3.2. For the purpose of fisheries management, the area and time could be defined as that falling outside the prohibitions indicated above: that is, Divisions IIa and Vb, Sub-areas VI, VII, and VIII, and Division IVa from 1 August - 31 December.

Because of the unpredictable shifts in mackerel distribution, it is difficult to find a basis for setting separate area TACs within the total TAC. Therefore, the TAC recommended for the Western mackerel stock should cover all parts of the total distribution areas (Divisions IIa, IVa, VIa, and Vb and Sub-areas VII and VIII), and catches taken by all nations should be counted against the TAC.

6.2 Conservation Measures to Protect Juvenile Fish

This was fully reviewed in the 1987 Mackerel Working Group report (Anon., 1987a, Section 7). This Working Group has little additional information.

6.2.1 The mackerel box

The distribution of mackerel and the percentage of fish <30 cm in and around the mackerel box is shown in Figure 6.1. A small fishery took place in the first quarter of 1988 in which there was a high proportion of juveniles in the catches.

6.2.2 Mesh regulations

Extensive experiments using conventional diamond-meshed trawls show that mesh selection is not an effective way of selecting adult mackerel (Eltink, 1983). However, provisional experiments with square-meshed midwater trawls carried out in 1987 indicate that there may be some protection of juveniles by this means (Casey and Warnes, 1987). Further work in February 1988 was attempted, but adverse weather conditions prevented further progress. The survival of mackerel escaping such meshes has not yet been investigated.

6.2.3 Minimum size regulations

The success of this measure depends on the avoidance of areas where small and large fish are mixed. When strong year classes have a wide distribution, however, this could be a major problem. For example, some evidence was available that the 1984 year class was present in a high proportion of the catches taken in Division VIa in 1985-1986. The concern that this might lead to a high discard level is reiterated. It was also pointed out that little is known of discarding practices for fish processed at sea.

7 DIVISIONS VIIIc AND IXa

At present, the mackerel stock in Divisions VIIIc and IXa is being considered by the Working Group on Pelagic Stocks in Divisions VIIIc and IXa and Horse Mackerel (Anon., 1987d). At the ACFM meeting in November 1987, the question was raised whether it would be advisable to incorporate the mackerel stock from Divisions VIIIc and IXa into the Mackerel Working Group. Therefore, ACFM is asking both working groups to comment on this question.

The management advice for this mackerel stock in Divisions VIIIc and IXa in relation to other stocks in that area concerning mesh-size regulations, closed areas, etc. could probably best be given by the working group which is dealing with all pelagic fish stocks from that area.

However, the viewpoint of the Mackerel Working Group is that mackerel from Divisions VIIIc and IXa could be incorporated into the Mackerel Working Group, which could then deal with all the problems related to assessing mackerel stocks in the Northeast Atlantic. If this mackerel stock is also going to be estimated by egg surveys in the future, it was assumed to be more practical that the Mackerel Working Group would deal with all mackerel stocks, because the problems related to estimating spawning stock biomass by egg surveys would be similar and could best be discussed by all experts in one working group.

8 DATA REQUESTED BY THE MULTISPECIES WORKING GROUP

8.1 Catch at Age by Quarter for the North Sea Mackerel Stock

The catch in number of the North Sea mackerel stock (see Section 3.8) in 1987 is given in Table 8.1 by age and quarter. The total catch (in t) in 1987 in each quarter is also included. The catch of the North Sea mackerel stock is the catch taken in Divisions IIIa, IVb, and IVc.

8.2 Mean Weight at Age by Quarter of the North Sea Mackerel Stock

This is given in Table 8.2. The mean weight-at-age data are the data observed in the catches.

8.3 Stock Distribution by Quarter

The main information on the distribution of the adult mackerel is obtained from the distribution of the fishery. However, due to regulations in the fishery and misreported catches by area, it is difficult to quantify the distribution of the stocks by quarter. For the immature age groups, survey data are also available. Based on this material, the Working Group concluded that the indication of the percentage of each stock that was in the North Sea during each survey in 1986 (Anon., 1987a) seemed also to reflect the distribution in 1987 (Table 8.3).

9 DEFICIENCIES IN DATA

9.1 Catch Data

In general, information about the quantity of mackerel landed by individual countries has improved considerably in recent years. There is still a problem, however, with a few countries whose catches in excess of their national quotas must be placed in the "unallocated" category. There is, however, a considerable problem in obtaining accurate information about the origin of catches.

In previous reports, the Working Group has drawn attention to the problems created by misleading information on the location of catches. In 1986 and 1987, large amounts of catches were again misreported but the Working Group had no objective means to assess and correct this false information. Attempts were made by the Group to re-allocate catches to the actual fishing areas, but there is, however, no guarantee that the subjective evaluation of Group members achieves a reliable result. This problem is particularly important because of the present rapid changes that are taking place in both the adult and juvenile distributions. The effect of these uncertainties on the stock assessments cannot be estimated, but since the splitting of catches into the appropriate stock is now done largely on an area basis, the error could be significant.

9.2 Discards

The Working Group had no data about the extent of discarding of juvenile fish for either stock during 1987. It was, however, believed that, while discarding did take place, the quantities were small compared with those in earlier years, particularly in the fishery in Divisions VIId,e. With the introduction of modern sorting and processing methods on board vessels and with the possibility of an increase in the numbers of young mackerel because of good recruitment, the problem of discards might recur again, particularly in the catches in the North Sea. It is important, therefore, that information about this aspect should be kept constantly under review.

9.3 Data on Spawning Areas, Maturity, and Fecundity

The data required to resolve the problems about the complete extent of the spawning areas, maturity ogives, and fecundity have been discussed in Section 2.1 (The Mackerel Egg and Recruitment Workshop Report). It is important to stress, however, that the whole assessment of both the North Sea and Western stocks depends on the accurate interpretation of all these aspects.

9.4 Recruitment Indices

To date, no satisfactory method has been established to obtain indices of recruitment. However, this lack of information was discussed by the Mackerel Egg and Recruitment Workshop in January 1988, and it is hoped to establish a single standard survey which will provide adequate information. The Working Group would like to stress the importance of carrying out these surveys as planned.

9.5 Hydroacoustic Surveys

For the Western stock, egg surveys are only carried out every three years. There are no fishery-independent methods of obtaining quick and accurate methods of stock biomass. Hydroacoustic surveys of the concentrations which are found in the winter off the coasts of Scotland and Ireland are encouraged.

9.6 Stock Separation

As explained in Section 3, the Working Group has major problems in separating catches belonging to the North Sea and Western stocks. The 1985 Working Group addressed this problem in detail and discussed a number of methods which could be used for distinguishing stocks. These methods included comparisons of growth rates, examination of otolith L_1s, otolith typing, parasites as biological tags, and immuno-genetics. At present, none of these investigations have been successfully used to distinguish stocks and some of the work has been discontinued. Preliminary work on otolith L_1s (Dawson, 1986b) has shown some potential. However, more recently, the otolith L_1s have been shown to increase in recent years for the North Sea stock to the same size as that observed for the Western stock (Dawson, 1987). This suggests, therefore, that this method of stock separation cannot be used until the North Sea stock recovers. The Working Group, therefore, stresses the need for further work on stock separation methods.

10 RECOMMENDATIONS

All recommendations made by the Mackerel Egg and Recruitment Workshop (Anon., 1988) and by the Mackerel Age Determination Workshop are all endorsed by the Mackerel Working Group and are included below:

* The participants in the North Sea Mackerel Egg Survey in 1988 should meet during the last week of October 1988 at the Institute of Marine Research in Bergen to assess the results and write a final report in order to make these available to the ACFM meeting in November 1988.

* A further exchange of plankton samples between all participants in the mackerel egg surveys would be beneficial and should be arranged to compare staging in relation to estimating reliable egg mortality estimates.

* The current method used for estimating spawning stock biomass from egg surveys should continue to be used, and research should be continued to evaluate the magnitude of any likely errors, such as atresia, area coverage, egg mortality, and determinate/indeterminate spawning. A pilot study on the batch fecundity method should be carried out.

* If a new maturity key receives general acceptance, it is proposed that ICES publish a manual with photographs for use by ICES countries.

* Further investigations should be carried out on maturity-at-age data in order to obtain a reliable maturity ogive.

* Plankton samples should be taken outside the standard egg survey area to show the percentage of the total egg production which is not covered by the standard area.

* Juvenile mackerel abundance indices should continue to be calculated from the IYFS data and a new standard sampling area should be accepted for this purpose.

* An annual joint standardized Western mackerel recruitment survey should be carried out during the fourth quarter of each year.

* All historical data available on the distribution and abundance of juvenile Western mackerel should be written up jointly by representatives of countries participating in the mackerel recruitment surveys.

* A manual for standard survey procedures should be prepared for future recruitment surveys in Western areas similar to that used for the North Sea International Young Fish Surveys.

* If standardization of fishing gears during the recruitment surveys is not possible, the different gears used should be calibrated by overlapping the area coverage of different countries.

* Hydroacoustic surveys should be carried out during the winter off the coasts of Scotland and Ireland.

* The report of the Mackerel Age Determination Workshop should be published by ICES as it contains information of general interest.

* The ages of mackerel should be determined up to age 15 and recorded as age groups 0-14, with all older fish aggregated as a 15+ group.

* The report of the Norwegian-EEC Joint Scientific Group on Migration and Area Distribution of Mackerel (Western Stock), Bergen 1987 should be published by ICES as it contains information of general interest.

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Table 3.1 Total estimated catches for both the North Sea and Western mackerel stocks (t).

Year	North Sea stock	Western stock	Total
1976	297,700	507,200	804,900
1977	241,050	326,000	567,050
1978	185,200	503,900	689,100
1979	210,050	605,750	806,800
1980	106,550	604,750	711,300
1981	65,900	661,750	727,650
1982	57,000	623,800	680,800
1983	42,750	614,300	657,050
1984	66,500	550,900	617,400
1985	34,600	561,300	595,900
1986	32,250[1]	537,350[1]	569,600
1987	13,100[1]	615,400[1]	628,500

[1] Provisional estimate, see Section 3.8.

Table 4.1 Nominal catch (t) of MACKEREL in the North Sea, Skagerrak, and Kattegat (Sub-area IV and Division IIIa) 1978-1987. (Data submitted by Working Group members.)

Country	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987[1,2]
Belgium	10	10	5	55	102	93	68	-	49	14
Denmark	18,068	19,171	13,234	9,982	2,034	11,285	10,088	12,424	23,368	28,217
Faroe Islands	33,911	28,118	1,770	-	720	-	-	1,356	-	-
France	3,452	3,620	2,238	3,755	3,041	2,248	-	322	1,200	1,466
German Dem. Rep.	233	-	-	-	-	-	-	-	-	-
Germany, Fed. Rep.	284	211	56	59	28	10	112	217	1,853	494
Ireland	-	-	738	733	-	-	-	-	-	-
Netherlands	1,065	1,009	853	1,706	390	866	340	726	1,949	2,761
Norway	82,959	90,720	44,781	28,341	27,966	24,464	27,311	30,835	50,600	108,250
Sweden	4,501	3,935	1,666	2,446	692	1,903	1,440	760	1,300	2,458
UK (Engl.& Wales)	142	95	76	6,520	16	16	2	143	18	94
UK (Scotland)	3,704	5,272	9,514	10,575	44	4	13	7	541	19,286
USSR	488	162	-	-	-	-	-	-	-	-
Unallocated + discards	-	500	-	3,216	450	96	202	3,656	7,431	10,789
Total	148,817	152,823	87,931	67,388	35,483	40,985	39,576	50,124	88,309	173,829

[1]Preliminary.
[2]May include catches taken in Division IIa.

Table 4.2 Nominal catches (t) of MACKEREL in the Norwegian Sea (Division IIa) and off the Faroes (Division Vb) 1978-1987.

Country	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987[3,4]
Denmark[2]	-	-	-	801	1,008	10,427	11,787	7,610	1,653	3,133
Faroe Islands[1]	283	6	270	-	180	-	138	-	-	-
France[2]	2	-	-	6	8	-	-	16	-	-
Germany, Fed. Rep.[2]	-	-	-	51	-	5	-	-	99	-
German Dem. Rep.[2]	53	174	2	-	-	-	-	-	16	292
Norway[1]	3,867	6,887	6,618	12,941	34,540	38,453	82,005	61,065	85,400	25,000
Poland[2]	-	-	-	-	231	-	-	-	-	-
UK (Engl. & Wales)[1]	1	-	-	255	-	-	-	-	-	-
UK (Scotland)[2]	-	-	296	968	-	-	-	-	2,131	157
USSR[2]	-	5	1,450	3,640	1,641	65	4,292	9,405	11,813	18,604
Total	4,206	7,072	8,340	18,662	37,608	48,950	98,222	78,096	101,112	47,186

[1]Data provided by Working Group members.
[2]Data reported to ICES.
[3]Preliminary.
[4]Includes catches probably taken in the northern part of Division IVa.

Table 4.3 Quarterly catches (t) of mackerel by division or sub-area in 1987.

Division/Sub-area	1	2	3	4	Total
IIa + IVa + Vb	1	256	159,287	166,457	326,001[2]
IIIa	1	715	9,065	237	10,018
IVb + IVc	-	274	1,570	1,236	3,080
VI	105,455	665	1,934	80,294	188,348
VII	78,787	15,024	3,999	3,150	100,960[1]
VIIIa + VIIIb	1	75	-	-	76
Total	184,245	17,009	175,855	251,374	628,483

[1] Includes French catches from Sub-area VI and Divisions VIIIa,b, d,e.
[2] Includes 128,000 t misreported in Division VIa.

Table 4.4 Quarterly catches (t) of mackerel by division or sub-area in 1986.

Division/Sub-area	1	2	3	4	Total
IIa + IVa + Vb	1	689	160,475[1]	166,453[2]	327,618
IIIa	-	1,605	4,196	752	6,553
IVb + IVc	-	237	3,038	2,437	5,712
VI	57,092	1,845	1,454	41,063	101,454
VII	77,274	44,125	4,028	2,777	128,204
VIIIa + VIIIb	-	-	-	-	-
Total	134,367	48,501	173,191	213,482	569,541

[1] Includes an estimated catch of 10,400 t misreported in Division VIa.
[2] Includes an estimated catch of 138,000 t misreported in Division VIa.

Table 4.5 Mackerel catch in numbers ('000) by age group for the northern part of the North Sea, Norwegian Sea (Divisions IVa, IIa, and Vb), the central and southern parts of the North Sea (Divisions IVb and IVc), and Skagerrak (Division IIIa).

Year class	Age	Divisions			
		IIa+IVa+Vb	IVb+IVc	IIIa	Total
1987	0	353	-	-	353
1986	1	3,688	769	6,962	11,419
1985	2	53,402	1,130	13,317	67,849
1984	3	317,270	1,166	8,729	327,165
1983	4	31,378	242	174	31,794
1982	5	39,436	953	346	40,735
1981	6	116,344	1,234	1,096	118,674
1980	7	65,861	909	606	67,376
1979	8	34,607	1,133	164	35,904
1978	9	12,281	394	85	12,760
1977	10	8,154	57	72	8,283
1976	11	9,748	227	99	10,074
1975	12	7,120	182	51	7,353
1974	13	5,568	52	104	5,724
1973	14	2,582	151	53	2,786
<1972	15+	11,286	326	334	11,946
Total		719,078	8,925	32,192	760,195
Tonnes		326,000	3,080	10,020	339,100

Table 5.1 Nominal catch (tonnes) of MACKEREL in the Western area (Sub-areas VI and VII and Divisions VIIIa,b). (Data estimated by Working Group.)

Country	1978	1979	1980	1981	1982
Belgium	1	3	3	-	-
Denmark	8,677	8,535	14,932	13,464	15,000
Faroe Islands	15,076	10,609	15,234	9,070	11,100
France	34,860	31,510	23,907	14,829	12,300
Germany, Fed.Rep.	28,873	21,493	21,088	29,221	11,200
Ireland	27,508	24,217	40,791	92,271	109,700
Netherlands	50,815	62,396	91,081	88,117	67,200
Norway	1,900	25,414	25,500	21,610	19,000
Poland	-	92	-	1	-
Spain	599	543	3,684	1,365	-
UK (England + Wales)	213,344	244,293	150,598	75,722	82,900
UK (N. Ireland)	46	25	-	4,153	9,600
UK (Scotland)	103,671	103,160	108,372	109,153	147,400
USSR	-	-	-	-	-
Unallocated	-	54,000	98,258	140,322	97,300
Total, ICES members	485,370	586,290	593,448	599,298	582,800
Discard	50,700	60,600	21,600	42,300	24,900
Grand total	536,070	646,890	615,048	641,598	607,700

Country	1983	1984	1985	1986	1987 [1,2]
Belgium	+	+	-	+	-
Denmark	15,000	200	400	300	100
Faroe Islands	14,900	9,200	9,900	1,400	7,100
France	11,000	12,500	7,400	11,200	11,100
Germany, Fed.Rep.	23,000	11,200	11,800	7,700	13,300
Ireland	110,000	84,100	91,400	74,500	89,500
Netherlands	73,600	99,000	37,000	58,900	31,700
Norway	19,900	34,700	24,300	21,000	21,600
Poland	-	-	-	-	-
Spain	-	100	+	-	-
UK (Engl. & Wales)	62,000	30,000	9,600	9,100	26,000
UK (N. Ireland)	800	1,100	-	1,700	300
UK (Scotland)	120,100	167,200	196,300	143,700	180,400
USSR	+	200	+	-	-
Unallocated	105,500	18,000	75,100	51,000	25,800
Total, ICES members	555,800	467,500	463,200	380,500	406,900
Discard	11,300	12,100	4,500	-	-
Grand total	567,100	479,600	467,700	380,500	406,900

[1] Preliminary.
[2] Includes catches misreported from Division IVa.

Table 5.2 Catches of MACKEREL (tonnes) by sub-areas in the Western area. Discards not estimated prior to 1978.

