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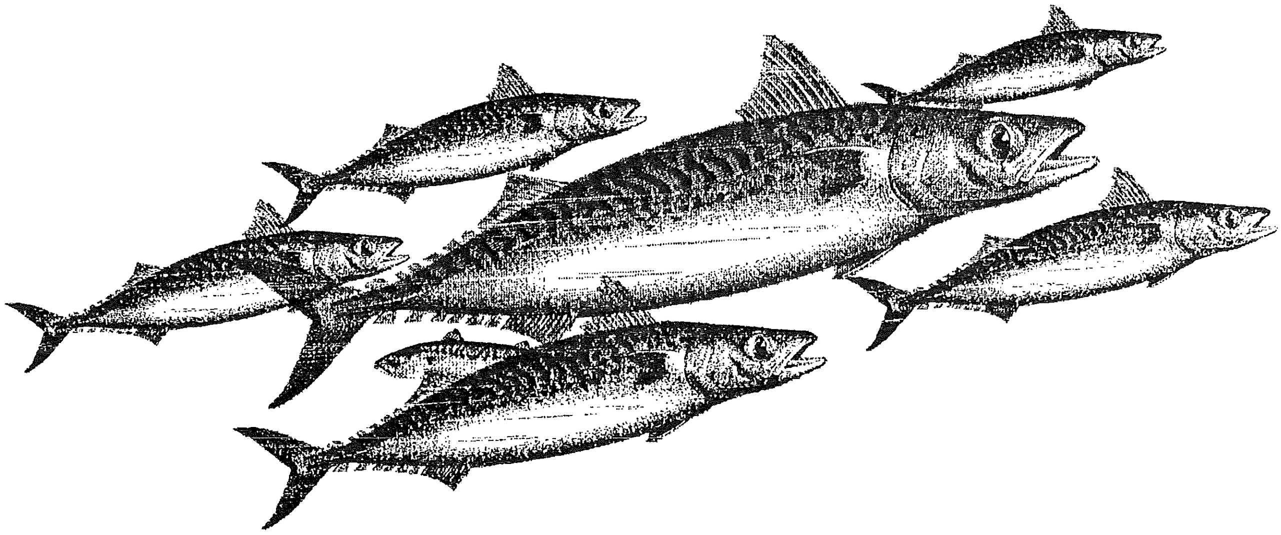

MACKEREL WORKING GROUP

COPENHAGEN, 29 APRIL - 8 MAY 1991

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1 INTRODUCTION

1.1 Terms of Reference

At the 78th Statutory Meeting in Copenhagen it was decided (C.Res.1990/2:5:14) that the Mackerel Working Group (Chairman: Mr E. Kirkegaard, Denmark) should meet at ICES Headquarters from 23 April - 1 May 1991 to:

a) assess the status of and provide catch options for 1992 within safe biological limits for the mackerel stocks and management units in Sub-areas II-IX;

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 possible fishery closures by area and season for mackerel in Divisions VIIIc and IXa which could be introduced to reduce the exploitation of juveniles;

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 1990 to the Multispecies Assessment Working Group as input for the multispecies VPA, and provide information on the likely level of Western stock mackerel which is seasonally present in the North Sea.

1.2 Participants

The Working Group met in Copenhagen with the following participants:

R.M. Cook (part-time)	UK (Scotland)
A. Eltink	The Netherlands
P. Hopkins	UK (Scotland)
S.A. Iversen	Norway
B.W. Jones (part-time)	UK (England)
E. Kirkegaard (Chairman)	Denmark
P. Lucio	Spain
M.M. Martins	Portugal
J. Molloy	Ireland
C. Porteiro	Spain
A. Richards	USA

2 WORKSHOP ON MACKEREL IN DIVISIONS VIIIc AND IXa.

In accordance with ICES C.Res.1990/2:20, a Workshop on Mackerel in Divisions VIIIc and IXa was convened in Lisbon from 5 - 7 March 1991 with M.M.Martins as Chairperson. The Report of the Workshop (Anon., 1991d) was presented as a Working Document to the Working Group.

The Report contained sections on

(1) egg surveys and the distributions and size compositions of fish from groundfish and acoustic surveys,

(2) descriptions of the fisheries by fleet with catch and length composition data and CPUE,

(3) biological parameters of growth, maturity and weight-at-age, and

(4) indices of recruitment and biomass.

The Report was discussed by the Working Group. It was noted that egg surveys off the Cantabrian coast of Spain in April and May, conducted mainly for sardine and anchovy (southern Biscay), showed mackerel eggs distributed over the whole area from Galicia to southern Biscay with the greatest concentrations off the central Cantabrian coast. Off the coast of Portugal, egg surveys had been undertaken for sardine in March - April but no mackerel eggs were reported from the samples although no systematic analysis for mackerel eggs had been undertaken. Pre-spawning and spent mackerel have been recorded off the coast of Portugal although fish in spawning condition are rarely encountered. However, spawning in this area area is believed to take place from January to March/April with a peak in February, whereas in the Cantabrian Sea peak spawning occurs in March and April.

Data from the commercial fisheries and from groundfish and acoustic surveys show that the 0-group fish appear on the grounds in the second quarter of the year and start to contribute significantly to the commercial catches in quarters three and four. 0-group fish reach a mean length of about 22cm at the end of the year in the Cantabrian Sea and may reach a slightly larger size in Division IXa.

The fishery in the eastern and central Cantabrian Sea exploits the larger fish in the first half of the year. These larger fish become unavailable in the second part of the year. In the Western Cantabrian Sea the fishery takes place in the second half of the year and catches predominantly juveniles. Off the Portuguese coast the length composition of the catch shows no marked change through the year although the greater part of the catch is normally taken in the first six months.

The only directed fishery for mackerel in Divisions VIIIc and IXa is the Spanish hand-line fishery, which is concentrated in the central and eastern parts of the Division VIIIc. This fishery has taken catches in the range 5,000 to 11,000 t during the last five years. The purse-seine fisheries, in addition to mackerel, also exploit sardine, anchovy and horse mackerel. The trawlers exploit a mixture of species including mackerel, horse mackerel, hake and blue whiting.

Quantities of mackerel caught in the fisheries in Divsions VIIIc and IXa, together with length and age compositions are referred to in detail in Section 7 of this report.

3 EGG SURVEYS

3.1 Review of Report of the Mackerel/Horse Mackerel Egg Production Workshop

The Mackerel/Horse Mackerel Egg Production Workshop met in IJmuiden the Netherlands from 15-18 January 1991 1) to coordinate the timing and planning of the 1992 Mackerel/Horse Mackerel Egg Surveys in ICES Sub-areas IV, VI-IX, 2) to coordinate the implementation in 1992 of the batch fecundity method for stock size estimation of mackerel and horse mackerel, 3) to make arrangements for processing the data from future egg survey results, 4) to evaluate problems in mackerel and horse mackerel fecundity estimation and 5) to review the basis for estimating spawning stock biomass from these surveys (Anon., 1991a).

The terms "total fecundity egg production method" and "batch fecundity egg production method" are used to describe the two approaches to estimating spawning stock biomass from the western mackerel and horse mackerel egg surveys. These terms are not commonly used by other workers in this field and their use by the present workshop could lead to some misunderstanding. The Workshop, therefore, recommended that in future these terms are replaced by "Annual Egg Production Method" and "Daily Egg Production Method", respectively. Both methods of estimating spawning stock biomss were discussed and reviewed. In addition, the problems in mackerel and horse mackerel fecundity estimation were evaluated for both the annual and the daily egg production method. Detailed information on this is reported in Anon. (1991a).

In the North Sea area Norway will carry out a restricted egg survey during the expected peak of spawning in the second half of June 1991. If there should be a substantial increase in the egg production during this survey compared to the 1990 survey, a joint Norwegian and Danish survey may be planned for 1992. The Workshop recommended that the daily egg production method be applied then for the North Sea survey in 1992.

In the western area, the surveys were arranged so that the daily and total egg production method could be carried out at the same time for both mackerel and horse mackerel. The planned research vessel deployment of the 1992 Mackerel/ Horse Mackerel Egg Surveys is listed in Table 3.1.

In the southern area, plans were made for carrying out the daily egg production method for horse mackerel (Table 3.1). This Working Group requests that mackerel eggs are also counted and staged during the survey.

The data base of the egg survey data of the western mackerel and horse mackerel will be transferred from the Fisheries Laboratory, Lowestoft, UK to the Marine Laboratory, Aberdeen, UK.