	VI			VII and VIII		
Year	Land-ings	Dis-cards	Catch	Land-ings	Dis-cards	Catch
1969	4,800	-	4,800	66,300	-	66,300
1970	3,900	-	3,900	100,300	-	100,300
1971	10,200	-	10,200	122,600	-	122,600
1972	10,000	-	10,000	157,800	-	157,800
1973	52,200	-	52,200	167,300	-	167,300
1974	64,100	-	64,100	234,100	-	234,100
1975	64,800	-	64,800	416,500	-	416,500
1976	67,800	-	67,800	439,400	-	439,400
1977	74,800	-	74,800	259,100	-	259,100
1978	151,700	15,200	166,900	355,500	35,500	391,000
1979	203,300	20,300	223,600	398,000	39,800	437,800
1980	218,700	6,000	324,700	386,100	15,600	401,700
1981	335,100	2,500	337,600	274,300	39,800	314,100
1982	340,400	4,100	344,500	257,800	20,800	278,600
1983	315,100	22,300	317,400	245,400	9,000	254,400
1984	306,100	1,600	307,700	176,100	10,500	186,600
1985	388,140	2,735	390,875	75,043	1,800	76,843
1986	252,100[2]	+	252,100[2]	128,499	+	128,400
1987[1]	305,900[2]	+	305,900[2]	101,100	+	101,100

[1] Preliminary.
[2] Includes misreported catches from Division IVa of approximately 148,000 t in 1986 and 117,000 t in 1987.

Table 5.3 Mackerel catch in numbers ('000) by age group for the Western area in 1987.

Year class	Age	Divisions				
		VIa	VIIa-c	VIId-k	VIIIa,b,d,e	Total
1987	0	517	-	1,617	-	2,134
1986	1	2,118	2,291	7,118	2	11,529
1985	2	27,568	2,712	50,338	7	80,625
1984	3	237,444	23,299	65,573	83	326,399
1983	4	14,090	1,804	4,255	5	20,154
1982	5	25,553	5,707	7,313	4	38,577
1981	6	68,262	34,191	16,291	35	118,779
1980	7	43,559	21,884	15,927	42	81,412
1979	8	32,055	7,431	8,505	16	48,007
1978	9	7,422	4,566	3,902	11	15,901
1977	10	5,308	2,927	1,478	-	9,713
1976	11	7,074	3,898	3,650	8	14,630
1975	12	4,092	1,762	1,963	5	7,822
1974	13	2,639	2,935	791	2	6,367
1973	14	2,201	367	1,040	2	3,610
<1972	15+	7,787	5,265	2,055	6	15,113
Total		487,689	121,039	191,816	228	800,772
Tonnes		188,340	53,900	47,060	80	289,380

Table 5.4 Catch in numbers ('000) by age by divisions in 1987.

Age	Division					Total	Division		Total
	IIa+IVa+Vb	VIa	VIIa-c	VIId-k	VIIIa,b,d,e		IVb+IVc	IIIa	
0	353	517	-	1,617	-	2,487	-	-	-
1	3,688	2,118	2,291	7,118	2	15,217	769	6,962	7,731
2	53,402	27,568	2,712	50,338	7	134,027	1,130	13,317	14,447
3	317,270	237,444	23,299	65,573	83	643,669	1,166	8,729	9,895
4	31,378	14,090	1,804	4,255	5	51,532	242	174	416
5	39,426	25,553	5,707	7,313	4	78,013	953	346	1,299
6	116,344	68,262	34,191	16,291	35	235,123	1,234	1,096	2,330
7	65,861	43,559	21,884	15,927	42	147,273	909	606	1,515
8	34,607	32,055	7,431	8,505	16	82,614	1,133	164	1,297
9	12,281	7,422	4,566	3,902	11	28,182	394	85	479
10	8,154	5,308	2,927	1,478	-	17,867	57	72	129
11	9,748	7,074	3,898	3,650	8	24,378	227	99	326
12	7,120	4,092	1,762	1,963	5	14,942	182	51	233
13	5,568	2,639	2,935	791	2	11,935	52	104	156
14	2,582	2,201	367	1,040	2	6,192	151	53	204
15+	1,128	7,787	5,265	2,055	6	26,399	326	334	660
Total	719,078	487,689	121,039	191,816	228	1,519,850	8,925	32,192	41,117
Tonnes	326,000	188,340	53,900	47,060	80	615,380	3,080	10,020	13,100

Table 5.5 Estimates of egg production, spawning stock biomass in maturity stage 4, and stock biomass at spawning time derived from egg surveys of the Western mackerel stock.

Year	Egg production (10^{15})	SSB estimates used prev.[3]	Spawning stock[4] biomass (10^6 t) maturity stage 4	Spawning stock[5] biomass (10^6 t) at spawning time
1977	1.98[1]	3.0	2.72	2.94
1980	1.84[2]	2.9	2.53	2.73
1983	1.50[2]	2.4	2.06	2.22
1986	1.166[3]	1.5	1.60	1.73

[1] Lockwood *et al*. (1981).
[2] Anon. (1984).
[3] Anon. (1987a).
[4] Biomasss estimated from the fecundity/weight relationship of 1,457 eggs per g of female mackerel at maturity stage 4 (Anon.,1987a, page 3).
[5] Spawning stock biomass adjusted using the relative weight at stage 4 and spawning fish on the spawning grounds.

Table 5.6 Spawning stock biomass estimates in t x 10^6 (at 1 January) from egg surveys and VPA at different values of input F at age 4+.

Year	Egg survey estimate (from fecundity/weight relationship) (x)	Biomass estimate from VPA (y)						
		0.20	0.22	0.25	0.27	0.28	0.30	0.35
1977	3.24	3.518	3.469	3.416	3.383	3.369	3.346	3.297
1980	3.18	2.943	2.876	2.797	2.754	2.735	2.700	2.631
1983	2.58	3.170	3.045	2.890	2.806	2.769	2.703	2.567
1986	2.03	2.410	2.240	2.038	1.928	1.880	1.792	1.616
$\Sigma[(\frac{x-y}{x}) \times 100]^2$ (all years)		1,003	573	319	301	320	399	717
$\Sigma[(\frac{x-y}{x}) \times 100]^2$ (excluding 1980)		947	482	174	121	124	171	419

Table 5.7

Title : MACKEREL, WESTERN STOCK
At 10.43.05 14 MARCH 1988
from 79 to 87 on ages 0 to 10
with Terminal F of .270 on age 4 and Terminal S of 1.000

Initial sum of squared residuals was 173.240 and
final sum of squared residuals is 51.717 after 94 iterations

Matrix of Residuals

Years / Ages	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87		WTS
0/ 1	2.333	1.314	2.490	1.051	-1.629	-2.051	-1.967	4.588	.000	.049
1/ 2	.463	.505	.289	-.498	.098	.662	.355	-.620	.000	.252
2/ 3	-.167	.557	.124	.033	.070	.494	-.439	-.159	.000	.353
3/ 4	.350	.569	.157	.142	.047	.349	-.191	-.349	.000	.377
4/ 5	-.107	.222	-.051	.019	.117	.076	.053	-.266	.000	.798
5/ 6	-.009	-.027	-.078	-.169	-.075	.007	-.002	.259	.000	1.000
6/ 7	-.055	-.254	.005	.005	-.177	.016	.023	.141	.000	.937
7/ 8	.047	-.344	-.227	.010	.133	-.439	.158	.218	.000	.465
8/ 9	-.417	-.315	-.159	.107	.059	-.307	.044	.097	.000	.558
9/10	.122	-.545	.074	.255	.253	-.181	.205	-.532	.000	.355
	.000	.000	.000	.000	.000	.000	.000	.000	6.852	
WTS	.001	.001	.001	1.000	1.000	1.000	1.000	1.000		

Fishing Mortalities (F)

	79	80	81	82	83	84	85	86	87
F-values	.2646	.2646	.2127	.2154	.2126	.1971	.1859	.2052	.2700

Selection-at-age (S)

	0
S-values	.0026

	1	2	3	4	5	6	7	8	9	10
S-values	.1961	.5316	.7560	1.0000	1.0535	1.0821	1.0775	1.0514	.9511	1.0000

Table 5.8 VIRTUAL POPULATION ANALYSIS

MACKEREL, WESTERN STOCK

CATCH IN NUMBERS UNIT: millions

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	1.6	.0	1.3	1.0	34.2	2.0	10.3	79.5	19.5	38.5	2.0	.0
1	12.4	33.3	37.0	52.5	279.4	153.5	31.3	351.1	484.5	266.1	203.0	43.6
2	12.1	49.4	24.3	104.0	184.9	289.5	563.8	61.6	468.7	506.4	435.9	712.7
3	29.4	64.0	123.5	94.5	322.3	154.0	425.0	602.5	75.2	225.1	433.6	444.6
4	507.7	113.5	103.5	306.5	170.6	166.0	243.7	365.5	381.3	31.7	134.1	391.6
5	.0	382.3	191.3	192.2	238.8	51.0	258.3	217.2	282.0	174.8	24.7	130.4
6	.0	.0	567.0	143.8	113.6	140.0	71.9	233.1	145.2	153.5	136.6	20.2
7	.0	.0	.0	1246.2	279.7	64.4	151.9	85.8	158.4	99.5	108.6	91.3
8	.0	.0	.0	.0	438.8	39.4	56.7	154.2	52.4	116.6	34.5	70.9
9	.0	.0	.0	.0	.0	158.5	83.2	70.5	139.6	35.3	37.0	47.1
10	.0	.0	.0	.0	.0	.0	210.8	74.6	43.6	138.7	24.4	48.9
11+	.0	.0	.0	.0	.0	.0	.0	189.1	163.3	205.5	237.9	145.3
A) SOP	222	319	411	862	682	381	628	767	803	700	700	678
B) NOMIN.	171	219	298	491	507	326	504	605	605	662	624	614
(B/A) %	77	69	72	57	74	85	80	79	75	95	89	91

	1984	1985	1986	1987
0	.5	.0	18.1	2.5
1	15.2	234.3	25.7	15.2
2	79.5	13.0	397.8	134.0
3	661.3	49.1	29.9	643.7
4	374.6	420.3	63.5	51.5
5	238.2	242.6	331.9	78.0
6	92.0	158.4	193.7	235.1
7	15.5	53.9	119.5	147.3
8	51.3	16.2	38.3	82.6
9	39.3	42.0	11.1	28.2
10	25.1	33.0	28.6	17.9
11+	65.5	100.6	80.3	33.9
A) SOP	565	556	535	615
B) NOMIN.	551	561	538	615
(B/A) %	98	101	101	100

Table 5.9 VIRTUAL POPULATION ANALYSIS

MACKEREL, WESTERN STOCK

FISHING MORTALITY COEFFICIENT UNIT: Year-1 NATURAL MORTALITY COEFFICIENT = .15

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.001	.000	.000	.000	.007	.002	.003	.115	.004	.006	.002	.000
1	.002	.021	.025	.019	.073	.040	.042	.147	.117	.063	.039	.050
2	.007	.010	.013	.032	.083	.095	.190	.104	.281	.163	.133	.178
3	.012	.042	.051	.083	.126	.087	.187	.301	.162	.200	.213	.184
4	.055	.057	.057	.095	.200	.084	.183	.230	.299	.095	.237	.261
5	.000	.096	.120	.218	.115	.080	.173	.233	.264	.205	.024	.243
6	.000	.000	.121	.118	.131	.071	.147	.220	.228	.220	.232	.099
7	.000	.000	.000	.326	.332	.134	.098	.251	.216	.223	.219	.226
8	.000	.000	.000	.010	.222	.155	.152	.129	.224	.231	.291	.204
9	.000	.000	.000	.000	.000	.111	.275	.284	.157	.213	.255	.247
10	.000	.000	.010	.000	.000	.000	.199	.270	.269	.218	.213	.210
11+	.000	.000	.000	.000	.000	.000	.199	.270	.269	.218	.218	.210
(4- 8)U	.013	.051	.066	.163	.210	.106	.152	.213	.246	.196	.214	.208

	1984	1985	1986	1987
0	.000	.000	.006	.001
1	.037	.044	.022	.036
2	.114	.048	.094	.145
3	.255	.191	.112	.204
4	.220	.213	.154	.270
5	.257	.205	.255	.270
6	.252	.231	.233	.270
7	.097	.252	.258	.270
8	.132	.132	.244	.270
9	.157	.210	.117	.270
10	.121	.182	.204	.270
11+	.171	.182	.204	.270
(4- 8)U	.200	.208	.229	.270

Table 5.10 VIRTUAL POPULATION ANALYSIS

MACKEREL, WESTERN STOCK

STOCK SIZE IN NUMBERS UNIT: millions

BIOMASS TOTALS UNIT: thousand tonnes

ALL VALUES, EXCEPT THOSE REFERRING TO THE SPAWNING STOCK ARE GIVEN FOR 1 JANUARY; THE SPAWNING STOCK DATA REFLECT THE STOCK SITUATION AT SPAWNING TIME, WHEREBY THE FOLLOWING VALUES ARE USED: PROPORTION OF ANNUAL F BEFORE SPAWNING: .400
PROPORTION OF ANNUAL M BEFORE SPAWNING: .400

	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	2073	4357	3447	4955	4943	944	3217	5576	5441
1	5965	1787	4155	2965	4273	4227	811	2760	4726
2	1775	5121	1307	5505	2594	3419	3496	567	2050
3	2654	1691	4352	1274	2913	1984	2675	2483	512
4	3477	2240	1396	3640	1009	2214	1565	1907	1555
5	0	6843	1321	1101	2849	711	1752	1122	1305
6	0	0	5551	1390	770	2135	565	1269	765
7	0	0	0	4031	1065	553	1751	420	877
8	0	0	0	0	2363	657	417	1367	231
9	0	0	0	0	0	1623	482	306	1034
10	0	0	0	0	0	0	1255	533	193
11+	0	0	0	0	0	0	0	358	743
TOTAL NO	21159	22519	22047	22919	22697	18522	17985	19080	19525
SPS NO	11344	12441	12378	11863	10950	10902	11777	8383	7594
TOT.BIOM	4671	4581	4739	4612	4205	4071	4011	3546	3529
SPS BIOM	3516	3544	3597	3471	3099	3064	3207	2219	2358

cont'd.

Table 5.10 cont'd.

	1981	1982	1983	1984	1985	1986	1987	1988
0	6545	1129	519	5747	1492	3075	5056	0
1	4665	5632	969	416	5807	1244	2659	2636
2	3617	3759	4793	774	370	4781	1081	2250
3	1333	2647	2840	3339	510	594	3747	877
4	377	938	1831	2054	2305	479	254	2630
5	1012	295	637	1214	1404	1575	354	154
6	863	709	251	423	825	934	1060	232
7	524	596	434	150	264	554	665	701
8	603	357	413	352	141	190	375	439
9	193	416	251	270	239	106	126	246
10	769	134	277	155	215	166	81	84
11+	1127	1394	924	406	659	467	389	305
TOTAL NO	21723	17973	13969	16415	14338	13995	13810	
SPS NO	7989	8549	6950	7545	6275	5059	6455	
TOT.BIOM	3427	3217	3246	2779	2399	2579	2497	
SPS BIOM	2457	2258	2450	2221	2124	1663	1858	

Table 5.11

List of input variables for the ICES prediction program.

WESTERN MACKEREL

The reference F is the mean F for the age group range from 4 to 8

The number of recruits per year is as follows:

Year	Recruitment
1988	3036.0
1989	3036.0
1990	3036.0

Proportion of F (fishing mortality) effective before spawning: .3000
Proportion of M (natural mortality) effective before spawning: .4000

Data are printed in the following units:

Number of fish:	millions
Weight by age group in the catch:	kilogram
Weight by age group in the stock:	kilogram
Stock biomass:	thousand tonnes
Catch weight:	thousand tonnes

age	stock size	fishing pattern	natural mortality	maturity ogive	weight in the catch	weight in the stock
0	3036.0	.00	.15	.00	.049	.000
1	2630.0	.01	.15	.03	.176	.070
2	2250.0	.14	.15	.60	.232	.137
3	307.0	.20	.15	.90	.313	.233
4	2650.0	.27	.15	.97	.379	.263
5	154.0	.27	.15	.97	.478	.365
6	232.0	.27	.15	.99	.513	.371
7	707.0	.27	.15	1.00	.492	.392
8	459.0	.27	.15	1.00	.476	.402
9	245.0	.27	.15	1.00	.517	.459
10	54.0	.27	.15	1.00	.655	.485
11+	503.0	.27	.15	1.00	.696	.507

Table 5.12

Effects of different levels of fishing mortality on catch, stock biomass and spawning stock biomass.

WESTERN MACKEREL

Year 1988					Year 1989						Year 1990	
factor	ref. F	stock biomass	sp.stock biomass	catch	factor	ref. F	stock biomass	sp.stock biomass	catch	stock biomass	sp.stock biomass
1.0	.27	2270	1705	500	F_{med}	.11	2284	1763	246	2437	1905
					$F_{0.1}$	.19		1723	419	2305	1743
					F_{87}	.27		1638	564	2182	1612
					F_{high}	.39		1535	775	2025	1426

The data unit of the biomass and the catch is 1000 tonnes.
The spawning stock biomass is given for the time of spawning.
The spawning stock biomass for 1990 has been calculated with the same fishing mortality as for 1989.
The reference F is the mean F for the age group range from 4 to 8

Table 8.1 Catch in numbers ('000) and t of the North Sea mackerel stock (Divisions IIIa and IVb,c) by quarter in 1987.

Age	Quarter			
	1	2	3	4
1	2	436	6,886	407
2	2	641	13,141	663
3	-	137	9,626	132
4	-	59	318	40
5	-	86	796	417
6	-	136	1,604	591
7	-	165	738	613
8	-	92	372	834
9	-	45	262	173
10	-	35	94	-
11	-	134	75	118
12	-	72	67	94
13	-	78	78	-
14	-	50	36	118
15+	-	254	311	94
Sum	4	2,420	34,404	4,294
Tonnes	1	989	10,635	1,473

Table 8.2 Quarterly mean weight at age (grams) for the North Sea mackerel stock (Divisions IIIa and IVb,c) in 1987.

Age	Quarter 1	2	3	4
1	176	164	175	177
2	305	271	292	300
3	-	301	330	297
4	-	446	374	345
5	-	473	388	335
6	-	435	531	368
7	-	557	487	294
8	-	490	519	403
9	-	523	524	410
10	-	523	605	-
11	-	622	641	415
12	-	637	634	362
13	-	669	771	-
14	-	665	721	571
15+	-	700	639	534

Table 8.3 Indicative percentages of each mackerel stock present in the North Sea during each quarter of 1987.

Age	1	2	3	4	1	2	3	4
	North Sea stock				Western stock			
1	100	100	100	100	-	20	30	30
2	80	100	100	80	10	10	50	70
≥3	80	100	50	70	10	+	50	70

+ = less than 5%

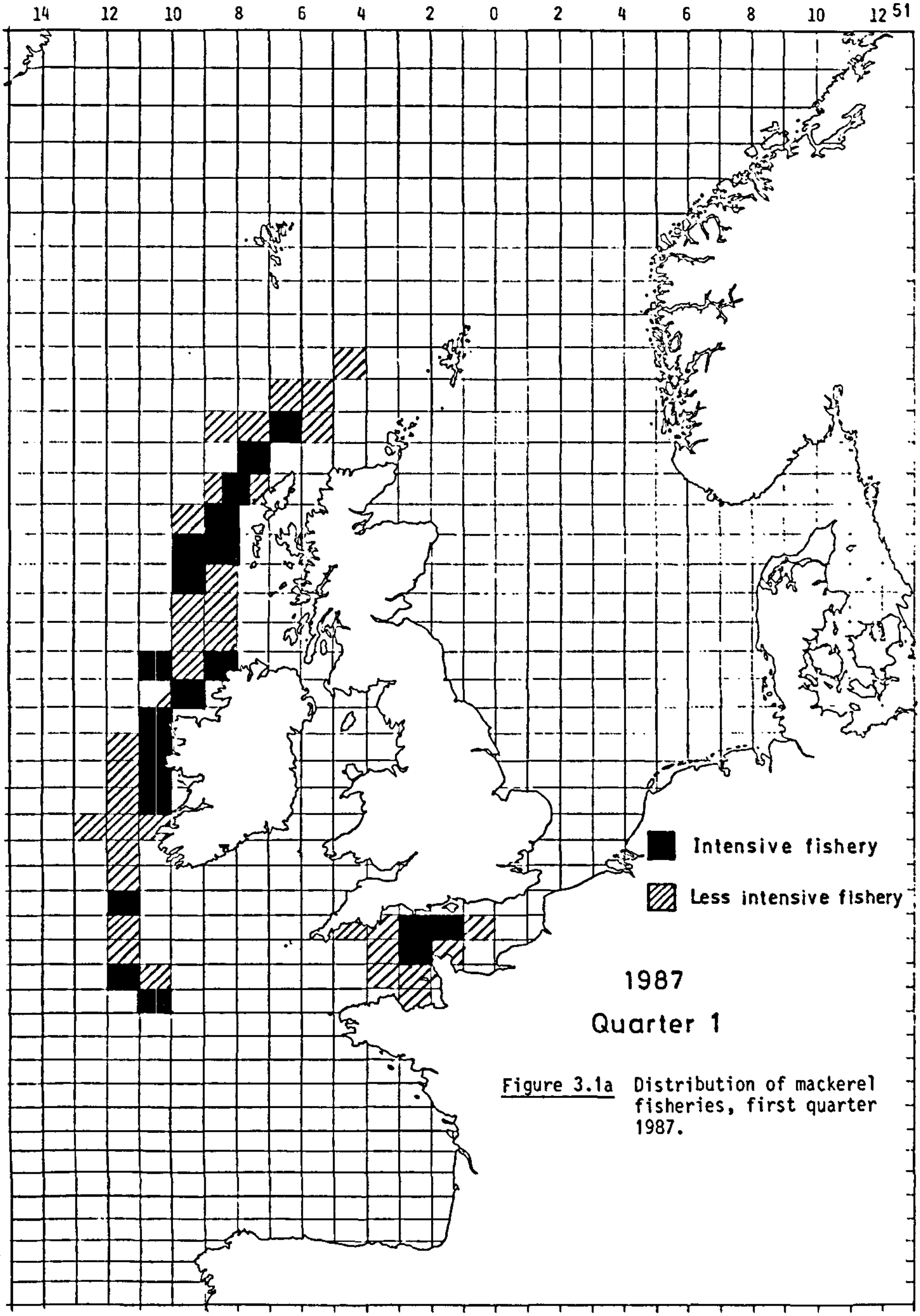


Figure 3.1a Distribution of mackerel fisheries, first quarter 1987.

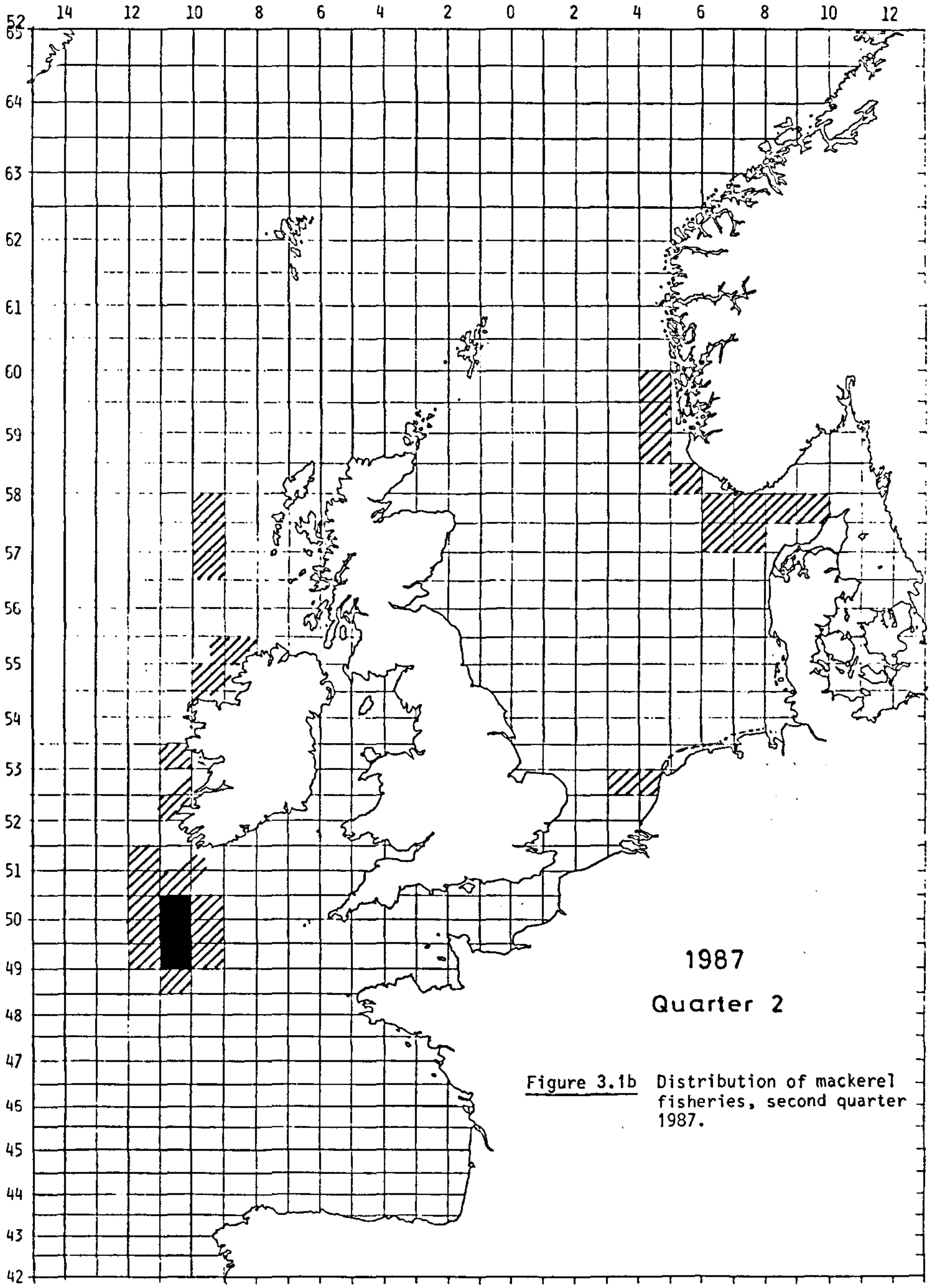


Figure 3.1b Distribution of mackerel fisheries, second quarter 1987.

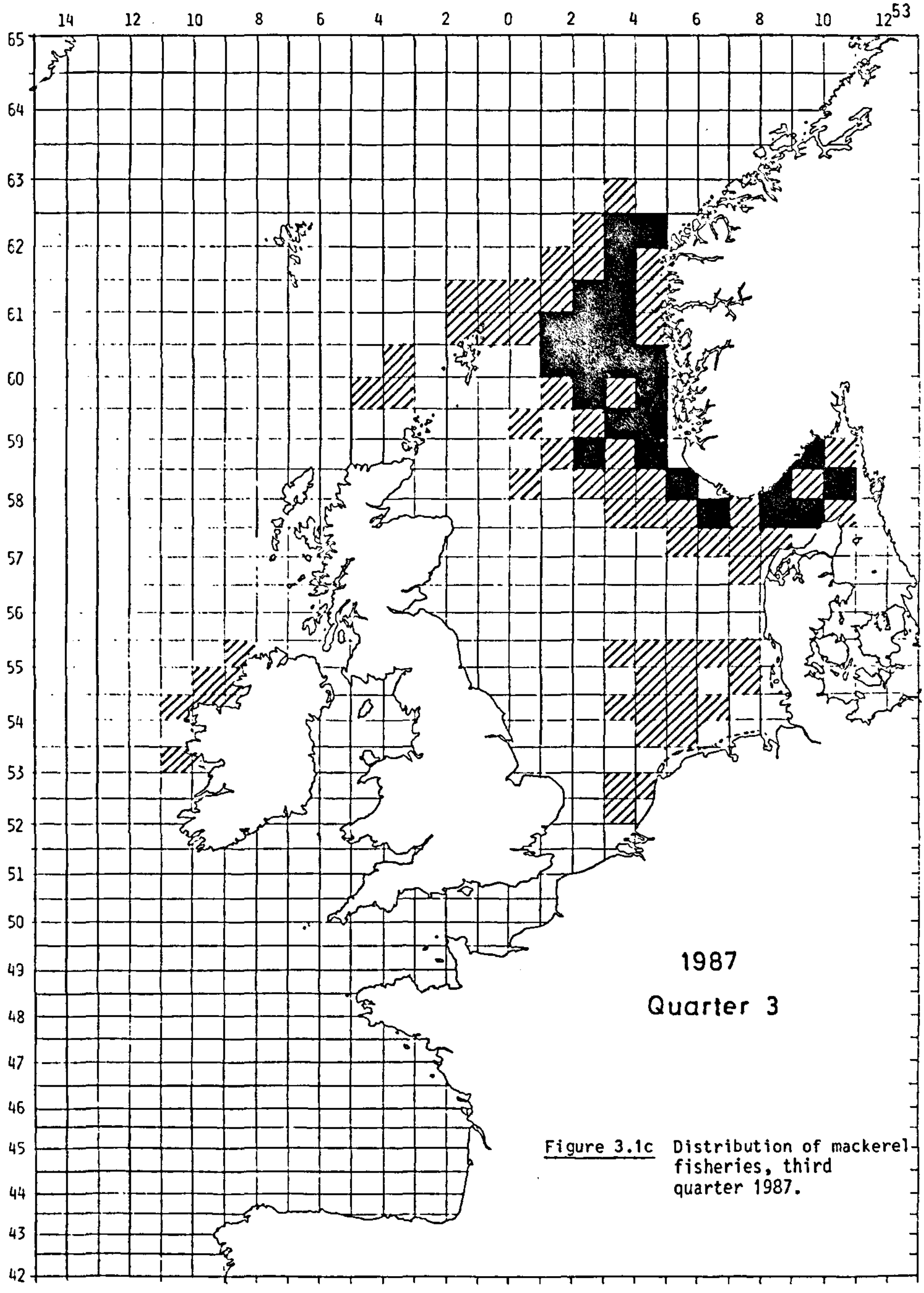


Figure 3.1c Distribution of mackerel fisheries, third quarter 1987.

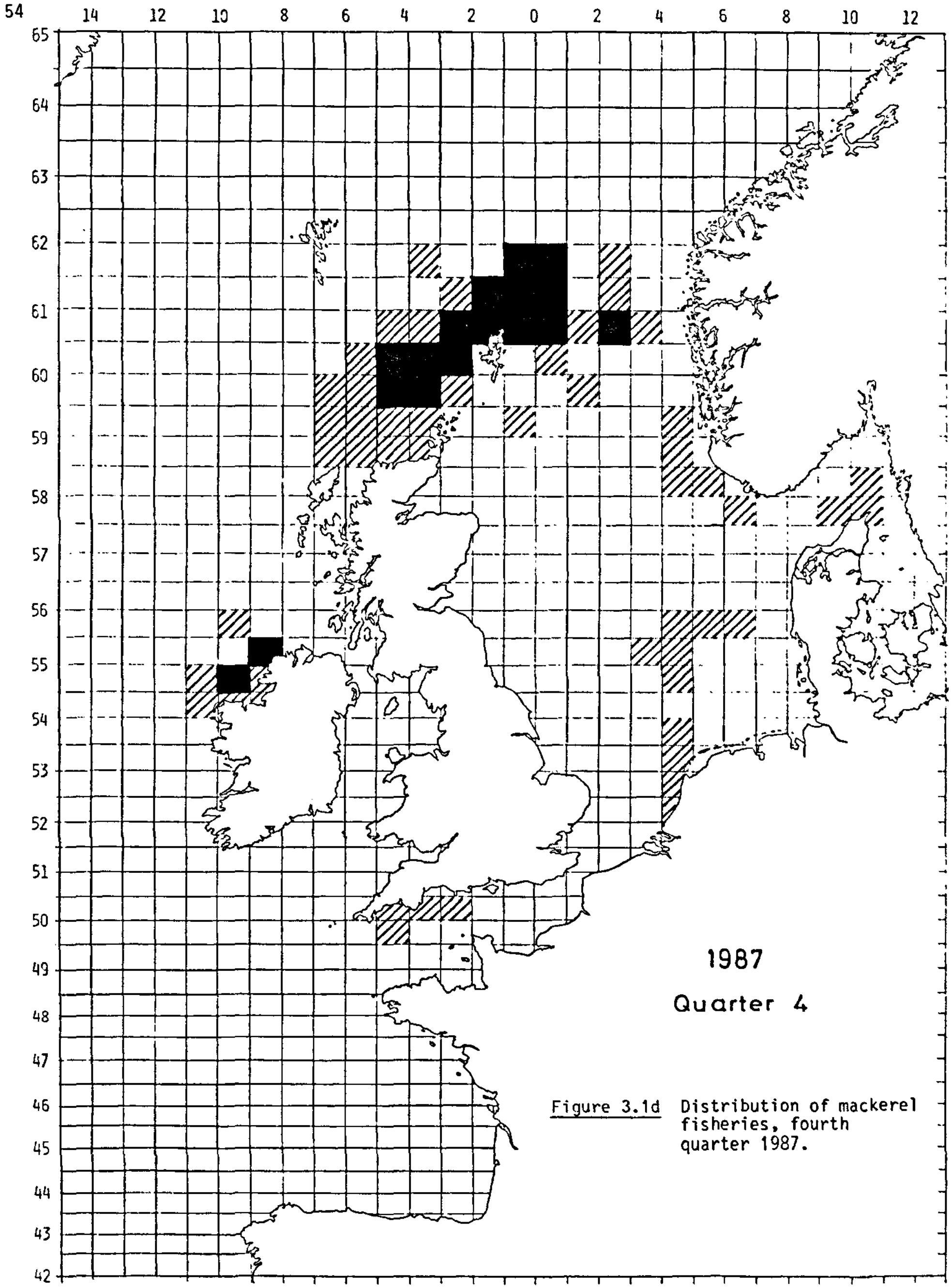


Figure 3.1d Distribution of mackerel fisheries, fourth quarter 1987.

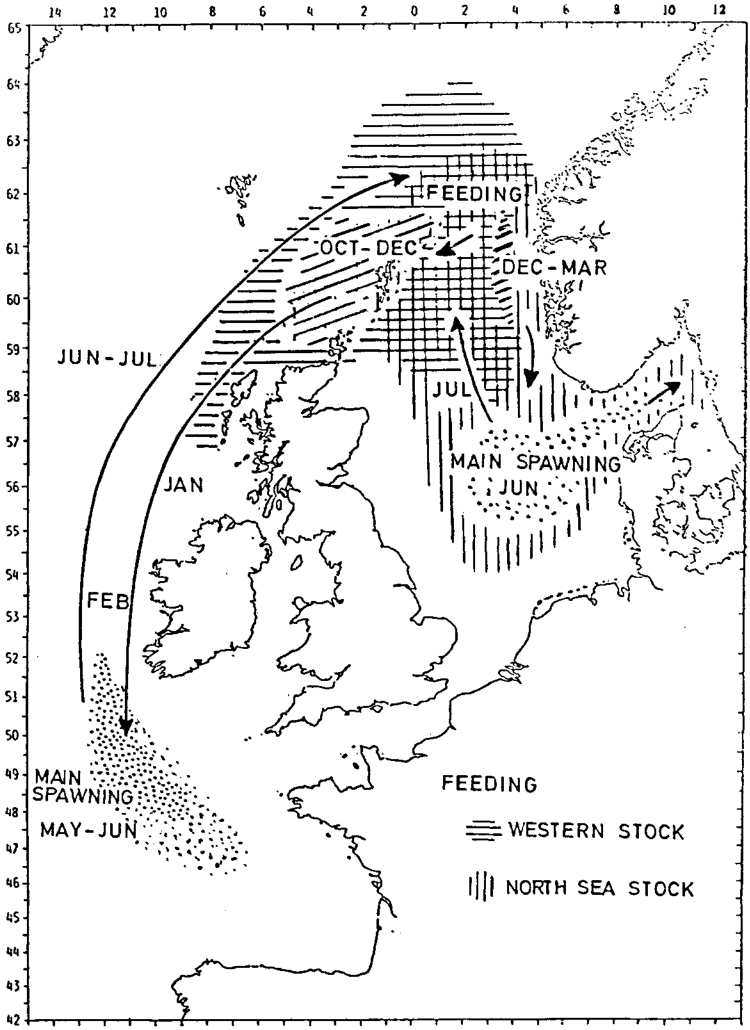


Figure 3.2 Schematic outline of migrations and distribution of adult mackerel of the Western and North Sea stocks.