The main potential source of systematic error in the biomass estimate of the daily egg production method is the lack of information on durations of oocyte or post-ovulatory follicle stages for both mackerel and horse mackerel. The Workshop recommended that studies on the durations of oocyte or post-ovulatory follicle stages be pursued as soon as possible.

The Mackerel Working Group endorses the recommendations made by the Workshop.

3.2 <u>Biomass Estimates</u>

<u>North Sea area</u>

The total egg productions and spawning stock biomass estimates, as derived from the North Sea egg surveys, are listed by year in Table 3.2. The estimate of spawning stock biomass in 1990 is 78,000 t, which is twice as high as the 1988 estimate.

<u>Western area</u>

In 1989, the spawning stock biomass of western mackerel was estimated by the annual egg production method and by the daily egg production method to be 2.01 and 2.36 million t, respectively. No egg survey was carried out in 1990. The series of egg production and spawning stock biomass estimates is given in Table 3.3.

The Working Group decided to use only the spawning stock biomass estimate from the annual egg production method for tuning the VPA, because only these data are available from previous egg surveys.

4 STOCK DISTRIBUTION AND MIXING

4.1 Stock Units

The Working Group discussed the report of the Workshop on Mackerel in Divisions VIIIc and IXa (see Section 2). Very little is known yet about the migrations of the mackerel in these areas and it is also not known what proportion of the mackerel migrates into the area of the western mackerel stock in Divisions VIIIa,b or even further north. Since the evidence for including the southern catches in the assessment of the western stock remains inconclusive, the present Working Group decided to continue to treat the western, southern and North Sea stocks as separate units. A preliminary assessment using the combined western and southern catch-at-age data is discussed in Section 8.

The available data for mackerel in Divisions VIIIc and IXa (Anon., 1991d) do not resolve the problem of stock identity of this fish. If mackerel in these areas belong to the western stock, the juvenile fishery in Division IXa may severely affect the recruitment to the western stock. The Working Group believes that a tagging program should be carried out to clarify stock identity and migration pattern of mackerel in Divisions VIIIc and IXa.

The Working Group recommends that a workshop should be set up to plan studies designed to establish the stock identity and migration pattern of mackerel in these areas.

4.2 Distribution of Mackerel Fisheries in 1990

As in earlier years the officially-reported distribution of catches could not be taken as a reliable guide to where mackerel were actually caught in all areas and seasons (Anon., 1988, 1989, 1990a). Flexibility to fish parts of the TAC for the western stock east of the 4^0W line resulted in a mixture of accurate and inaccurate landing statistics for these areas. In 1989, misreporting decreased compared to 1988, but misreporting increased again in 1990.

The quarterly distributions of the fisheries in 1990, as estimated by the Working Group, are shown in Figures 4.1a-d. The distribution of the fishery in 1990 is similar to those of 1988 and 1989 (Anon., 1989, 1990a). The minor changes that occurred in the fishery by quarter in 1990 compared to that of 1989, are described below.

First quarter

In the first quarter (Figure 4.1a), catches were taken along the edge of the continental shelf to the west of the British Isles, off Ireland, and in the western part of the Channel. The fishing area was much the same as in 1988 and 1989 with the exception of the fishery north of Scotland, where the fishery shifted to east of the 4^0W. Most of the catch was taken by trawlers. During the first quarter, mackerel migrate from north to south through Divisions VIa and VIIb,c. The fishery reflects the migration from the northern area to the main spawning area.

In Division VIIIc, fishing was mainly on adult mackerel. The highest catches were taken in the eastern part of Division VIIIc. In Division IXa, fishing was mainly on 1-group mackerel (Figure 4.2).

Second quarter

In the second quarter (Figure 4.1b), the main catches in the western area were taken south of Ireland in the spawning area. The fishing area was the same as in previous years. The catches north of Ireland were mainly taken as by-catch in the herring fishery. Another mackerel fishery in the second quarter took place off the coast of southwest Norway and in the Skagerak. A small quantity was taken, mainly by drift nets and as by-catch in the trawl fisheries. In Division VIIIc, the fishery in the second quarter was similar to that in the first quarter.

Third quarter

In the third quarter (Figure 4.1c), the major fishery took place in the southeastern part of Division IIa and in the eastern part of Division IVa. The fishing area in Division IIa in 1990 seems further to the east than in 1989, but this may be due to the absence of catch information by rectangle for the USSR. Most of the catches were taken by purse seiners. Small by-catches were recorded in the southern and central North Sea. In the eastern and central parts of Division VIIIc, the catches decreased to almost zero. Significant catches were only taken in the western part of Division VIIIc and in Division IXa.

Fourth quarter

In the fourth quarter (Figure 4.1d), the main fishery shifted southwards from Division IIa to Division IVa. Although there are uncertainties about the exact fishing locations, it seems that most of the catches in this quarter were taken north and east of Shetland, which is further to the east than in 1989. In addition to the Shetland area fishery, smaller quantities were taken off northwest Ireland, off Cornwall and in Divisions IIIa and IVb,c. In Divisions VIIIc and IXa, the fishery in the fourth quarter was rather similar to that in the third quarter.

4.3 Distribution of Adults

At the Working Group meeting in 1990 the distribution of the adults was extensively reviewed (Anon., 1990a).

Adult western mackerel are now thought to follow a migration pattern as is illustrated in Figure 4.3. After spawning to the west and south of Ireland they migrate quickly to the feeding grounds in the northern North Sea. The fisheries indicate that a major part of the western mackerel follows a migration route across the northern part of Division IVa (Figure 4.1). They remain mainly to the north and the east of Shetland until the following year. In the first quarter they migrate quickly to the spawning area again.

The very low size of the North Sea stock and the mixing with mackerel from the western stock in the third and fourth quarters 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. Figure 4.3 shows the spawning area of the North Sea mackerel in the central North Sea. The North Sea mackerel are assumed to feed in the northern North Sea together with the western mackerel. Nothing is known about the area of overwintering. According to Eltink (1986), a small proportion of the mackerel from the western area migrates in spring to the central North Sea for spawning but does not migrate to the northern North Sea for feeding. Instead of this they probably remain in the eastern central North Sea for feeding and return to the western area in the fourth quarter (Figure 4.3).

The main spawning activity by the southern mackerel occurs in the central and possibly eastern parts of Division VIIIc. The migrations after spawning are still unknown.

4.4 Distribution of Juveniles

At the Working Group meeting in 1990 the distribution of juvenile mackerel was extensively reviewed (Anon., 1990a). Figure 4.4a shows the general distribution of the juvenile mackerel during the first and fourth quarters of the year based on data from both research vessels and commercial catch data covering the period 1986-1990. It shows that the juveniles are mainly distributed on the continental shelf between 45^0 and 61^0N and also in the English Channel, southern North Sea and part of the central North Sea. In the southern part they are mainly distributed west of the Iberian peninsula. Figure 4.4b shows the general distribution of the juvenile mackerel during the the third quarter also based on the data from research vessels and commercial catch data covering the period 1986-1990. During this quarter the juveniles are found further north in the area northwest of Ireland, west of Scotland and also in the eastern part of the Divisons IIa and IVa,b and in the Skagerrak.

The 1990 year class

During the trawl surveys in the fourth quarter in 1990 and the first quarter in 1991, the 1990 year class was very abundant and was mainly distributed west and northwest of Ireland and was also abundant in the Celtic Sea, Western Channel and west/northwest of Scotland (Figure 5.2). The year class was also present in the Dutch Groundfish Survey during the fourth quarter in the central and southern North Sea (Figure 4.5). During the first quarter it showed up in the northern North Sea during the IYFS in 1991 (Figure 5.1). In the fisheries in 1990, the year class had already appeared in the second quarter off the Portuguese coast. During the third and fourth quarters it appeared to the north and west of the Iberian peninsula. In the areas further to the north, the year class was only caught during the fourth quarter in the fisheries in the western Channel (Figure 4.2).

The 1989 year class

During the trawl surveys in the fourth quarter in 1989 and the first quarter in 1990, this 1989 year class was very abundant as first winter fish (Anon., 1990a and Table 5.2) and had a more northerly distribution than did the 1990 year class. During this time period, the 1989 year class was also abundant off Cornwall and in the central North Sea (Anon., 1990a, Figure 3.5). During the trawl surveys in the fourth quarter in 1990 and the first quarter in 1991, it was extremely abundant (Figure 5.3 and Table 5.2) and had a distribution in the Western Channel and all along the continental shelf between Shetland and the south of France. Also in the central and southern North Sea,this year class was very abundant in the Dutch Groundfish survey during the same time period (Figure 4.6). In the fisheries in 1990, the year class was well represented. In the first quarter it was distributed in the Divisions IIIa, IVc, VIId,e,h, VIIIa,b,c and IXa (Figure 4.2). In the second quarter it was distributed in Divisions IIIa, IVc, VIIa,d,e, VIIIc and IXa. In the third quarter it was distributed in Divisions IIIa, IVb,c, VIa, VIIa,d,e, VIIIc and IXa. In the fourth quarter it was distributed in Divisions IIIa, IVa,b,c, VIa, VIIa,d,e,h, VIIIc and IXa (Figure 4.2).

The 1988 year class

In the fisheries in 1990, the 1988 year class had a very wide distribution during all quarters (Figure 4.2) and was abundant in those areas indicated as juvenile distribution in Figure 4.4. These 2-year-olds have a more northerly distribution than the younger year classes.

5 RECRUIT SURVEYS

5.1 Review of the Report of the Study Group on the Coordination of Bottom Trawl Surveys in Sub-areas VI, VII, VIII and Division IXa

The Study Group on the Coordination of Bottom Trawl Surveys met in Nantes, France from 11-16 April 1991 to 1) collate information on the existing surveys conducted in Sub-areas VI, VII, VIII and IX, 2) to consider whether and how these surveys might evolve into a coordinated international programme and 3) to consider the feasibility of making the data available in an agreed common format (Anon., 1991b).

In recent years an almost complete coverage of all shelf areas in ICES Sub-areas VI-IX was achieved during the fourth quarter of the year. Most of Division VIIa and the inshore areas of Division VIa were not covered. In recent years the English Channel and the continental shelf between 44^0N and 61^0N was covered primarily by the GOV-trawl. A Baka trawl and a Campell trawl were used on the Spanish and Portuguese continental shelf, respectively.

The Workshop recommendations relevant to the Mackerel Working Group were:

> "An internationally-coordinated bottom trawl survey should be carried out in the fourth quarter each year. The maximum area of coverage should be attempted in this quarter.
>
> Standardization of fishing gear and survey strategy should be the eventual aim.
>
> Length measurements should be collected for all finfish and Norway lobster. Otoliths of important fish species should be collected on request.
>
> For the exchange of survey data, the agreed exchange file format of the North Sea IYFS should be used.
>
> For the purpose of calculating recruitment indices, the area west of Ireland should be surveyed in the first quarter."

The Mackerel Working Group supports the coordination of the bottom trawl surveys in the fourth quarter in Sub-areas VI, VII, VIII and IX, but also stresses the need for a good coverage during the first quarter when the catch per effort is much higher for mackerel in these areas. This may not only improve the index, but might also demonstrate that the within season changes are a result of immigration.

The Working Group, therefore, recommends that coordinated bottom trawl surveys be carried out in the first quarter in Sub-areas VI, VII, VIII and IX.

5.2 Recruitment Indices

North Sea surveys

Catch rates of the 1990 year class during the 1991 International Young Fish Survey (IYFS) were very low, apart from in two statistical rectangles in the north-eastern North Sea (Figure 5.1). Recruitment indices calculated from the mean catch rates in hauls south of 59^0N during the IYFS from 1970 to 1990 are shown in Table 5.1. The provisional index from the 1991 survey for the 1990 year class is less than 0.5. This contrasts with the value of 427 from last year's survey for the 1989 year class, which was the highest since 1971. The index for the 1989 year class as 2 group from the 1991 survey is not yet available.

Western surveys

Recruitment indices for the western stock are calculated from the mean catch rates in the bottom trawl surveys carried out during the fourth quarter and during the first quarter of the following year (Dawson et al., 1988). The series of 0/1 group and 1/2 group indices for year classes 1980 to 1990 are shown in Table 5.2. Note that the indices from the 1988/89 surveys exclude one haul with an anomalously high catch rate. The provisional estimates from the 1989/90 surveys used last year by the Working Group have been revised.

The index for the 1990 year class from the 1990/91 surveys is 126, the third highest of the series. The catch rates for this year class during the surveys are shown in Figure 5.2. The highest catch rates were to the west of Ireland. All the surveys in this area were carried out in the fourth quarter.

The index for the 1989 year class as first winter fish calculated from the 1989/90 surveys is the highest in the series (Table 5.3). The index for this year class as second winter fish from the 1990/91 surveys is 399, also the highest in the series. Figure 5.3 shows that high catch rates were observed over a wide area, so the index is not driven by a small number of hauls with anomalous catches. The evidence that the 1989 year class is strong is, therefore, rather firm.

The indices in Table 5.2 are used to predict recruitment by regressing with the numbers of the corresponding year classes from the converged region of the latest VPA. The results are given in Section 6.4.4.

6 NORTH SEA, NORWEGIAN SEA, AND WESTERN AREAS (SUB-AREA IV, DIVISIONS IIIA, IIA AND VB, SUB-AREAS VI AND VII, AND DIVISIONS VIIIA,B,D,E)

6.1 The Fishery in 1990

The nominal catches from the North Sea, Skagerrak and Kattegat and from the Norwegian Sea and from the Faroes (Divisions IIa and Vb) are given in Tables 6.1 and 6.2. The catches in these areas increased by about 40,000 t compared to 1989. However, misreporting is known to have occurred also this year, and the catches by area as given in Tables 6.1 and 6.2 are, therefore, inaccurate.

The catches from the western area (Sub-areas VI, VII and Divisions VIIIa,b,d,e) are shown in Table 6.3. The landing figures for 1990 are preliminary and are mainly based on data submitted by Working Group members. The total catch taken from these areas was 303,000 t, which was similar to the figure for 1989. However, it must again be pointed out that the officially-reported catch, as it did each year from 1986-1989, includes considerable quantities of mackerel which were reported as having been taken from the northern part of Division VIa in the fourth quarter, but were in fact taken east of 4^0 in Division IVa. The Working Group estimated that the amount misreported in this way totalled about 126,000 t. The amounts misreported in recent years were 92,000 t in 1989, 180,000 t in 1988, 117,000 t in 1987, and 148,000 t in 1986. The increase in the misreported catches between 1989 and 1990 took place despite changes in the management regime which permitted specific amounts of the TAC to be taken from Division IVa in the fourth quarter.

The main catches reported to have been taken from Division VIa in 1990 were by UK (Scotland) and Ireland. The main catches taken from Sub-area VII were by the UK (England and Wales), the Netherlands, and Ireland, while the main catches taken from Divisions VIIIa,b,d,e were by France.

The estimated catch by quarter for the various Sub-areas and Divisions are given in Table 6.4. This table is based on information provided by Working Group members. In Divisions IIa and Vb, there was a considerable increase in the catches taken in the fourth quarter compared with 1988 and 1989. The major portion of the catch from Division IVa (190,000 t) was also taken in the fourth quarter. The fishery in Division VIa was carried out mainly in the first quarter (105,000 t) while the main catches from Sub-area VII were from the first and second quarters.

The trends in catches taken in the different Sub-areas are shown in Table 6.5. This table shows clearly the changes that have taken place in the location of the fishery since 1969. The table has been corrected for some typing errors in various years. The catches taken from Sub-area VII and Divisions VIIIa,b,d,e, which amounted to 62,000 t in 1990, have decreased consistently since the 1975-1980 period when they averaged about 380,000 t. In contrast, the catches from Divisions IIa and Vb have shown a gradual increase, particularly since the early 1980s. The catches taken from Sub-area IV and Division IIIa decreased from a very high level of 739,000 t in 1969 to less than 36,000 t in 1982 (when the fishery in most of Sub-area IV was closed). The fishery remained at a low level up to 1985 but subsequently increased rapidly and in recent years has averaged about 282,000 t. In 1990, 70% of the catch was taken in the northern areas.

6.1.1 Discards

Large-scale discarding of mackerel first became a problem in the fishery in the late 1970s. It subsequently remained a serious problem until the mid-1980s, after which the amounts discarded appear to have decreased considerably. However, there are now suggestions that during 1990 discarding of mackerel in Divisions IVa and IIa may once again have reached serious proportions. The Working Group is, therefore, concerned about these reports of large-scale discarding. If the quantities cannot be estimated then less confidence can be attached to the accuracy of the assessment of the stock. Previously, the Working Group has never been able to obtain accurate information about the extent of discarding and estimates have usually been provided by countries for only one or two fleets. At the moment, however, data are available for only one fleet and the quantity of mackerel discarded by this fleet constitutes about 4% of the total catch of the western stock. The Working Group is aware that this can only be assumed to be a minimum value and that it may be seriously under-estimated.