Figure 3.3. Distribution and abundance of the 1987 year class between October 1987 and February 1988 from Danish, Dutch, English, Federal Republic of Germany, Irish, Norwegian, and Scottish research vessel surveys (provisional).

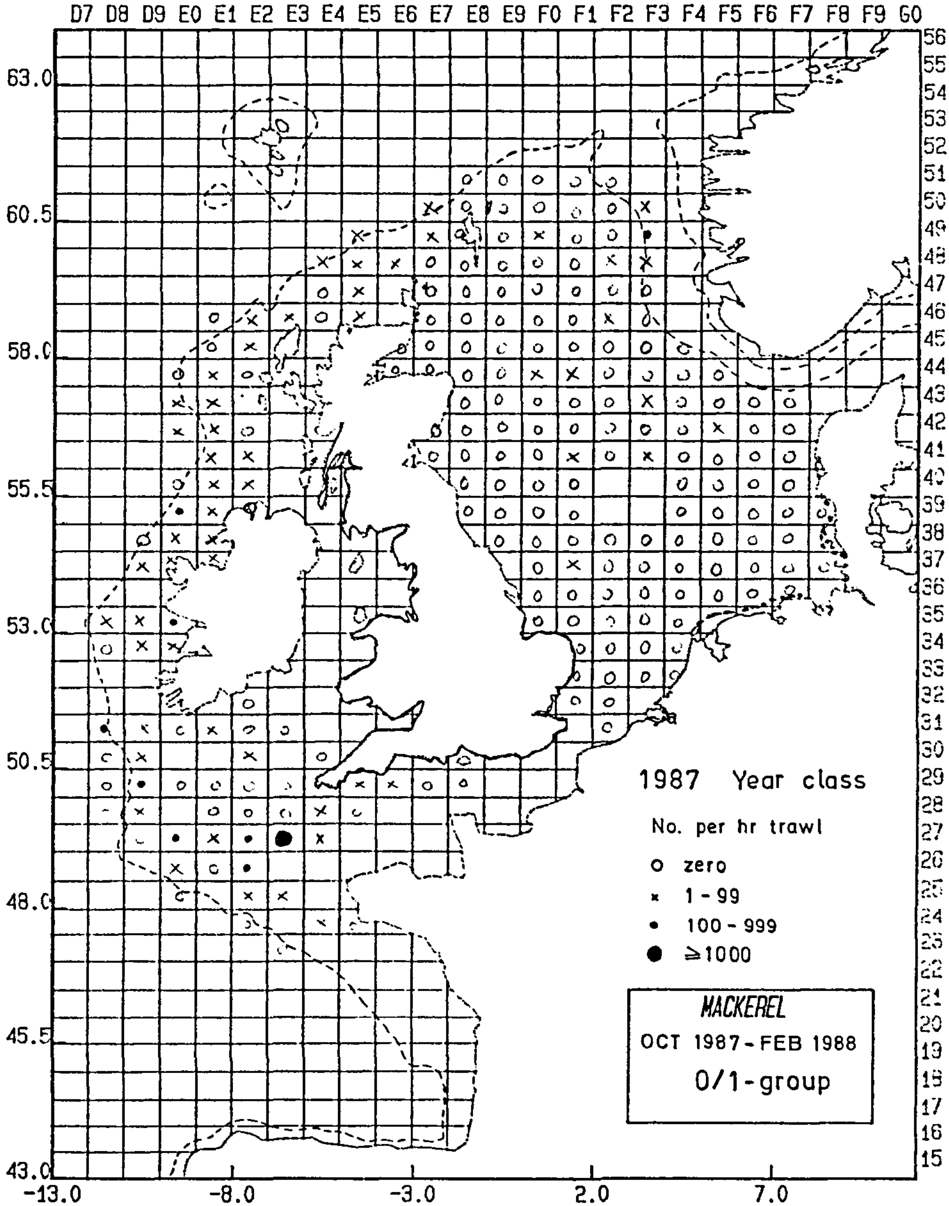


Figure 3.4 Distribution and abundance of the 1986 year class between October 1986 and March 1987 from Danish, Dutch, English, Federal Republic of Germany, Irish, Norwegian, and Scottish research vessel surveys (revised).

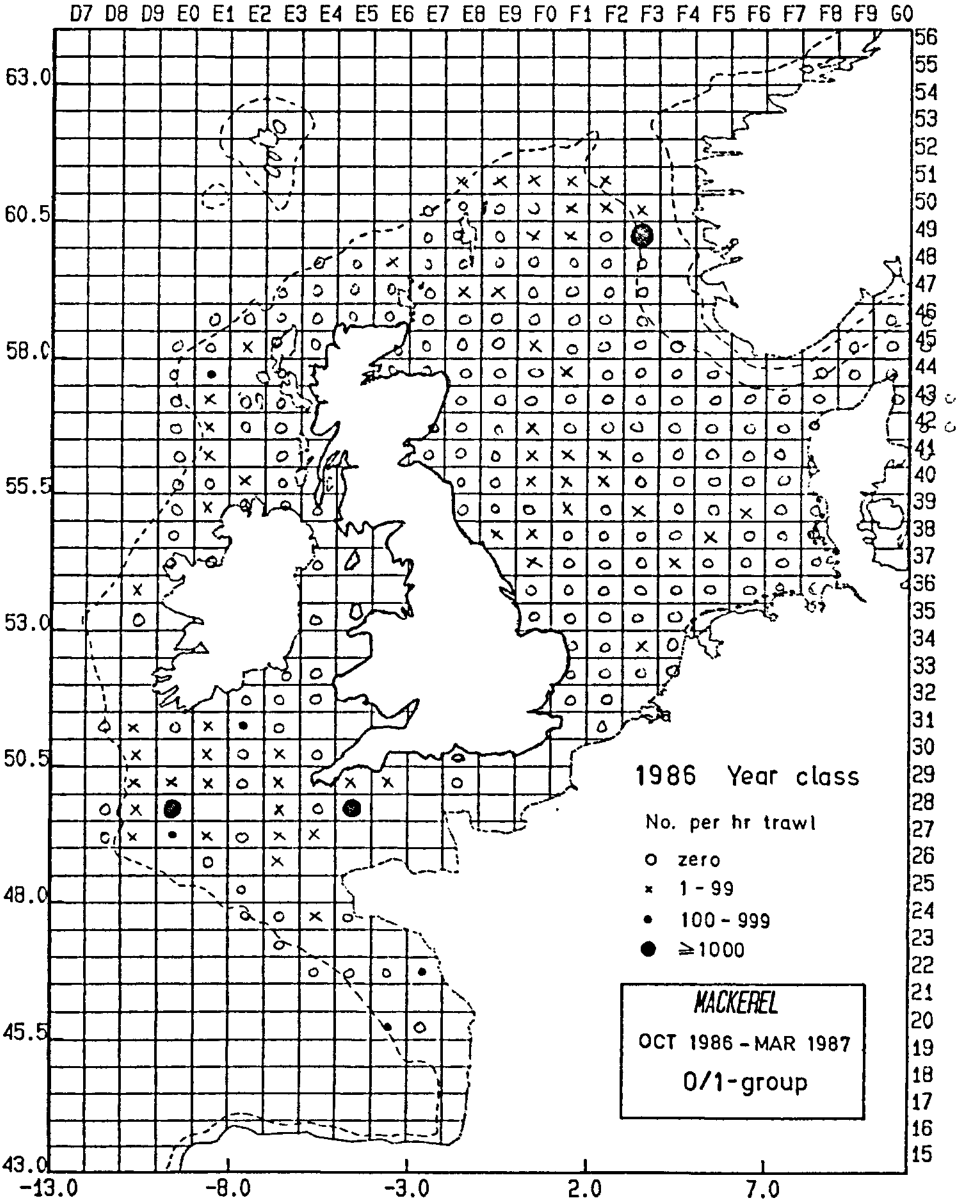


Figure 3.5 Distribution and abundance of the 1986 year class during the fourth quarter 1987 from Dutch, English, Irish, and Scottish research vessel surveys (provisional).

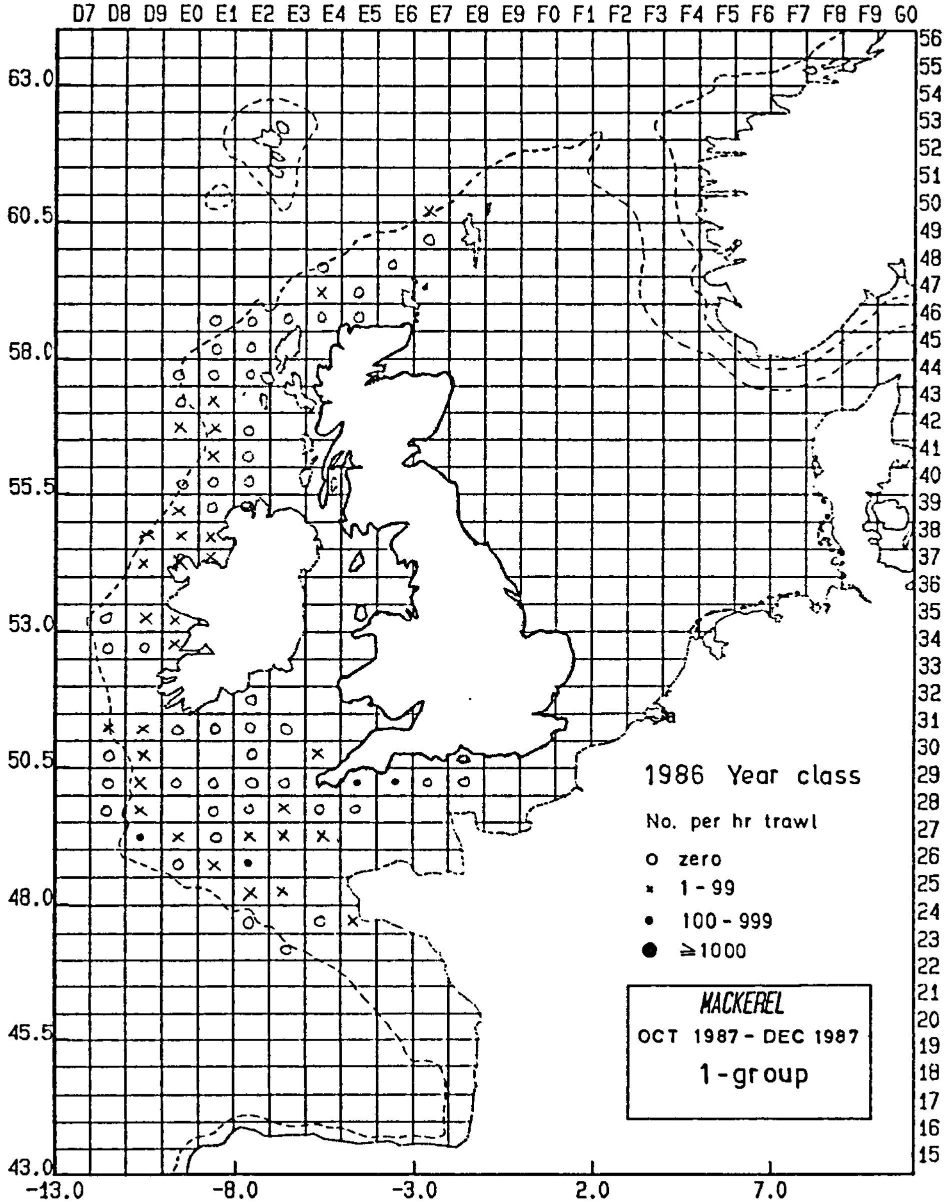


Figure 3.6 Distribution and abundance of the 1985 year class between October 1985 and March 1986 from Danish, Dutch, English, Federal Republic of Germany, Irish, Norwegian, and Scottish research vessel surveys (revised).

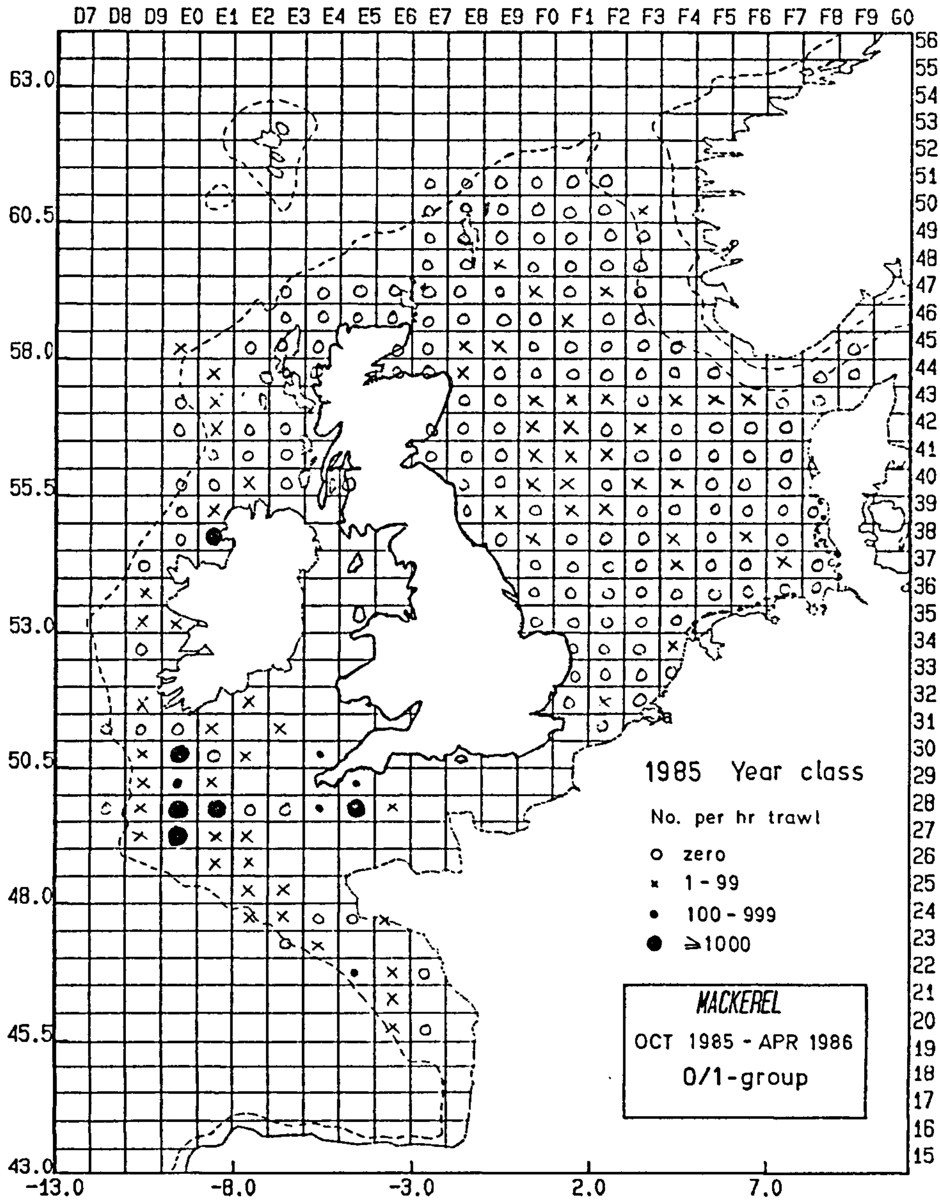


Figure 3.7 Distribution and abundance of the 1985 year class between October 1986 and March 1987 from Danish, Dutch, English, Federal Republic of Germany, Irish, Norwegian, and Scottish research vessel surveys (revised).