Discards of mackerel appear to take place for a number of reasons:

Discarding/slipping of small mackerel (unsorted). The discarding of mackerel, which was practised in the late 1970s and early 1980s, usually consisted of catches of small mackerel which were not marketable. This problem was largely eliminated by the introduction of the "Box" off Cornwall and also by the shift of the winter fishery away from this area and by the lifting of the individual UK boat quota system (Anon., 1985). Although recently the Working Groups has indicated that the discarding of small mackerel has decreased, it has been continually pointed out that the problem may arise again if a very strong year class enters the fishery.

With this type of discarding the catch is usually taken alongside the vessel, it is then examined and if it is found to contain a large amount of small mackerel then the entire catch is "slipped". Very few of these mackerel are thought to survive.

Discards of small mackerel (sorted). The reports of large-scale discarding of small mackerel in 1990 particularly concern the fishery in Divisions IVa and

IIa. At the moment there is a very strong demand for large mackerel (>600 g) for the Japanese market and the price for mackerel of this type is more than three times the price of small mackerel. This has led to the practice whereby the catches are sorted at sea and all the large mackerel are retained while a proportion of the small mackerel is discarded. There appears to be a particularly high level of discarding for this reason when vessels are trying to maximise the value of their catches when their individual boat quotas are nearly exhausted. In order to eliminate such problems, Norway has for some years introduced a general ban on discarding in its economic zone. In addition, the Norwegian fishery for large mackerel is regulated by permitting an upper limit to the percentage of large fish in the landings throughout the season. This percentage, which is determined before the season starts, is based on an estimate of the amounts of large mackerel likely to be in the fishable population.

Although there are regulations in Divisions IVa and IIa which prohibit discarding of fish at sea, they do not appear to be effective in the case of the mackerel fishery, and the Working Group has been unable to obtain any accurate information on the quantities involved. However, it has been suggested that a very high proportion of the catches by some fleets in this area is discarded. The situation may deteriorate even further if automatic graders, which would permit sorting of small mackerel while taking the catch on board, are introduced into the fishery.

Discards of medium/large mackerel: Discarding of unsorted large or medium size mackerel usually takes place for two reasons.

a) When vessels which are taking part in directed mackerel fisheries have exceeded their individual boat quotas and are unable to transfer their catches. Quantities of surplus mackerel are, therefore, "slipped" at sea.

b) When vessels which are taking part in directed fisheries for either horse mackerel or herring and catches of mackerel are taken as a by-catch. In this case the mackerel are separated from the catch (freezer trawlers) and are dumped because they are considered unmarketable, either because 1) they have been damaged by the horse mackerel, or 2) because the mackerel fishery may be closed or 3) because the captain considers that the value of a horse mackerel catch will be greater than that of a mackerel catch. In the case of purse seiners or refrigerated sea water (RSW) boats the entire catch, if it contains a mixture, may be discarded if it is not considered worthwhile to bring it ashore for fish meal.

c) When vessels are taking part in directed fisheries for mackerel and quantities of horse mackerel are taken as by-catch. In this case the mackerel are not considered marketable and are discarded at sea.

Discarding for these reasons appears to be most frequent in the fisheries west of Ireland. Again it has not been possible to obtain any reliable information of the quantities involved for all fleets.

The Working Group is, therefore, concerned about the lack of information about the extent of discarding throughout the various fleets and the quantities of fish involved. It is particularly concerned because of the possibility that the rate of discarding may increase because of the introduction of automatic grading machines coupled with the recruitment of the very strong 1989 year class. The Working Group would, therefore, recommend that all countries should obtain and provide to the Working Group accurate information on discarding by their fleets as soon as possible.

In addition to the quantities of mackerel which, as discussed above, are discarded for deliberate reasons, quantities of mackerel are also "lost" at sea when nets are torn or burst. These quantities may be quite significant, particularly in those fisheries where very dense concentrations of fish are encountered. As very few of these fish are thought to survive, it is important that details of these quantities should also be collected as soon as possible.

6.1.2 Catch in numbers in 1990

The catch in numbers at age by quarter for Divisions IIa, IVa and Vb, IIIa, IVb,c, VIa,b, VIIa,d-h, VIIb,c,j,k and VIIIa,b,d,e are shown in Table 6.6.

Countries providing sample data were Denmark, Ireland, Netherlands, Norway, Portugal, Spain, France and the United Kingdom (England and Wales, Scotland). Catches for which there were no sampling data were converted to numbers at age using data from the most appropriate fleet working in the same area. The sampling intensity is dicussed in Section 10.

The total catch in numbers for the western stock is given in Table 6.10.

6.1.3 Revision of catch data from previous years

Only slight revisions of catch data from last year's report (Anon., 1990a) were given for 1989. The revisions amounted to about 3,300 t which is less than 0.5% of the total catch in 1989.

6.1.4 Length compositions

Annual length compositions by fleet were provided by Denmark, Ireland, Netherlands, Norway, Portugal, Spain, France, and the United Kingdom (England, Wales and Scotland). Length distributions were available from all of the major fishing fleets in 1990 except for the USSR.

The percentage length distributions by country and fleet for 1990 are shown in Table 6.8. The Spanish purse seine and trawl fisheries tend to take a broader size range and land more juvenile fish than similar fleets from other nations.

6.2 Allocation of Catches to Stock

As for the catches in 1987, 1988 (Anon., 1989) and 1989 (Anon., 1990a, the Working Group was not able to split the 1990 catches by stocks.

The Working Group decided, as for the years 1987-1989, to allocate all mackerel caught in Sub-area IV, Divisions IIIa, IIa and Vb, Sub-areas VI and VII and Divisions VIIIa,b,d,e in 1990 to the western stock. The catch of North Sea mackerel was estimated at about 10,000 t (Section 6.3.1), which is 1.6% of the mackerel catch in these areas in 1990. Including a small catch of North Sea fish in the western stock will have very little influence on the assessment of the western stock. The catch in numbers by year for the western stock is given in Table 6.10.

6.3 Assessment of the North Sea Stock

6.3.1 The state of the North Sea stock

Based on the egg surveys in 1990 the North Sea spawning stock was estimated at 78,000 t (Iversen _et al._, WD 1991). This indicates a doubling of the spawning stock size estimated from the egg survey in 1988 (Iversen _et al._, 1989). The increase is due to the year classes of 1987 and 1988 which are stronger than the rather low year classes recruiting to the stock in the 1970s and 1980s. The estimated stock size in number at spawning time is given in Table 6.9. However, the stock size is still considered to be at an extremely low level. The samples obtained during the egg survey indicated that 80% of the two-year olds were mature as compared to 37% applied for the North Sea stocks previously. This higher proportion of maturity of two-year-old fish was applied by this Working Group for the years 1988, 1989 and 1990.

During the egg surveys the spawning stock was sampled by pelagic trawl. Based on these samples the number of two year old and older mackerel was estimated at 115 x 10^6 (Iversen et al., WD 1991). This working document estimates the total mortality at 0.36 per year from 1988 for four-year-olds and older. If the same mortality is applied for three year old mackerel in 1990, it is possible to estimate a catch of three year old and older mackerel in 1990, 1989 and 1988 (Table 9.1). The last VPA run by the Working Group for North Sea mackerel was in 1985 (Anon., 1985) and showed that the fishing mortalities one and two-year-old mackerel were respectively for 9% and 29% of the average fishing mortality of 3-8-year-old mackerel.

Thereby catches were also estimated for the 1- and 2-year-olds (Table 9.1). The total estimated catches were about 6,000 t in 1988, about 7,000 t in 1989 and about 10,000 t in 1990. This indicates higher catch rates of North Sea mackerel than assumed earlier (Anon., 1989, 1990a).

6.4 Assessment of the Western Stock

6.4.1 Mean weight at age

Mean weight at age in the catch

Mean weights at age in the catches by quarter in 1990 were provided by Scotland (Divisions VIa and IVa,b), England (Divisions VIId,e,f), Ireland (Divisions VIa and VIIb,j), Norway (Divisions IIa, IIIa, and IVa), Denmark (Division IVa), France (Division VIId), the Netherlands (Divisions IVa,b,c, VIa, VIIb,d,e,f,j), and Spain (Divisions VIIIa,b).

Weighted (by number) mean catch-weight-at-age estimates were made by divisions by quarter and by division by year for catches from the western and North Sea areas. These are shown in Table 6.7 by division, but Divisions VIIb,c,j,k and Divisions VIIa,d-h and also Divisions VIIIa,b,d,e were combined. The overall mean weights at age in the catch are given in Table 6.11.

Mean weight at age in the stock

Mean weights at age of the spawning stock at spawning time were estimated for 1990 by using samples from Dutch commercial freezer trawlers in Division VIIj in March, April and May. These weights (in kg) are shown in Table 6.12. (1-year-olds are rarely taken in samples, therefore, a constant weight of 0.070 kg was assumed for all years for this age group.

6.4.2 Maturity at age

Estimates of maturity at age can have a large influence on the estimated spawning stock biomass when large year classes recruit to the stock. The maturity ogive usually assumes that 60% of 2-year-olds are mature. However the proportion of the very large 1984 year class mature at age 2 was assumed to be 20%. This was based on a lower than average growth rate and a scarcity of mature fish of this year class during the 1986 egg survey. No such revision was considered justified for the large 1987 year class. The 1989 year class is also likely to be strong, but in the absence of any evidence to the contrary, the proportion mature at age 2 is assumed to be 60% (Table 6.18).

6.4.3 Fishing mortality and tuning of the VPA

Separable VPAs were run over a range of fishing mortalities with all years prior to 1985 downweighted, a reference age of 5 and a terminal S of 1. Each run was used to calculate a VPA with input F values based on the terminal populations. The fishing mortality chosen for the final VPA was the one which minimised the sum of squared residuals between the VPA estimates of spawning stock biomass and those of the series of egg survey in 1977, 1980, 1983, 1986 and 1989. The sum of squares was minimised at 0.275 (Figure 6.1). The results of the separable VPA with a terminal F of 0.275 are given in Tables 6.13 to 6.15 and in Figures 6.2A and B.

The spawning stock biomass in 1990 is estimated to have been 2.0 million t, the same as that predicted from last year's assessment. Figure 6.2 shows that yield and spawning stock biomass have remained relatively stable since about 1980. There has been an increasing trend in fishing mortality since 1984, but note that the large increase in the mean F from 1984 to 1990 is largely the result of anomalously high values at ages 7 and 8 (Table 6.14). The fishing mortalities are based on the terminal populations, and, therefore, reflect noise in the catch-at-age data, The weighted mean Fs, using the same age range, do not show the same increase. Figure 6.2 shows that the average level at recruitment has increased in recent years, with the last weak year class being that of 1983.

The time series of spawning stock biomasses estimated by the VPA and the egg surveys are shown in Figure 6.3.

6.4.4 Forecast for the western stock

Three levels of recruitment were defined by the 1989 and 1990 Working Groups. These were the geometric mean numbers of recent strong and weak year classes, with an intermediate level between these two. The reason for using these three categories was that recruitment has tended to be either very weak or very strong in recent years, so that the regressions of the recruitment indices with VPA estimates contained no data points at intermediate values. The indices were therefore used only to indicate the whether recruitment was likely to be strong, intermediate, or weak.

The 0/1 group regression with VPA is now well enough established to be used to predict recruitment directly (Figure 6.4). This was done using the RCRTINCX2 program (Table 6.16), which estimated the number of the 1990 year class as 1 group in 1991 to be approximately 4500 million. This is the value used for the prediction. For the 1991 and 1992 year classes, recruitment was assumed to be the geometric mean of the numbers of the 1979 - 1988 year classes as 0 group, which is 3300 million.

There is now firm evidence that the 1989 year class is strong. The 1/2 group index by far the highest on record (Table 5.2), and the year class is well represented in the catches, as reflected in the high preliminary estimates from the latest VPA (Table 6.15). The relation between the 1/2 group index and converged VPA estimates of year class strength is however rather poor and would give unreliable estimates of year class strength (Figure 6.5). For this reason, both the 0/1 group and 1/2 group indices were used to predict the recruitment of the 1989 year class as 2 group in 1991 using the RCRTINX2 program. This was estimated at 5000 million (Table 6.17).

The input variables used in the prediction are summarised in Table 6.18. The fishing mortalities used to generate the numbers at age in the stock in 1991 were the separable fishing mortalities, not those based on the terminal populations. The separable exploitation pattern was used for the predictions for 1992 and 1993. The catch weights used were for 1990 and these were well estimated from samples. The stock weights used were averages for 1987-1990 because these estimates are based on much fewer samples.

Predictions were made assuming a catch of 605,000 tonnes in 1991 (see Section 6.5.2) correponding to the agreed TAC and the likely level of USSR catches. Predictions were also made assuming status quo fishing mortality in 1991 corresponding to a catch of 668,000 t. In each case, the predictions for stock and catch in 1992 and 1993 were calculated for F_{med} (0.18) (Figure 6.6), $F_{0.1}$ (0.20), and F92 = F90. The results are given in Table 6.19. The detailed output assuming status quo F is given in Table 6.20. Short-term yield and spawning stock biomass in relation to F are also given in Figure 6.7.

The results indicate that the spawning stock biomass will increase in 1992 to around 2.4 million t. In 1993 the stock will further increase to around 2.5 million t if catch rates remain near their current levels. The detailed output (Table 6.20) shows that the 1989 year class contributes about 25% of the catch in weight and nearly 30% of the spawning stock biomass in 1992. The prediction is, therefore, highly sensitive to the estimate of the size of the 1989 year class.

6.4.5 Sensitivity analysis

In order to identify the input parameters to the forecast which contribute most to the result, a sensitivity analysis was performed using the FAST method (Cubier et al., 1978) using the same procedure described in Cook et al. (1991) and Anon. (1991c). Analyses were done for forecasts from 1992 to 1994 and the results are given in Figure 6.8. The results all give the sensitivity of the forecast to the populations in 1991, the baseline for the forecast. The forecasts are all "status quo" forecasts and hence the Fs are the same for all years. It can be seen that the forecasts are sensitive to the largest year classes, in particular the 1989 and 1985 year classes. However, in the 1993 and 1994 forecasts, the 1990 year class is important. These are the most recent year classes and therefore are estimated with lowest precision and the forecast should be interpreted accordingly. It is noteworthy that only the 1994 forecast is sensitive to recruitment in 1991, a year class which has yet to be determined. This would suggest that it is possible to make a forecast up to 1993 without encountering serious problems with year classes of unknown strength entering the calculation.

6.4.6 Precision of the forecast

In performing the integrated analysis (Appendix I), variance estimates on the parameters were obtained. These can be used to estimate the variances of the estimated populations and fishing mortalities up to and including 1990. In addition, given estimates of recruitment in 1991 onwards, it is possible to calcuate variances of the forecast catch, SSB and TSB. Figure 6.9 shows the estimated standard deviation of log yield, log SSB and log TSB as calculated from the integrated analysis. Since log quantities are used, the standard deviations are approximately equal to the coefficient of variation of the arithmetic values. It can be seen that for the converged VPA values the standard deviation is low but as the terminal year(1990) is approached it increases rapidly as expected given the convergence properties of VPA. In the forecast period, the error increases somewhat but remains stable until 1993. This suggests that the forecast up to and including 1993 is possible without loss of precision and this is consistent with the sensitivity analysis.

This method of estimating the precision of the forecast suggests a coefficient of variation of about 25%. Since the calculation does not take into account all sources of error (eg variability in M) it is certainly an underestimate. However, what is more interesting is the relative change in the error over the range of years and into the forecast period. This is probably adequately reflected in the calculations and offers some support to the view that forecasts for this stock need only be made every two years.

It should be noted that both the sensitivity analysis and the precision estimates refer to one stock configuration pertaining at present. The conclusions about the possibility of forecasting another year ahead are contingent on this. It may be that given a different sequence of year classes, the forecast more than two years ahead cannot be made with the same precision.

6.5 Management Considerations

6.5.1 Western and North Sea stocks

Management Policy

The management of the fishery in recent years has been discussed in detail by the Working Group at recent meetings and by ACFM. The management policy should reflect the necessity of providing maximum protection for the North Sea spawning stock until it shows some evidence of recovery while at the same time allowing fishing on the western stock to be continued at the optimum exploitation rate.

For a number of years now the agreed TACs have been higher than the recommended TACs, while the actual landings have consistently exceeded the agreed TACs. The Working Group has recommended that the TAC for the western stock should apply to all areas where western mackerel are taken, which includes the western areas together with Divisions Vb, IIIa, IIa, and IVa. At the same time the North Sea stock has been protected by the prohibition of fishing in Divisions IVb and IVc.