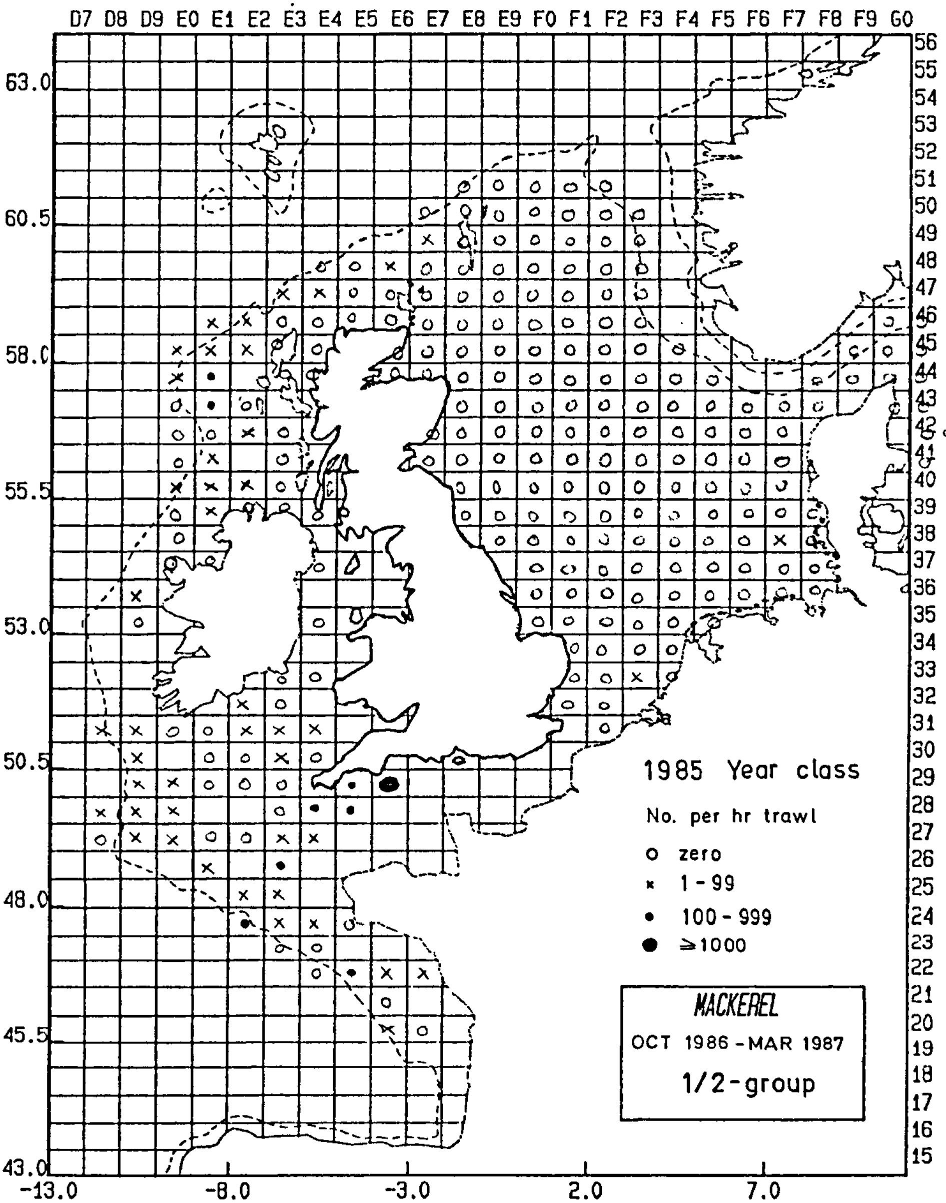


Figure 3.8. Distribution and abundance of the 1984 year class between October 1984 and March 1985 from Danish, Dutch, English, Federal Republic of Germany, Norwegian, and Scottish research vessel surveys (revised).

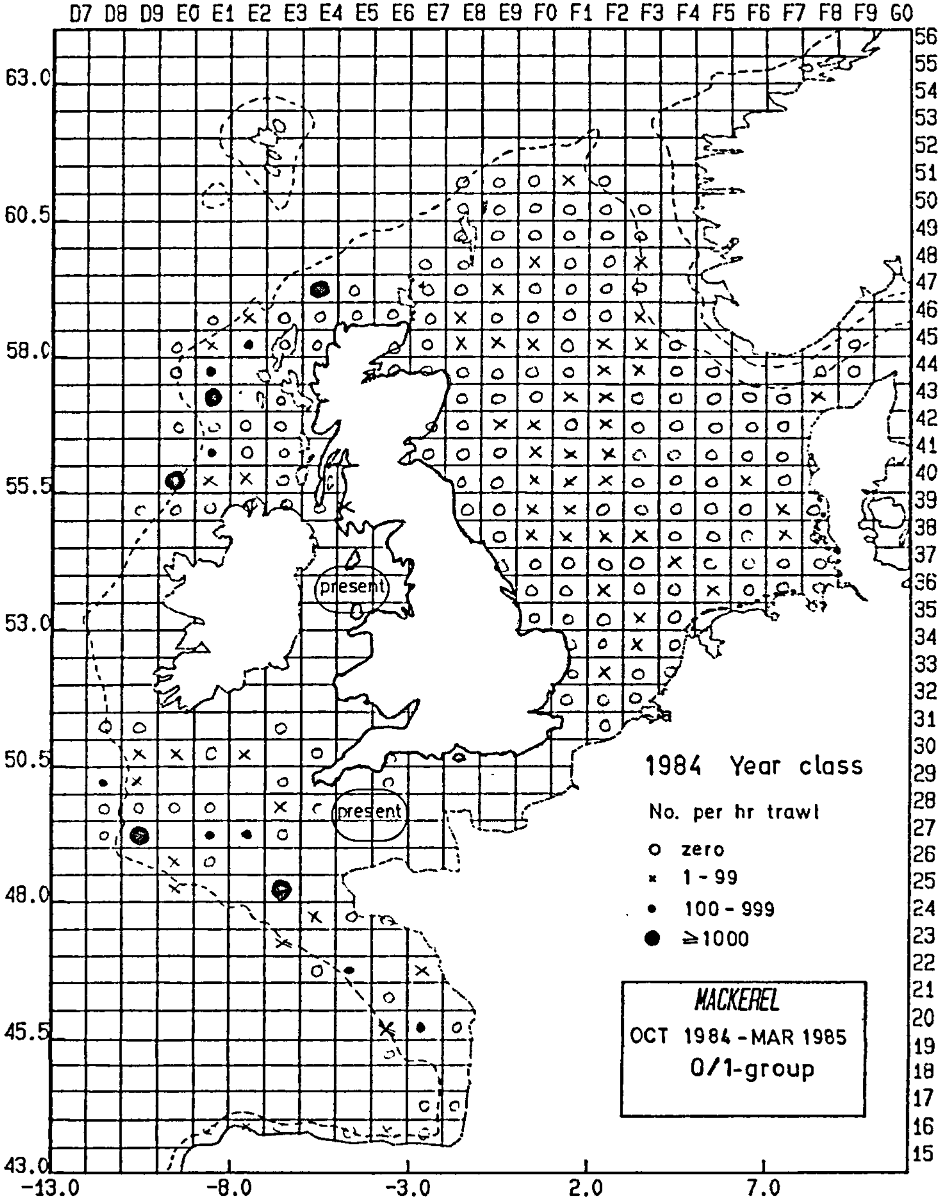
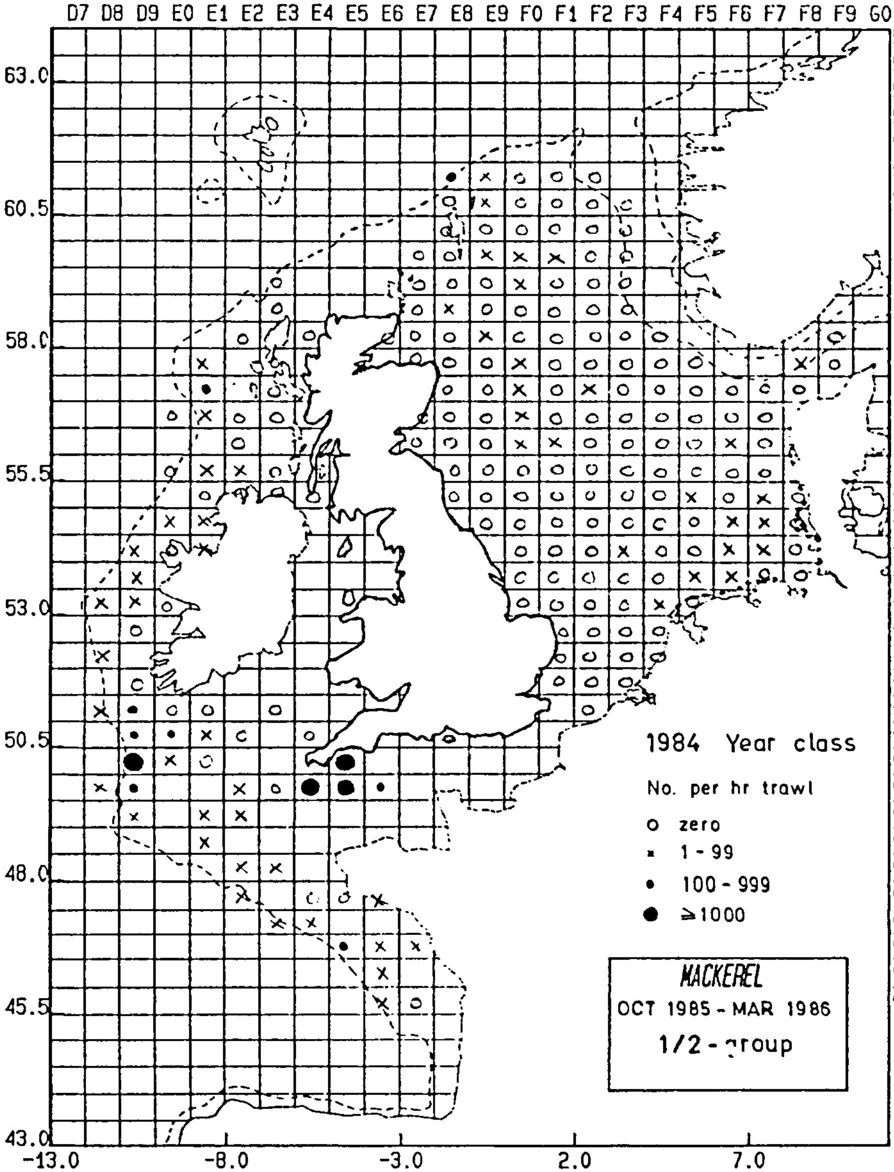


Figure 3.9 Distribution and abundance of the 1984 year class between October 1985 and March 1986 from Danish, Dutch, English, Federal Republic of Germany, Irish, Norwegian, and Scottish research vessel surveys (revised).



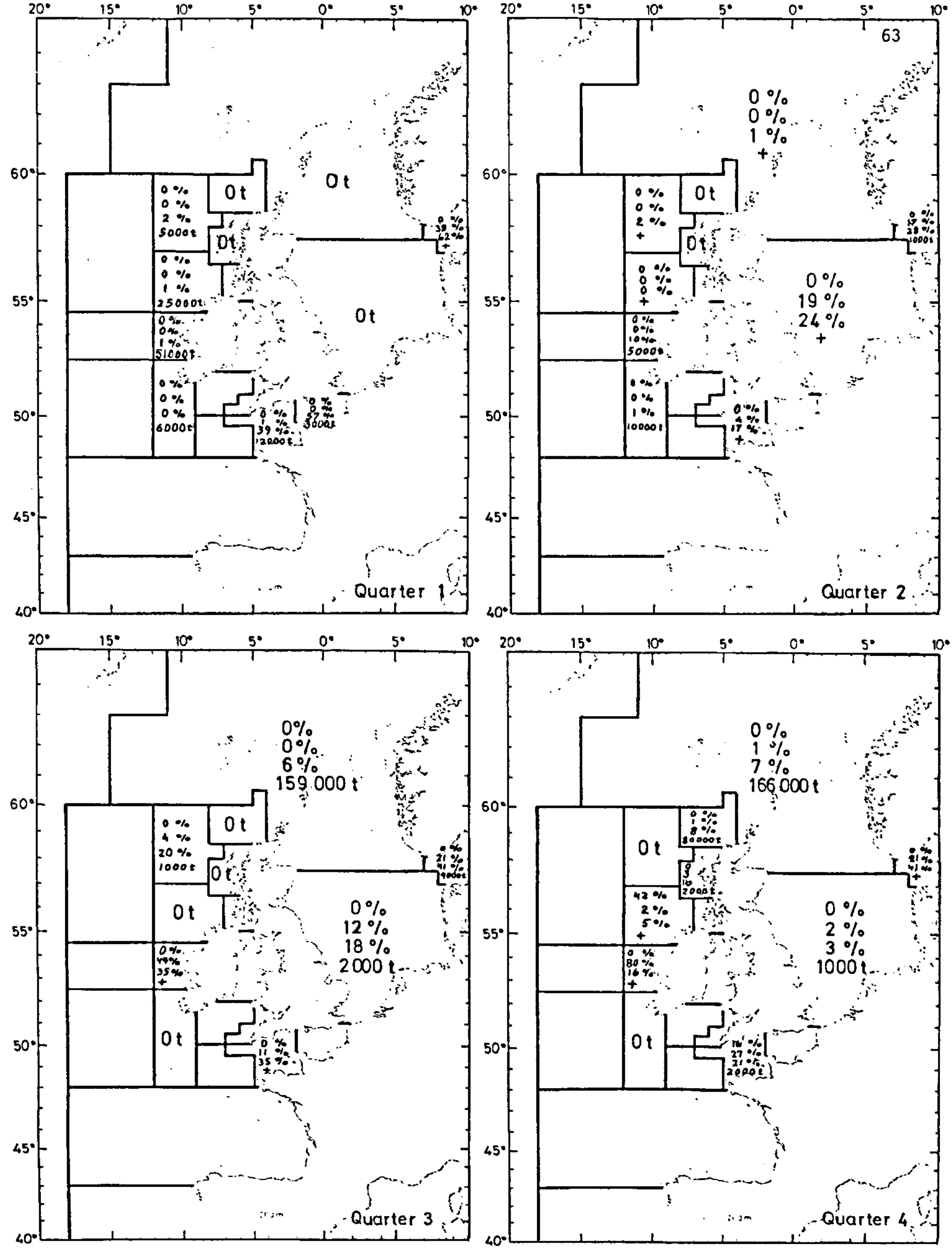


Figure 3.10 The occurrence of juvenile mackerel expressed as a percentage by numbers in the commercial catches that could be allocated to ICES divisions or sub-divisions in 1987. Values in each area are expressed from top to bottom as: 0-group; 1-group; 2-group; tonnage that would be allocated (+ = less than 500 t).

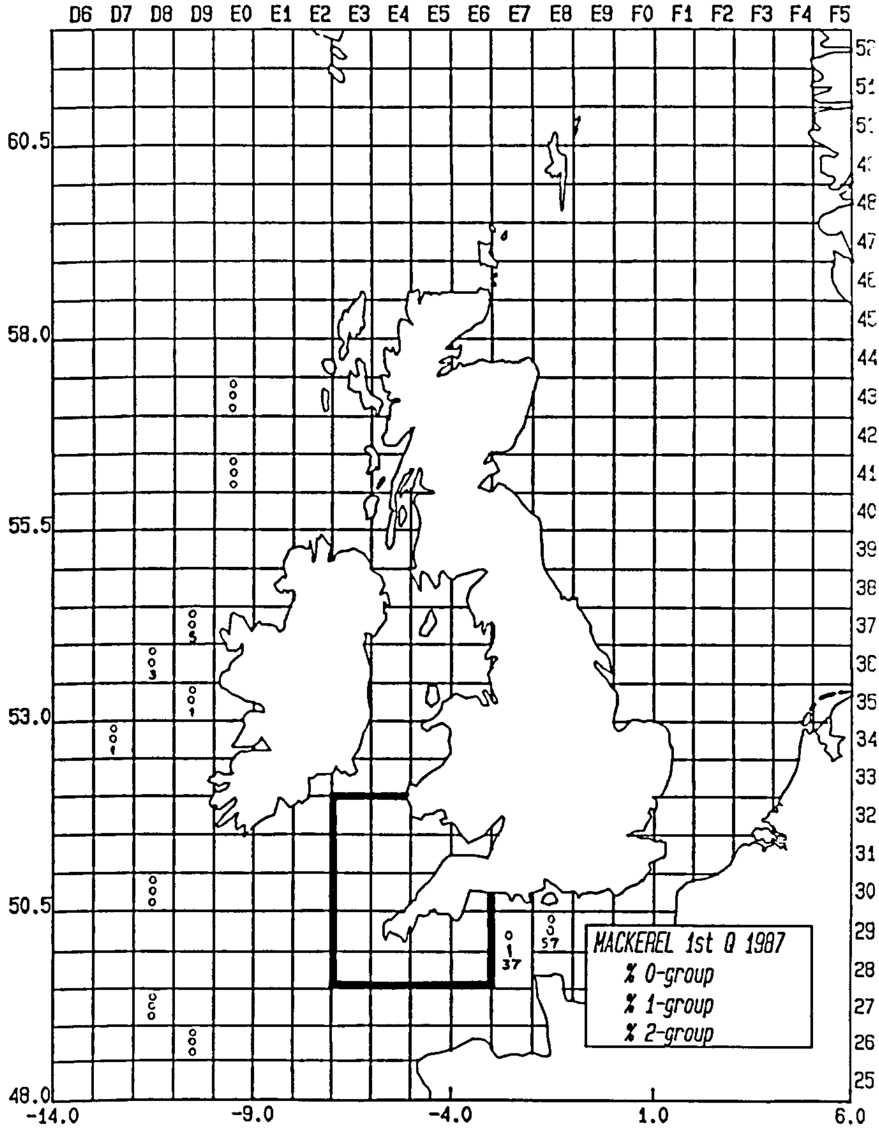


Figure 3.11a The percentage of 0-, 1-, and 2-group mackerel in the Dutch, Irish, and English commercial catches by rectangle and by quarter in 1987. The 0-group caught during the Irish herring fishery is indicated with a +.

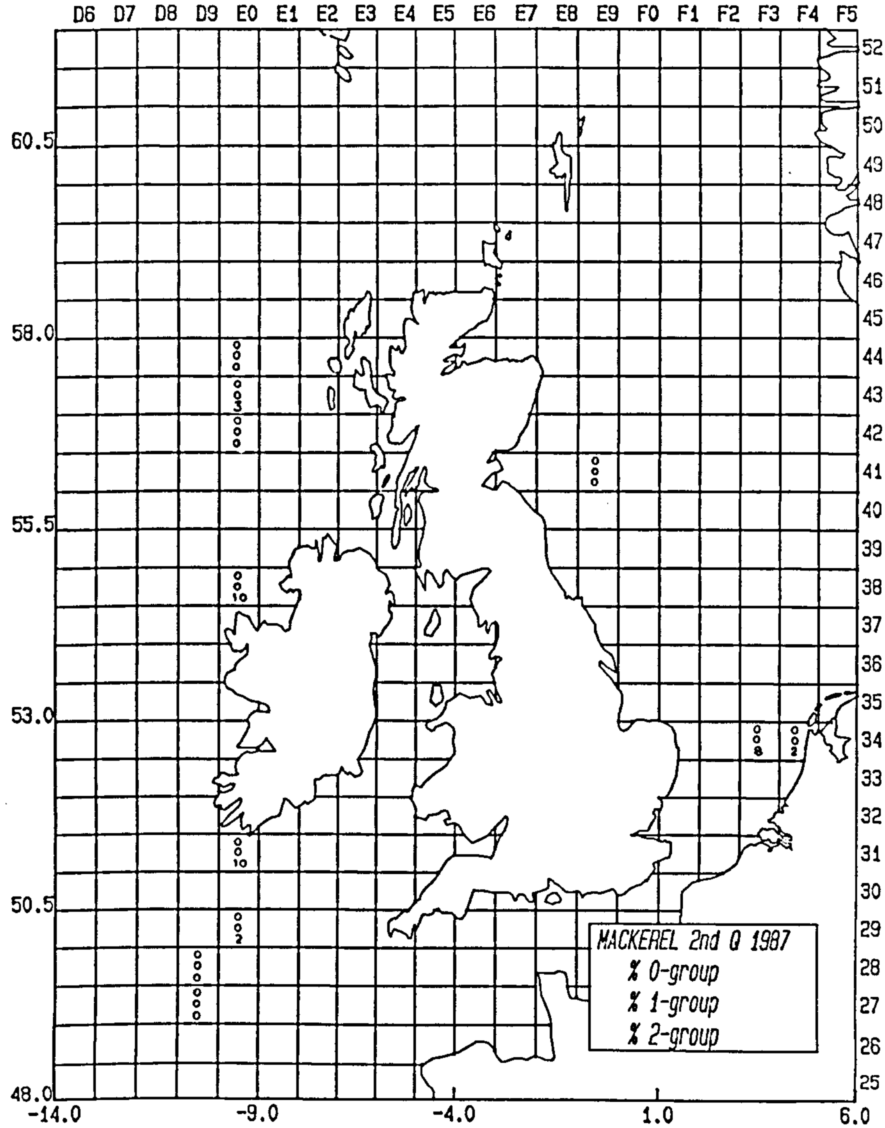


Figure 3.11b The percentage of 0-, 1-, and 2-group mackerel in the Dutch, Irish, and English commercial catches by rectangle and by quarter in 1987. The 0-group caught during the Irish herring fishery is indicated with a +.

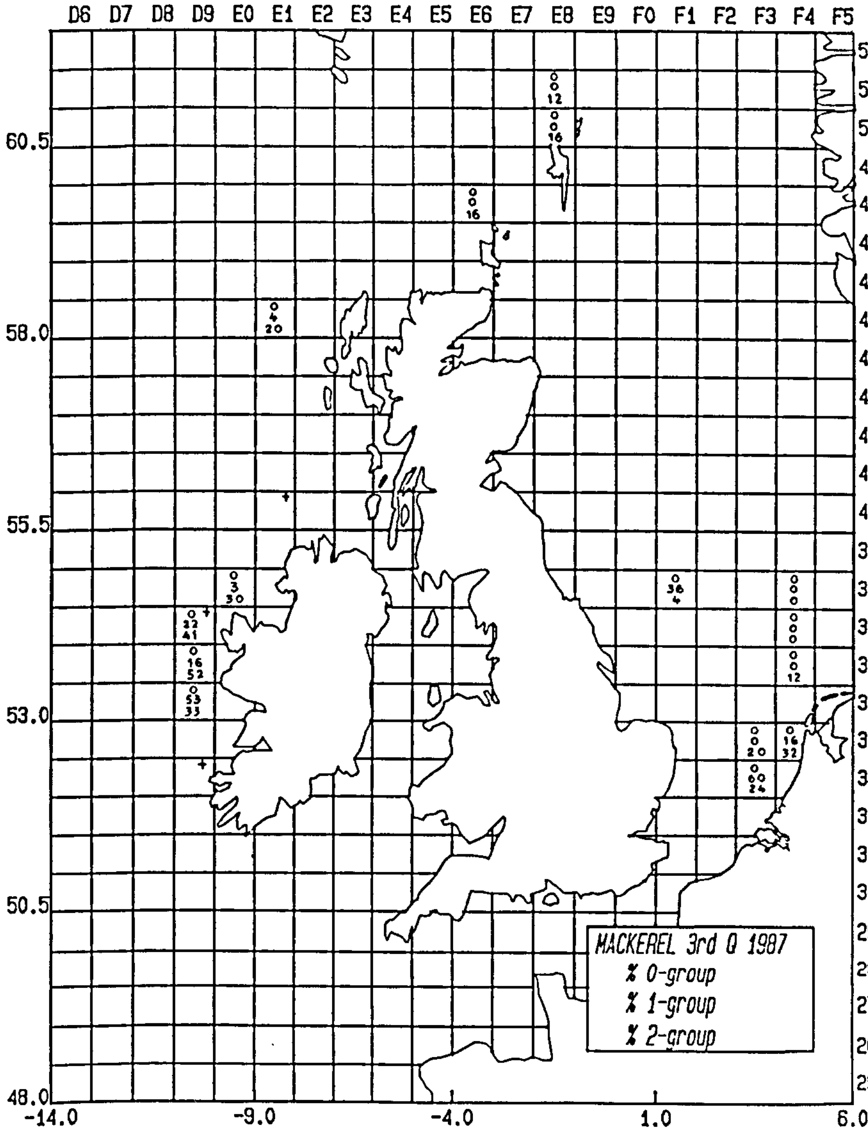


Figure 3.11c The percentage of 0-, 1-, and 2-group mackerel in the Dutch, Irish and English commercial catches by rectangle and by quarter in 1987. The 0-group caught during the Irish herring fishery is indicated with a +.

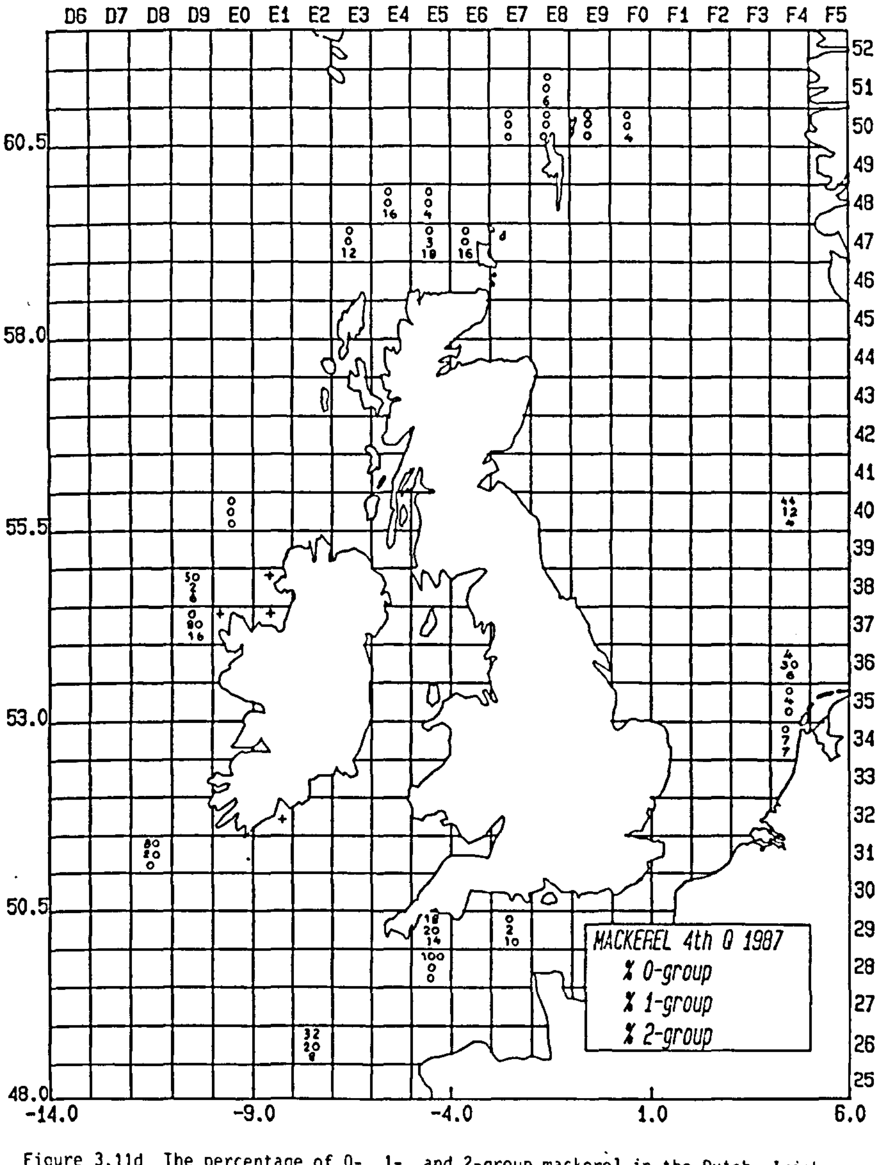


Figure 3.11d The percentage of 0-, 1-, and 2-group mackerel in the Dutch, Irish, and English commercial catches by rectangle and by quarter in 1987. The 0-group caught during the Irish herring fishery is indicated with a +.

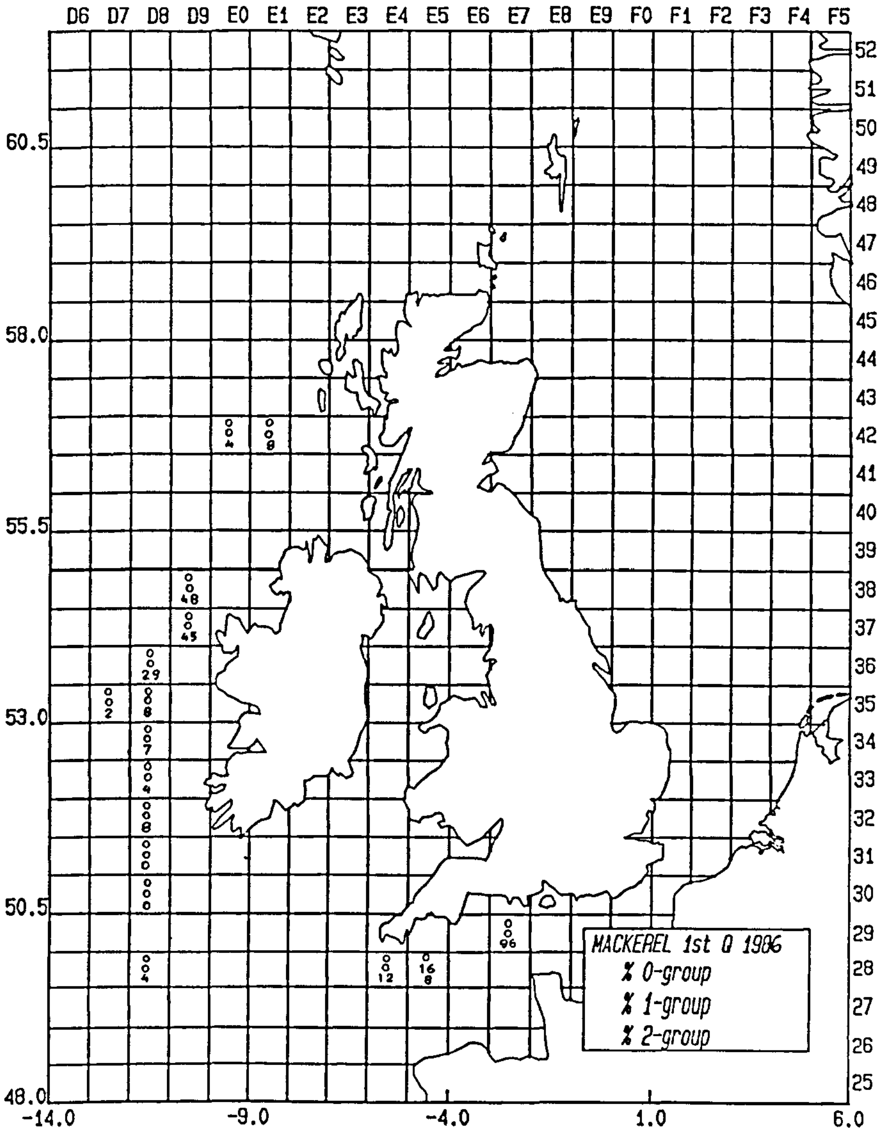


Figure 3.11e The percentage of 0-, 1-, and 2-group mackerel in the Dutch commercial catches by rectangle and by quarter in 1986.

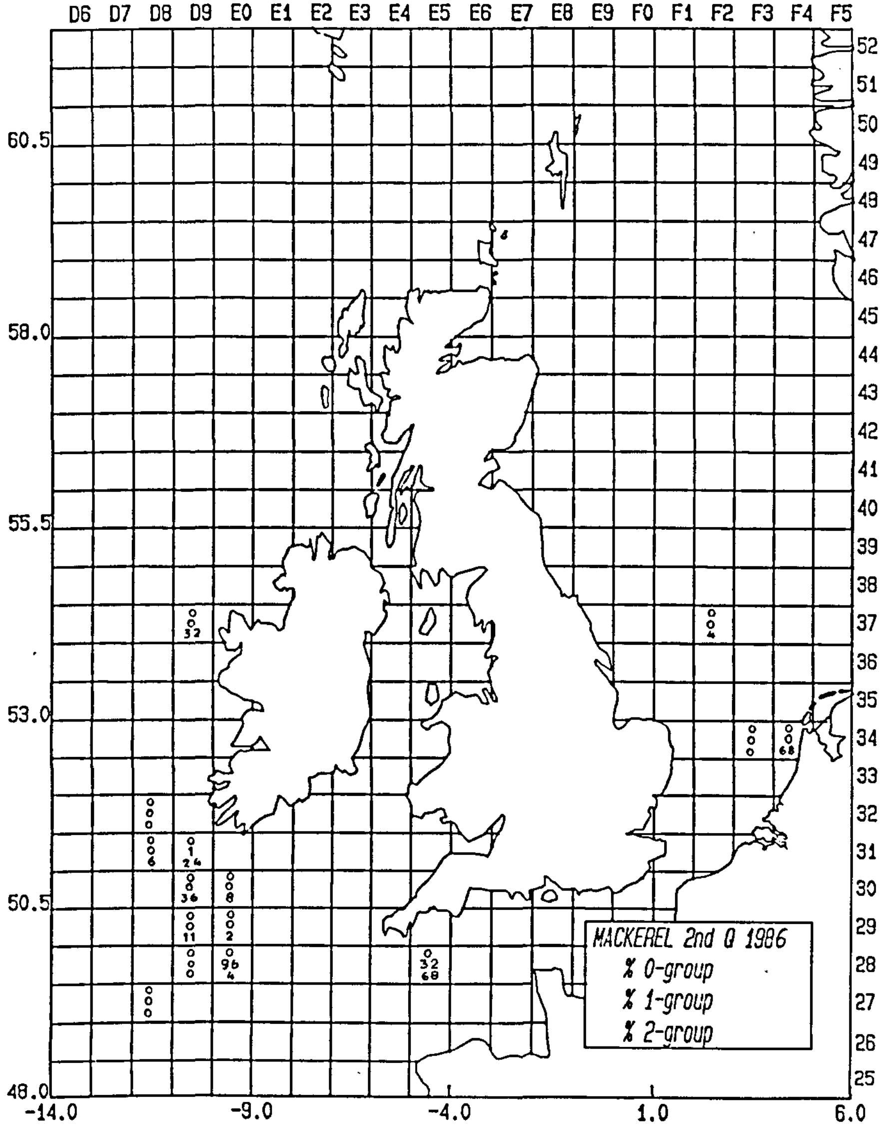


Figure 3.11f The percentage of 0-, 1-, and 2-group mackerel in the Dutch commercial catches by rectangle and by quarter in 1986.

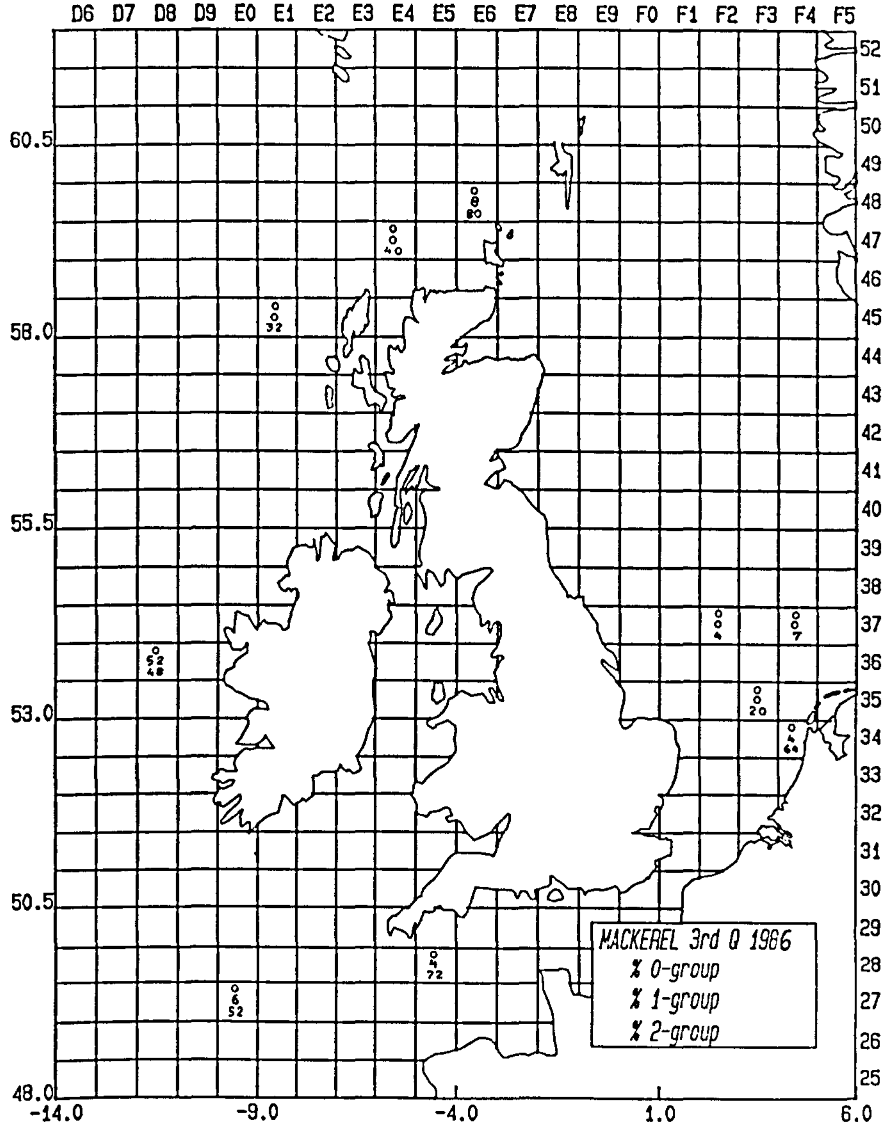


Figure 3.11g The percentage of 0-, 1-, and 2-group mackerel in the Dutch commercial catches by rectangle and by quarter in 1986.