6.5.2 International agreements

The distribution of the stocks at the moment and the various international arrangements about fishing rights have led to a fairly complicated composition of the TACs in recent years. ACFM advised that the TAC for 1991 should be set at the $F_{0.1}$ level, corresponding to a catch of 500,000 t and recommended that the likely USSR catch, taken in international waters not subject to restrictions, should also be taken into account. Following the various international agreements, the permitted catch in 1991 can be broken down as shown in the text table below. This table also includes quantities which have been exchanged between parties without altering the overall agreed figures.

Agreed TACs for 1991

Vb, VI, VII, VIII (except VIIIc), XII, XIv	EEC	349,170	
	Norway	14,000	
	Faroes	20,000	383,170
IVa	EEC	21,900	
	Norway	43,600	65,500
IIa	EEC	14,000	
	Norway	112,340	126,340
Total			575,010

The permitted catch, therefore, for 1991 of the western stock is 575,010 t. Together with this catch there will be a likely USSR catch of about 25,000 - 30,000 t. As in 1989 and 1990, a certain proportion of the TAC for the western stock is permitted to be taken from Division IVa, but in a limited area east of the Shetland Islands.

6.5.3 Current exploitation pattern

The consistent overshooting of the TAC in recent years has been commented on frequently by the Working Group and by ACFM and it has been suggested that a continuation of this practice would eventually lead to a decrease in the stock. However, it now appears that despite the excessive catches, the stock has increased in recent years and will continue to increase in the near future. This is mainly because of the recruitment of good year classes in 1987 and 1989.

The fact that the main catches are now taken during the third and fourth quarters ensures that the exploitation pattern has improved considerably. At this time of year, fish are at their heaviest with a very high oil content and, therefore, at their greatest value. The numbers per kilogramme are also at a low level compared with the situation that prevailed some years ago when a large proportion of the catches came from the more southerly areas and contained larger amounts of young fish. The corresponding fishing mortality for the same amount of catch is now at a much reduced level.

6.5.4 Misreporting of catches

During 1990, the amounts of mackerel actually taken in Division IVa but reported to be taken in the northern part of Division VIa again increased dramatically. The corresponding figures for recent years were: 1986 - 148,000 t; 1987 - 117,000 t; 1988 - 180,000 t; 1989 -92,000 t; and 1990 - 126,000 t. From a biological point of view, there appears to be no reason why fishing on the western stock should not be permitted without restriction in Divisions IVa and IIa provided the catches are confined to the third and fourth quarters. However, no fishing should be permitted in Divisions IVb and IVc in order to protect the North Sea stock. The misreporting of catches does, however, present some problems in interpreting the data on the location of the fisheries. At present, however, the Working Group is reasonably confident that the misreported catches are being interpreted correctly although it must be stressed that this interpreation depends very much on personal information obtained from fisheries.

6.5.5 Protection of juveniles

Discards

The problem of discards has been discussed in detail in Section 6.1.1. It is important, however, to emphasize that the Working Group is concerned that the increased demand for large mackerel, which has taken place in Divisions IVa and IIa, may lead to an increase in the discarding of small mackerel in those areas. There is, therefore, an urgent need to obtain accurate information about the extent of this problem and to estimate the quantities involved.

"Cornwall box"

The regulation imposed by the EC some years ago, whereby a "box" was introduced around Cornwall to protect juvenile mackerel from being exploited, will lapse during 1991 unless it is re-introduced. The Working Group examined the concentrations of juveniles in the area presented in a working document (Hume and Watson) which described the results of fishing survey carried out in the box in February 1991. Although it is clear that juvenile mackerel are found over a wide area throughout Sub-areas VI, VII, and VIII, 70-90% of the mackerel found around Cornwall are juveniles. The removal of the box might, therefore, lead to a revival of the fishery for juveniles in the area and, therefore, to a reversion to a more unsatisfactory exploitation pattern. It is recommended, therefore, that the "box" be retained in this area with its existing boundaries.

6.5.6 Protection of the North Sea stock

As stated elsewhere in the report, the North Sea stock is still at a very low level. It is important, therefore, that adequate protection be given to this stock throughout the year. The Working Group would, therefore, re-iterate the recommendations made by ACFM in 1991:

1) There should be no fishing for mackerel in Divisions IIIa and IVb,c at any time of the year.

2) There should be no fishing for mackerel in Division IVa during the period 1 January - 31 July.

3) The 30 cm minimum landing size at present in force in the North Sea area (Sub-area IV and Division IIIa) should be retained and the present by-catch regulations should be enforced.

It should also be noted that the closure of the fishery in Divisions IIIa, IVb and IVc prevents the exploitation of the juvenile mackerel which are present in those areas, particularly during the third and fourth quarters.

7 MACKEREL IN DIVISIONS VIIIc AND IXa

7.1 The Fishery in 1990

Catches by Division and country are given in Table 7.1. Catches in 1990 increased in relation to 1989, but they represent approximately the mean value of the catches for the last ten years. Division VIIIc, as usual, accounted for more than the 75% of the total 1990 catch. Sampling intensity data (Table 10.1) indicate that good sampling coverage was achieved. Catches by gear and country are shown in Table 7.2.

It is likely that a part of the Spanish catches from the more eastern part of Divisions VIIIc might come from Division VIIIb. This may be in the order of 10% of the catches reported from Division VIIIc. In the absence of any accurate estimates, no transfer of catches was made. Division IXa figures exclude catches from the Gulf of Cadiz (southern Division IXa) because no accurate catch data are available from this area.

A Spanish mackerel (Scomber japonicus) fishery also occurs in the eastern and central parts of Division VIIIc, mainly in late summer and autumn. There is not likely to be any misidentification of species in this fishery (Lucio et Villamor, WD 1991).

7.2 Discards

No data on mackerel discards or "slippings" are available, but they are thought not to be significant.

7.3 Catch in numbers

The catches in numbers at age from the Portuguese fishery (Division IXa) for the years 1981-1990 are shown in Table 7.3 and those from the Spanish fishery (Divisions VIIIc and IXa) for the years 1982-1990 in Table 7.4. Some catch data from previous years have been revised according to the results of the Workshop on Mackerel in Divisions VIIIc and IXa (see Section 2).

Table 7.5 summarises the catch in numbers and mean weight at age by quarter and area.

7.4 Length composition

The quarterly length distributions in 1990 by geographical areas of Divisions VIIIc and IXa are shown in Figure 7.1a-d.

Comparison of the length distributions show very different patterns in the mackerel fishery. In the eastern part of Division VIIIc, catches are predominantly adult fish and these represent 45% of the total Spanish catches. More than 95% of the catches in this area are taken in March and April.

As in the eastern and central areas, the largest catches in the western part of Division VIIIc are taken in the first and second quarters. In 1990 in the central and western part of Cantabrian Sea (off Asturias and north Galicia), remarkably high catches of small mackerel occurred throughout the year. This might indicate a strong 1989 year class. In both areas important catches of adult fish were also obtained.

Off south Galicia (Division IXa), mackerel catches are usually relatively small in tonnes but not in number as the catches are mainly composed of small fish (<30 cm). The main catches in the Galician waters are taken by trawlers in the first part of the year and by purse seiners in the second half.

Portuguese catches (in the central and southern part of Division IXa) are taken mainly in the first half of the year. They consist primarily of small fish (<30 cm).

7.5 Management Considerations

7.5.1 Mixed juvenile fisheries?

The management of the juvenile fisheries in these areas was discussed by the Working Group in 1990. The fisheries in Division IXa and in some parts of Divisions VIIIc are mainly mixed fisheries in which large quantities of juvenile fish of several species including mackerel, horse mackerel, hake and blue whiting are taken. The catches are taken mainly by purse-seiners fishing directly for sardines and by trawlers fishing for all species. The minimum mesh size for trawlers operating in NEAFC Region III is 65 mm. A derogation, however, permits the use of a minimum mesh size of 40 mm for trawlers fishing for pelagic species in Divisions VIIIa-c and in the Gulf of Cadiz.