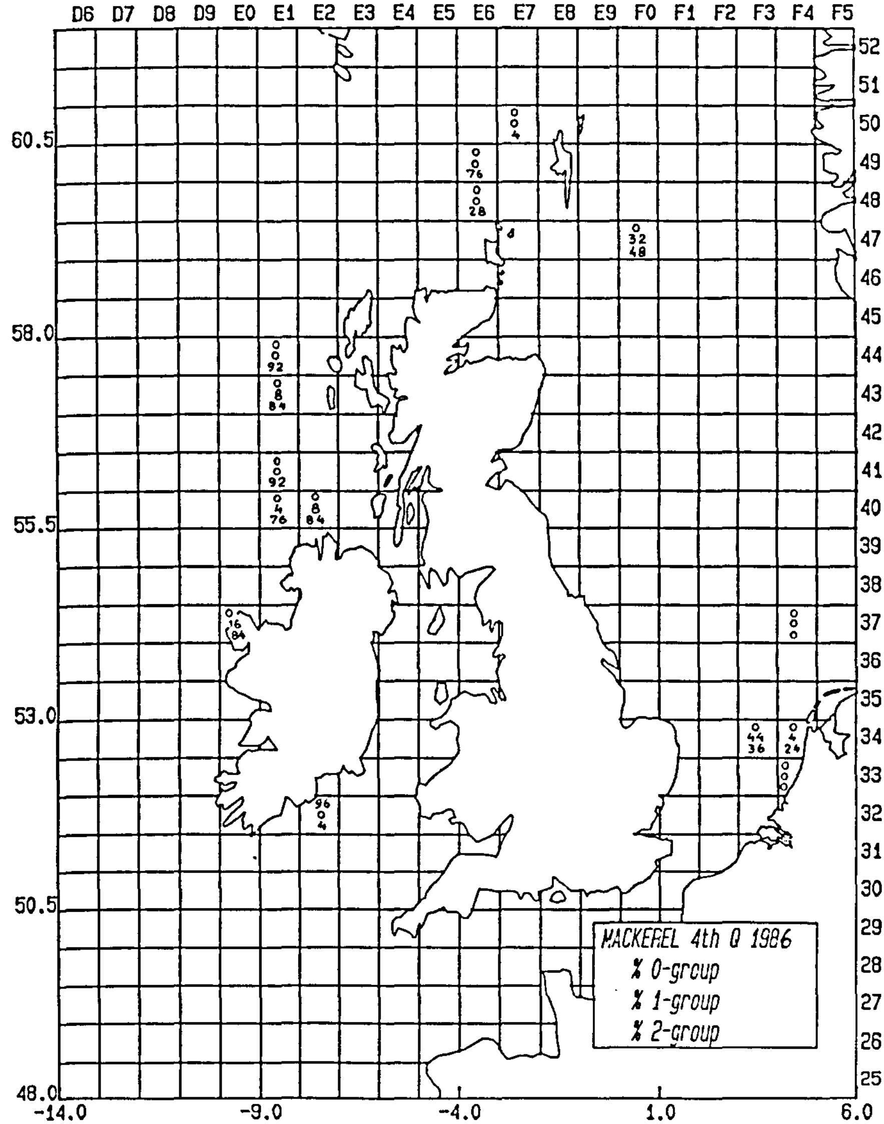


Figure 3.11h The percentage of 0-, 1-, and 2-group mackerel in the Dutch commercial catches by rectangle and by quarter in 1986.

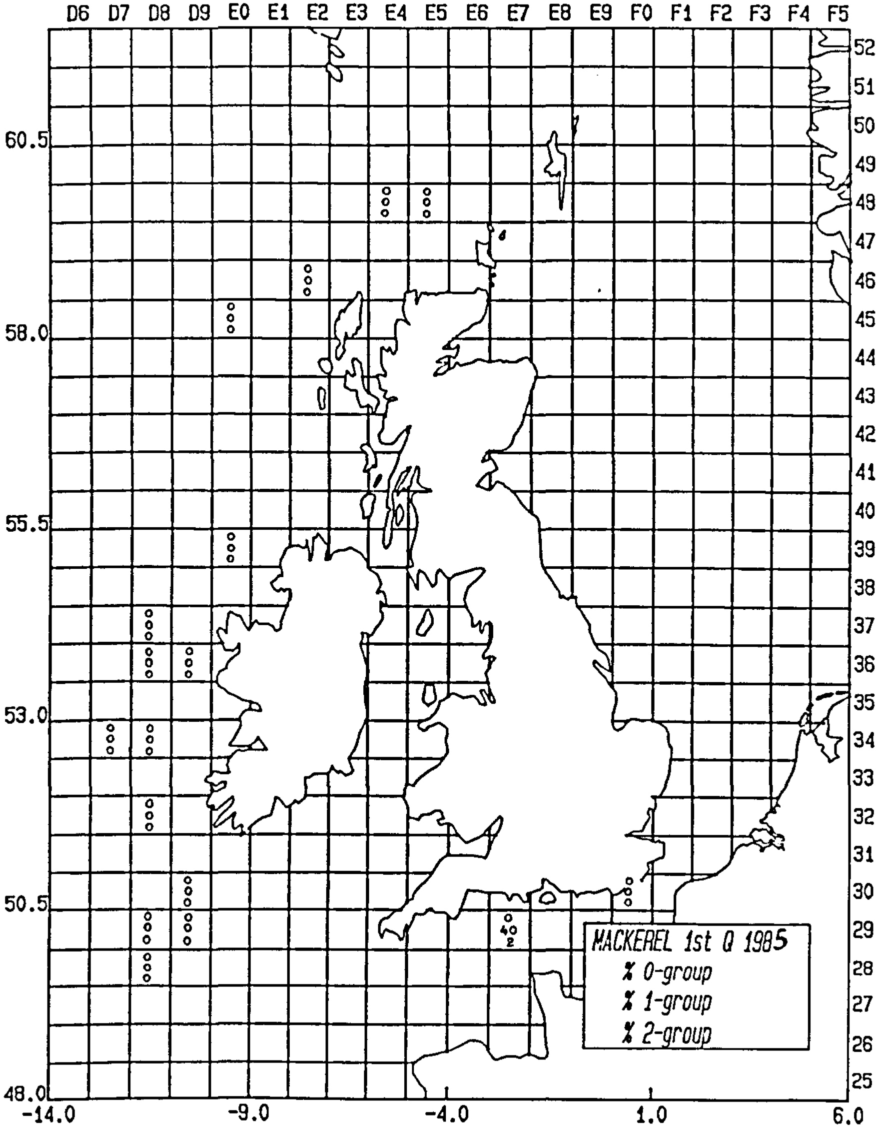


Figure 3.11i The percentage of 0-, 1-, and 2-group mackerel in the Dutch commercial catches by rectangle and by quarter in 1985.

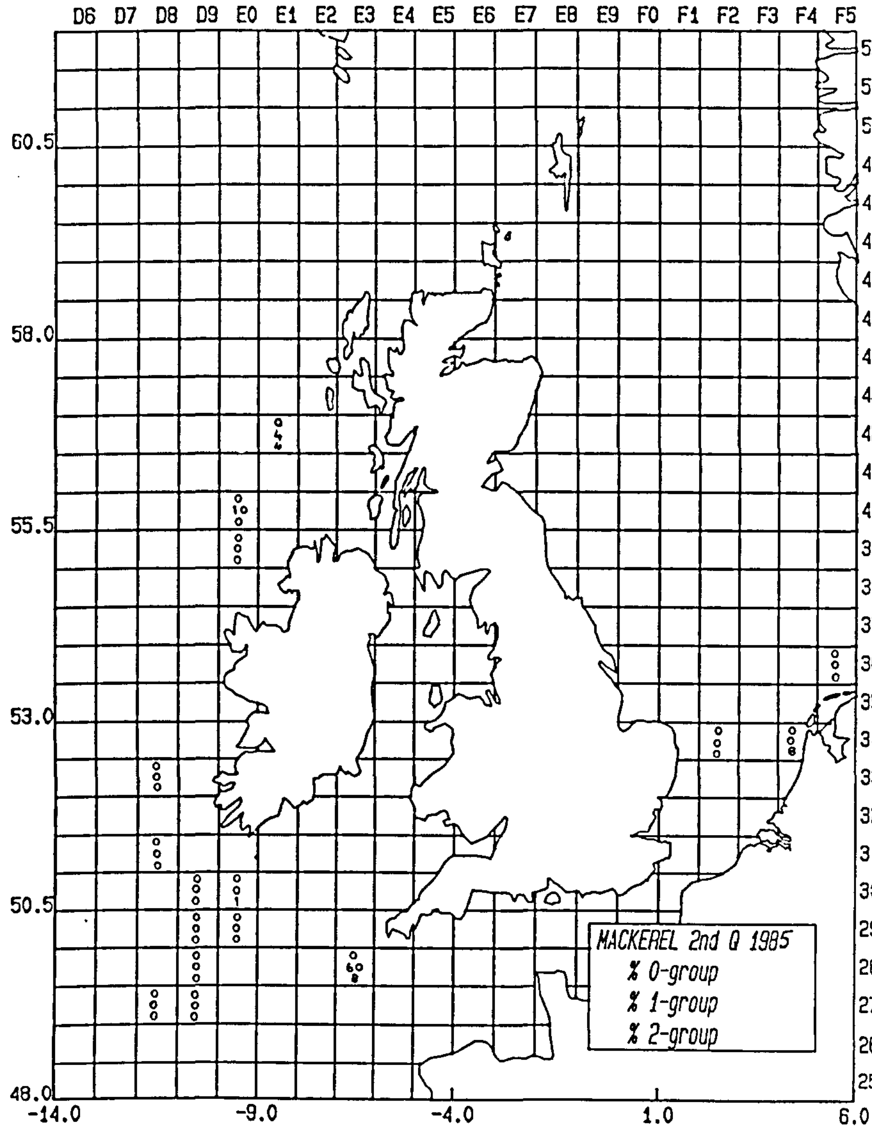


Figure 3.11j The percentage of 0-, 1-, and 2-group mackerel in the Dutch commercial catches by rectangle and by quarter in 1985.

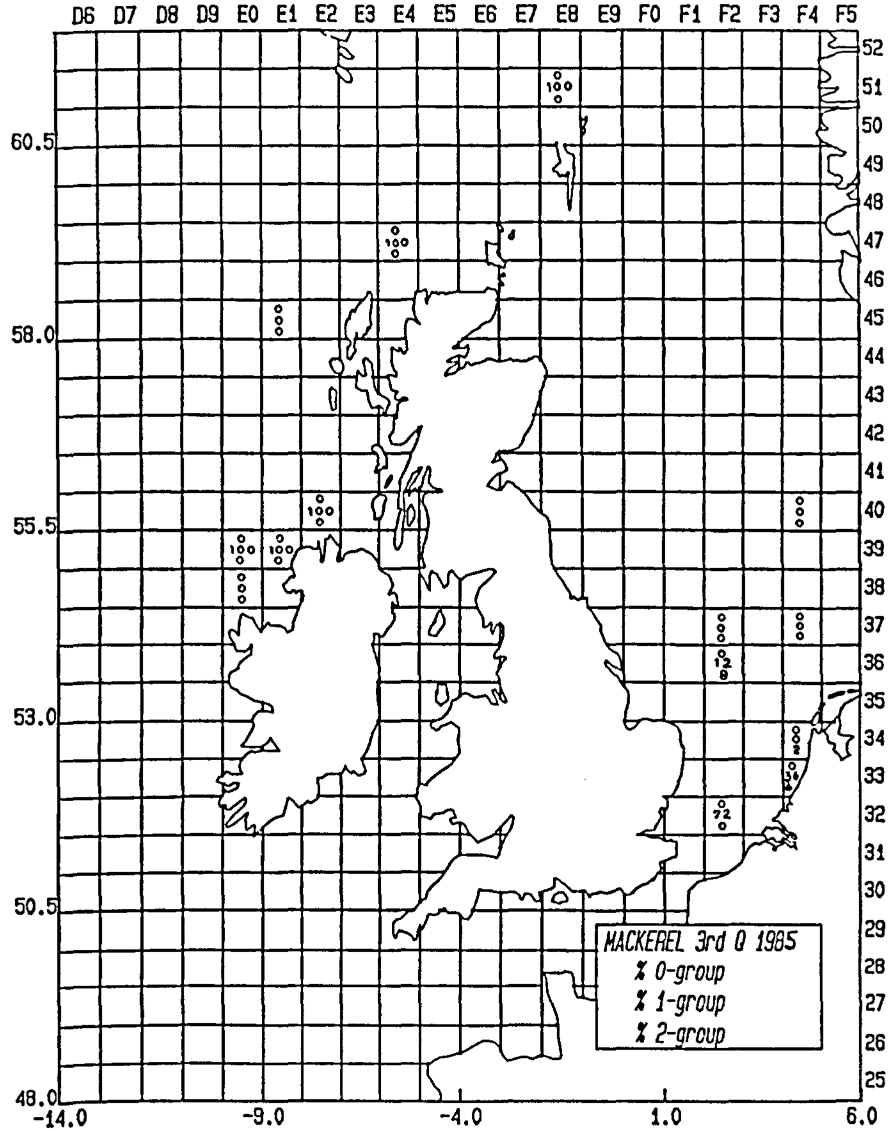


Figure 3.11k The percentage of 0-, 1-, and 2-group mackerel in the Dutch commercial catches by rectangle and by quarter in 1985.

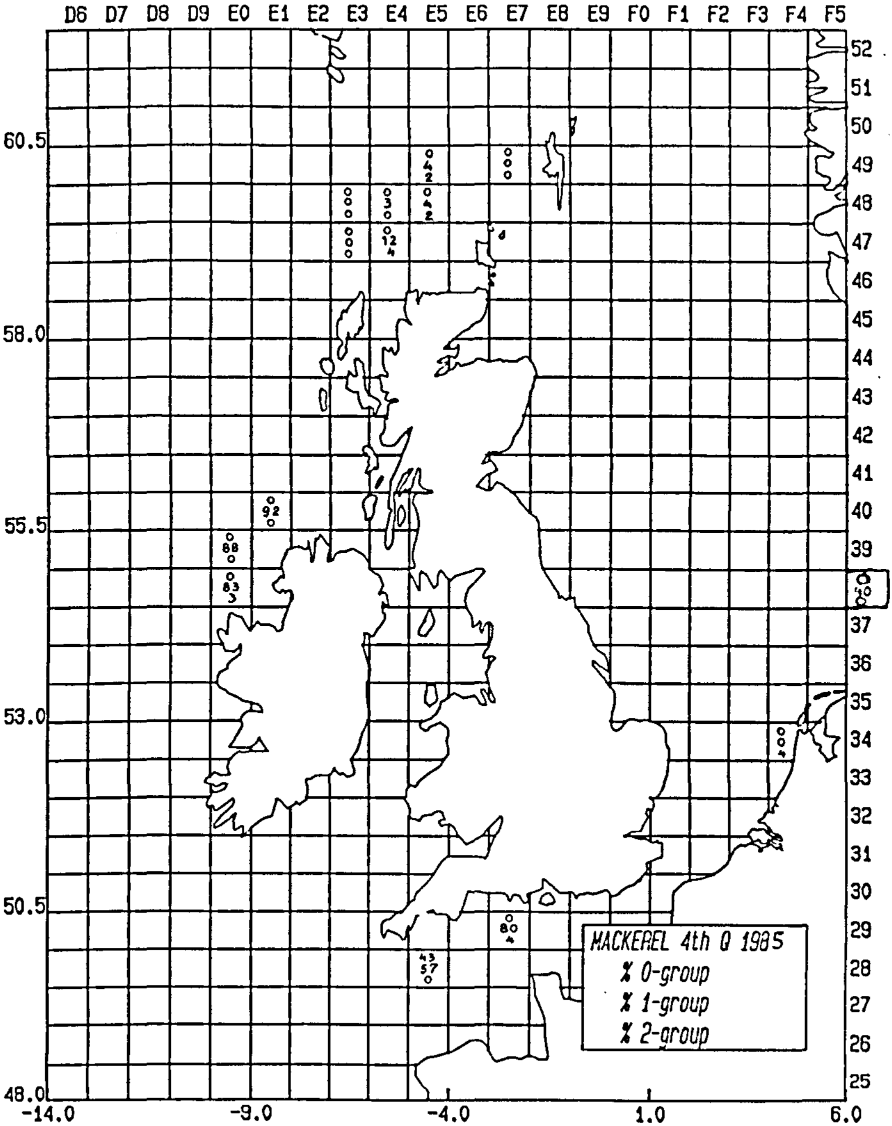


Figure 3.111 The percentage of 0-, 1-, and 2-group mackerel in the Dutch commercial catches by rectangle and by quarter in 1985.