The catches taken from Divisions VIIIc and IXa have been reasonably constant since 1977 (Table 7.1). Because of this and because of the fact that the juvenile mackerel catches are taken in a mixed fishery, there has been no defined management policy for this mackerel fishery as a separate unit. As the catches are largely composed of juvenile fish, recent Working Group reports have suggested that the fishery may have a considerable effect on the recruitment to whatever stock they may belong. However, this effect cannot be calculated with any accuracy because of the absence of information on natural mortality and on the migration patterns. It is important, therefore, that such information should be obtained as soon as possible. In normal circumstances, fisheries for juvenile fish are actively discouraged in order to improve the exploitation pattern on the adult component. However if no adverse effects on the adult mackerel fisheries are caused by these juvenile catches it may not be considered necessary to alter the existing fishing pattern.

It is clear, however, that the fisheries on juveniles of all species must be considered as a combined management unit. The Working Group is not in a position to give specific advice in relation to the fishery on juvenile mackerel at present and suggests that either the new Technical Measures Assessment Working Group or a special workshop should investigate this problem. Matters that should be considered might include the closure of the purse-seine fishery for certain periods (as happened in the first quarter of 1991), the increase in the mesh size from 40 mm to 65 mm for all trawler fleets operating in Divisions VIIIa-c and all of IXa, the increase in the minimum landing size for mackerel from 15 cm to approximately 25 cm and the introduction of closed areas. It would obviously be necessary to first define a management objective before the effects of any of these measures could be evaluated.

It is apparent that the catches of juvenile mackerel from the eastern part of Division VIIIc are very low compared with catches from the remainder of Divisions VIIIc and IXa (Table 7.5).

8 ASSESSMENT USING THE COMBINED WESTERN AND SOUTHERN CATCHES IN NUMBERS AT AGE

Although the evidence that the southern mackerel are part of the western stock remains inconclusive, the Working Group carried out a preliminary assessment using the combined western and southern catches in numbers at age. Because of difficulties in obtaining reliable data for southern catches prior to 1984, only catches for the years 1984 - 1990 were used in the combined assesment (Table 8.1).

With a reference age of 5, a terminal S of 1 and the year 1984 downweighted, a separable VPA was run with a terminal F of 0.275. This is the same value as that used for the western assessment, since no separate tuning procedure was used for the combined assessment. The results are shown in Tables 8.2 - 8.4. The fishing mortalities on the juveniles are much higher than those estimated by the separable VPA using only the western catches (Table 6.14). The residuals for ages 0 to 2 are also much smaller, suggesting a better fit to the separable model. However, using the terminal populations to run a conventional VPA, it can be seen that the fishing mortalities on the youngest age groups are still very variable (Table 8.3). This is illustrated by comparing the catches of the 1985 and 1987 year classes in relation to the estimated year class strengths (Tables 8.1 and 8.4).

It is also apparent that the VPA estimates of recruitment are substantially different from those using only the western catches in the assessment. The two series of recruitment estimates are compared in Figures 8.1 and 8.2 by plotting them against the 0/1 group and 1/2 group recruitment indices for the western stock. Note that these plots are for all years in the VPA from 1984 to 1989, so that unconverged estimates are included. Excluding the 1989 year class, the combined estimates of recruitment of 1 group show a marginally better correlation with the 0/1 group indices than those of the western assessment, with r squared values of 0.77 and 0.70 respectively, whereas estimates of recruitment of 2 group show a marginally worse correlation with the 1/2 group indices, with r squared values of 0.72 and 0.77 respectively.

Forecast using the combined assessment

If the recruitment indices are used in the RCRTINX2 program using the combined VPA estimates and following the same procedures as those used in Section 6.4.4, the new estimate of the recruitment of the 1990 year class as 1 group in 1991 is 3,800, and the new estimate of the recruitment of the 1989 year class as 2 group is 4,200. Both estimates are somewhat lower than those used previously. For the recruitment of the 1991 and 1992 year classes as 0 group, the geometric mean recruitment from 1984 to 1989 was used, which is 4,100 million. Again, this includes unconverged estimates which cannot be considered reliable.

The list of input variables used for the prediction is given in Table 8.5. The separable fishing mortalities were used to calculate the stock numbers at age in 1991. No new yield per recruit calculations were made, so only one prediction was made for comparison with that based on the western assessment. This was based on an assumed catch in 1991 of 626,000 t, comprising 605,000 t for the western area and 21,000 t for the southern area, and status quo F in 1992 and 1993. Comparing the results shown in Table 8.6 with the equivalent options in Table 6.19, it can be seen that forecast has been changed very little.

The time series of the catch at age data is too short to draw firm conclusions from this preliminary assessment.

9 DATA REQUESTED BY THE MULTISPECIES WORKING GROUP

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

As for the previous years 1987-1989 (Anon. 1988, 1989, 1990a) the catches of mackerel in Sub-area IV and Division IIIa in 1990 were included in the assessment of the western stock.

Based on the data from the egg surveys in the North Sea in 1990 (Iversen et al., WD 1991) and the egg surveys in 1988 (Iversen et al., 1989), the catches for the years 1988-1990 were estimated (Section 6.3.1). The estimated catch in numbers for 1988-1990 are given in Table 9.1. These catch in numbers are split by quarter for each of the years according to the quarterly total catches in Sub-area IV and Division IIIa.

9.2 Weight at Age by Quarter for the North Sea Mackerel Stock

The weight by age group as obtained during the egg surveys in 1990 (Iversen et al., WD 1991) were similar to the weights given in last year's Working Group Report (Anon. 1990a) for the second and third quarter. Therefore the Working Group considered the weight at age in the stock by quarter in 1990 to be the same as in 1989 (Table 9.2). This table also gives the average weight in the catch for 1990.

9.3 Stock Distribution by Quarter

The relatively small size of the North Sea stock and the relatively large catches fished in the North Sea and Skagerrak demonstrate that large proportions of the western stock must have been distributed in these areas, particularly in the third and fourth quarters. During July-December 1990, parts of Divisions IVa and IIa were surveyed by Norwegian purse seiners to study the distribution and migration pattern of mackerel. These surveys demonstrated that there were large quantities of mackerel in these areas throughout the period (Iversen, pers. comm.). In January 1991, the fishery for mackerel continued in Division IVa indicating that the western mackerel probably left the North Sea later this winter than in previous years.

One- and two-year-old fish were observed in large concentrations in the eastern part of Division IVb during a Danish acoustic survey in July-August 1990 (Kirkegaard, pers. comm.). During the Dutch Groundfish Survey in the fourth quarter of 1990, high concentrations of the 1989 year class were observed (Figures 4.6 and 4.7). In July, Norwegian surveys observed large quantities of 2-year-old mackerel in particular in the eastern part of Division IVa, but also to some extent 1-year-old mackerel (Iversen, pers. comm.).

Based on this information, the Working Group decided to assume the same quarterly distribution of the two stocks, in 1990 as during the period 1986-1989 (Table 9.3). As for previous years the Working Group assumes that no western 0-group are migrating into the North Sea.

10 DEFICIENCIES IN DATA

Catch data

The Working Group has discussed the quality of the catch data in recent years. In general, there appears to be reasonable satisfaction about the accuracy of the data. However, as pointed out in last year's report, there is a 20% tolerance level permitted in the EC log book scheme. Those countries, therefore, which rely on data collected from the log books should be aware that their catches may be underestimated by up to 20%.

The amount of catches reported as having been taken in Division VIa but which was believed to have been taken in Division IVa was 123,000 t. While at the moment the Working Group is satisfied that it can correct for this misreporting, this can only be done on the basis of personal information. Accurate official information on the distribution of the catches is, therefore, required.

The Working Group had available estimates of the latest catches for most countries. Data were, however, missing in relation to the catches taken by the USSR from their important fisheries in Divisions IIa and Vb.

Discards

As detailed in various sections throughout the report, there is little information available about the quantities of mackerel which have been discarded for various reasons or which have been lost because of burst nets. The absence of such data affects the precision of the stock estimates and the quality of the advice given in relation to TAC.

Intensity of commercial sampling

The Working Group examined the intensity of commercial sampling carried out during 1990 in different areas and quarters. Table 10.1 gives an overview of the sampling coverage. However, it should be noted that samples are taken using different methods by different countries. Thus, some samples are more intensive than others, and the degree of bias in the resulting estimates could vary widely. For 1990, there were no age distributions for the German and the USSR data, which together account for about 50,000 t.

In general, commercial sampling covers the bulk of the fishery; however, there is substantial variability in the level of sampling among areas and quarters. For instance, the number of samples taken per 1,000 t of landings is much higher in Divisions VIIIc-IXa than in other areas, and is relatively low in Sub-areas IV and VI in quarter 1. The number measured per sample is fairly consistent over all areas and quarters, but the number aged per sample varies considerably.