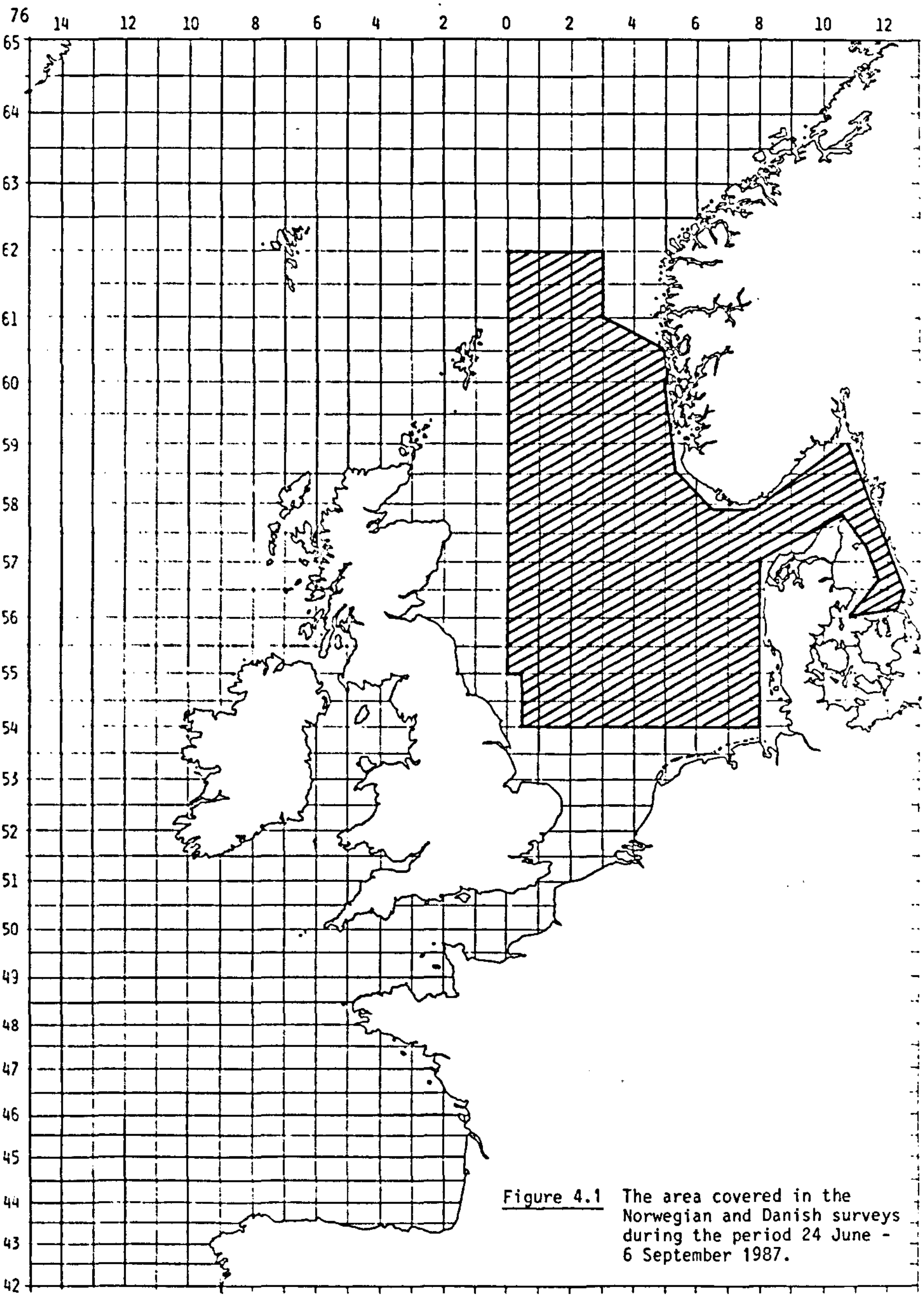
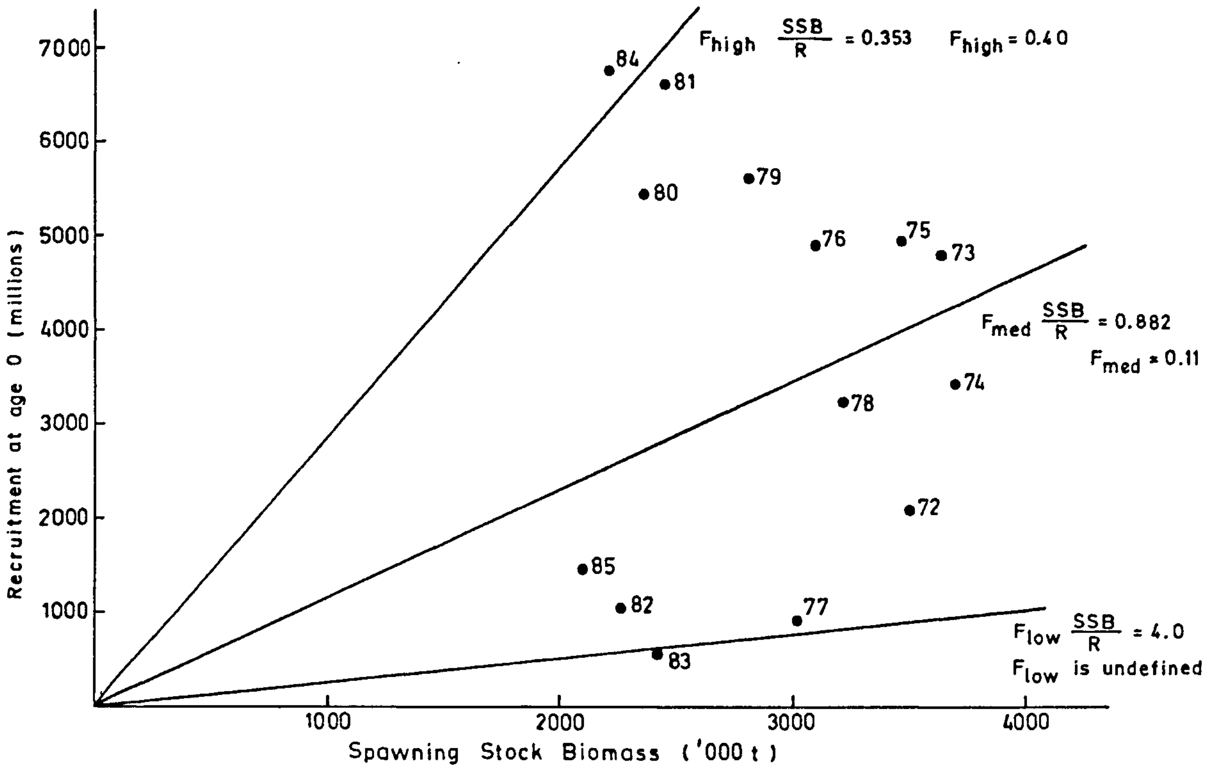


Figure 4.1 The area covered in the Norwegian and Danish surveys during the period 24 June - 6 September 1987.

Figure 5.1 Western mackerel. Stock-recruitment.



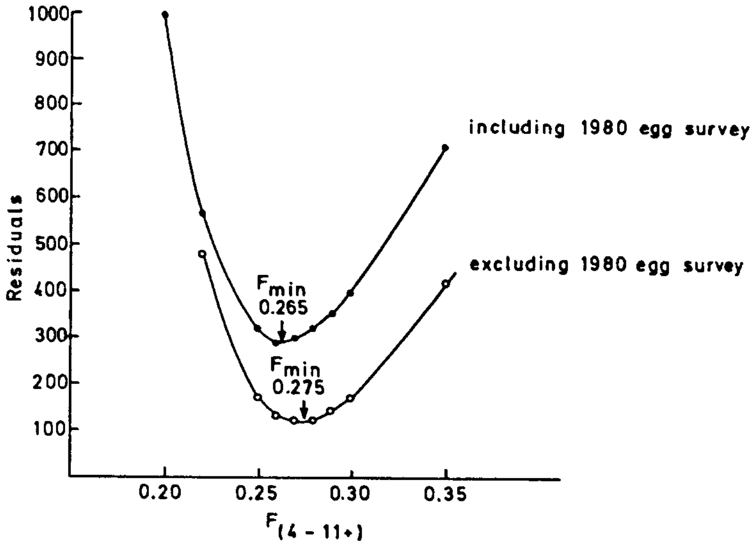
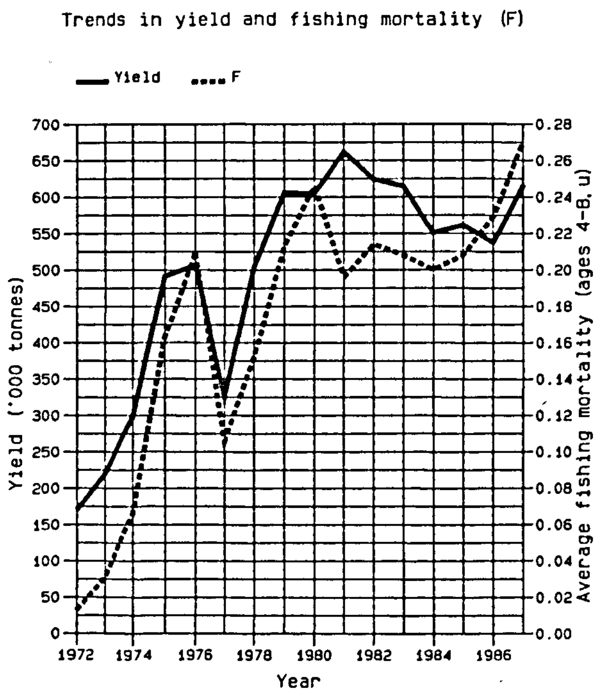


Figure 5.2 Sum of squared residuals against F at ages 4-11+.

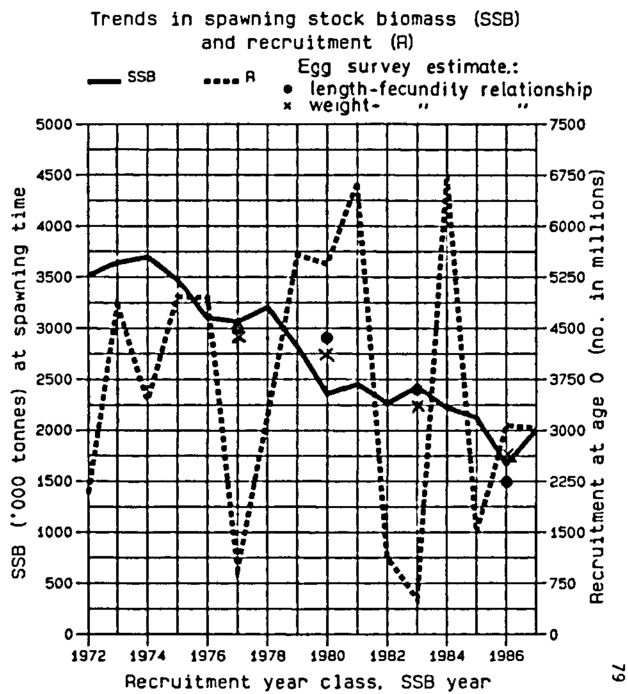
Residuals are calculated as $\Sigma\left[\frac{(x-y)}{x} \times 100\right]^2$
where x = egg survey estimate of spawning stock biomass
and y = VPA estimate of spawning stock biomass.

Figure 5.3

FISH STOCK SUMMARY
STOCK: Mackerel, Western Stock
09-03-1988



A



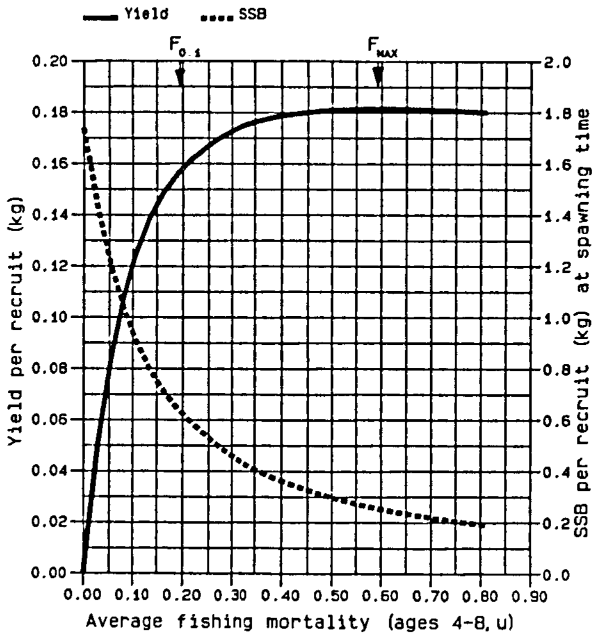
B

cont'd.

Figure 5.3 cont'd.

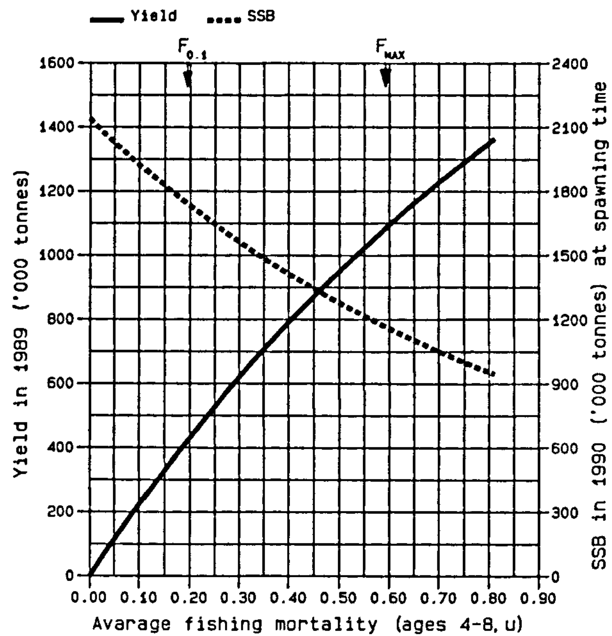
FISH STOCK SUMMARY
STOCK: Mackerel, Western Stock
09-03-1988

Long-term yield and spawning stock biomass



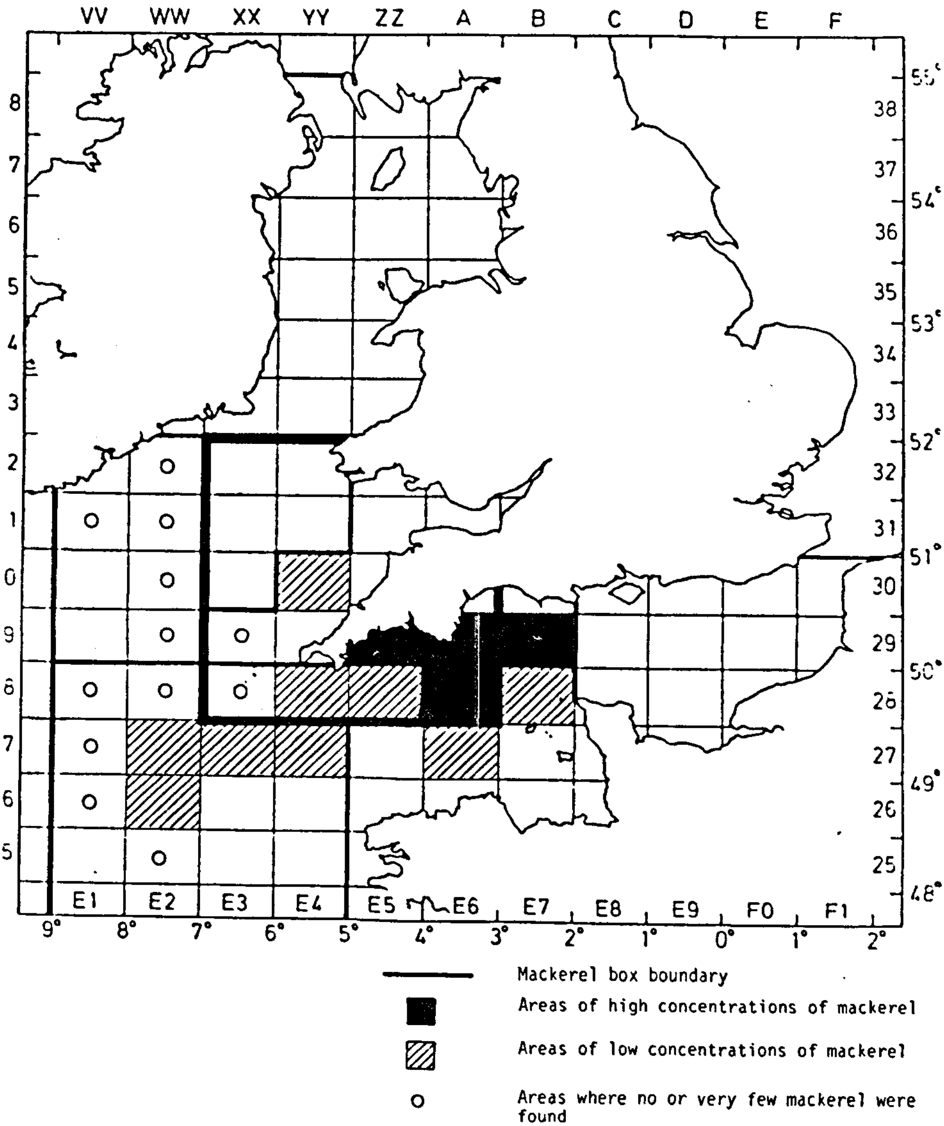
C

Short-term yield and spawning stock biomass



D

Figure 6.1 Distribution of mackerel off SW England for the winter seasons 1987/1988. Information is based on both research vessel data and commercial catches.



cont'd.

Figure 6.1 cont'd.