Ideally, the number of samples taken in each area and quarter should be proportioinal to the variance in age composition in the fishery for that area and quarter. Similarly, the numbers measured and aged from each sample should be proportional to the variation in size/age composition within samples. Without information on the sampling variability, it is not possible to specify what the optimal levels of sampling are.

Stock identification

At present, there is no major problem in stock identification. This is because of the low size of the North Sea stock and because of the small catches from Sub-area VIII and Division IXa. However, in the event of a recovery of the North Sea stock the Working Group would face major difficultires in allocating catches to the correct unit. It is important, therefore, that investigations should be continued so that accurate identifications of catches be made possible.

11 RE-ARRANGEMENT OF WORKING GROUPS AND THE NECESSITY OF ANNUAL ASSESSMENTS

In the proposal for re-arrangements of working groups ACFM suggests that the Mackerel Working Group and the Working Group on the Assessment of Sardine, Horse Mackerel and Anchovy should be merged into one working group. ACFM further suggests that, as a long-term objective, the Blue Whiting Assessment Working Group should be integrated into the Mackerel, Horse Mackerel, Sardine and Anchovy Working Group.

The Working Group discussed the likely advantages and disadvantages of one group having the responsibilities for all the assessments, taking the biology, the fishery and the logistical problems of the different stocks into consideration.

There is a very high degree of similarity in the distribution and migration of mackerel and horse mackerel. For both species three main spawning areas are recognized. The assessments for both species are dependent on results of egg-surveys, which in some areas are carried out as one survey.

In the northern and western areas mackerel and horse mackerel are in general caught by the same fleets. There is however, very little mixing of the two species in the majority of the catches, and both fisheries are considered to be relatively "clean".

In most institutes, work on mackerel and horse mackerel is carried out by the same people.

There are relatively few biological similarities between mackerel, sardine, and anchovy. Sardine and anchovy are mainly found in the southern areas where the abundance of mackerel is relatively low. Even though egg surveys play an important role in the assessment of the mackerel, sardine and anchovy stocks, the methods used in assessment of the three species are different. In Divisions VIIIc and IXa juvenile mackerel is caught in a mixed fishery together with hake, horse mackerel, sardine, etc. Mackerel may be taken as by-catches in the anchovy fishery.

Based on the above comments, the Working Group felt that the assessments for mackerel and horse mackerel would benefit if carried out by the same group. However, the advantage of including sardine and anchovy in a mackerel - horse mackerel group is less obvious. The Working Group, however, felt that the assessments of sardine and anchovy should be integrated in a larger group and that the Mackerel and Horse Mackerel may be the most appropriate group.

The Working Group did not find any important assessment relationships between mackerel and blue whiting and, therefore, there is no obvious advantages in including the assessment of blue whiting with the mackerel, horse mackerel, anchovy and sardine groups.

As described in Section 6.4, the key parameters for the assessment of the western mackerel stock are the catch-at-age data, the estimates of spawning stock size from the egg surveys and the estimates of recruitment from the recruitment survey. As the VPA is tuned using the SSB estimates from the egg surveys, major revisions or changes in the assessment are only likely to take place in years where results from a new egg survey are included in the assessment. At present the egg survey takes place every third year in the western area and every second year in the North Sea.

In Section 6.4.6 the precision of the forecast for the western stock is evaluated. It is concluded that with the present stock configuration it is possible to make two year predictions without significant loss of precision.

The analyses of the precision of the forecast and the likelihood that major revisions to the assessment would only take place in those years in which egg surveys are carried out suggest that new mackerel assessments and predictions need not be made on an annual basis.

It is suggested, therefore, that although the assessments should be updated every year, new predictions may only be necessary every second year and when results of new egg surveys are available.

12 RECOMMENDATIONS

12.1 Research Recommendations

The Mackerel Working Group endorses the recommendations made by the Study Group on the Coordination of Bottom Trawl Surveys in Sub-areas VI, VII, VIII, and Division IXa (Anon., 1991b) but also stresses the need for good coverage during the first quarter.

The Mackerel Working Group endorses the recommendations made by the Mackerel/ Horse Mackerel Egg Production Workshop (Anon., 1991a).

The Mackerel Working Group further recommends that:

a) mackerel eggs obtained during the egg surveys in 1992 in Divisions VIIIc and IXa should be counted and staged;

b) all countries should provide estimates of discards;

c) a workshop should take place to plan studies to investigate the stock identity and migration pattern of mackerel in Divisions VIIIc and IXa;

d) a special workshop should take place to investigate the problem of giving specific advice in relation to the fishery on juveniles in Divisions VIIIc and IXa.

12.2 Management Recommendations

1) The overall TAC should apply to all areas in which mackerel are caught, i.e., including Divisions IIa, Vb, and VIIIa,b, Sub-areas VI and VII (all for the whole year), and Division IVa from 1 August - 31 December.

2) There should be no fishing for mackerel in Divisions IIIa and IVb,c at any time of the year.

3) There should be no fishing for mackerel in Division IVa during the period 1 January to 31 July.

4) The 30 cm minimum landing size at present in force in the North Sea (Sub-area IV and Division IIIa) should be maintained and the present by-catch regulations should be continued.

5) The present closed area in Divisions VIIe,f should be retained with its present boundaries.

13 REFERENCES

Anon. 1984. Report of the *ad hoc* Working Group on Mackerel Egg Surveys. ICES, Doc. C.M.1984/H:3.

Anon. 1985. Report of the Mackerel Working Group, ICES, Doc. C.M.1985/ Assess:7.

Anon. 1987. Report of the Mackerel Egg Production Workshop. ICES, Doc. C.M. 19897/H:2, 58 pp.

Anon. 1988. Report of the Mackerel Working Group, ICES, Doc. C.M.1988/ Assess:12, 82 pp.

Anon. 1989. Report of the Mackerel Working Group. ICES, Doc. C.M.1989/ Assess:11, 85 pp.

Anon. 1990a. Report of the Mackerel Working Group. ICES, Doc. C.M.1990/ Assess:19, 109 pp.

Anon. 1990b. Report of the Mackerel/Horse Mackerel Egg Production Workshop. ICES, Doc. C.M.1990/H:2, 89 pp.

Anon. 1991a. Report of the Mackerel/Horse Mackerel Egg Production Workshop. ICES, Doc. C.M.1991/H:2, 43 pp.

Anon. 1991b. Report of the Study Group on the Coordination of Bottom Trawl Surveys in Sub-areas VI, VII, VIII and Division IXa. ICES, Doc. C.M.1991/G:13.

Anon. 1991c. Report of the Roundfish Working Group. ICES, Doc. C.M.1991/Assess:4.

Anon. 1991d. Report of the Workshop on Mackerel in Divisions VIIIc and IXa. Lisbon, 5-7 March 1991. ICES, Doc. C.M.1991/H:47.

Cook. R.M., P.A. Kunzlik and R. Fryer. 1991. On the quality of North Sea cod stock forecasts. ICES, Journ. of Marine Sciences (in press).

Cubier, R.I., H.B. Levine, and K.E. Schuler. 1978. Nonlinear sensitivity analysis of multiparameter model systems. J. Comp. Phys., 26:1-42.

Dawson, W.A., M. Walsh, P. Hopkins, A. Eltink, and J. Molloy. 1988. The distribution and abundance of juvenile mackerel (Scomber scombrus L.) west and south of the British Isles. ICES, Doc. C.M.1988/H:16.

Eltink, A., M. Warmerdam and A. Heinen. 1986. Origin, migration and spawning of southern North Sea mackerel with respect to the overspill of Western mackerel to the North Sea stock. ICES, Doc. C.M.1986/H:49.

Hulme, T. J. and A.M. Watson. 1991. Report on a fishing survey in the mackerel box in February 1991. Working Document, Mackerel WG, 1991.

Iversen, S.A. and T. Westgaard. 1984. Mackerel egg investigations in the North Sea. ICES, Doc. C.M.1984/H:38.

Iversen, S.A., T. Westgaard, E. Kirkegaard, A. Eltink, P. Hopkins, and M. Walsh. 1985. The egg production and spawning stock size of the North Sea mackerel stock in 1984. ICES, Doc. C.M.1985/H:38.

Iversen, S.A., E. Kirkegaard and T. Westgaard. 1987. Mackerel egg production and spawning stock size in the North Sea 1986. ICES, Doc. C.M.1987/H:8.

Iversen, S.A., A. Eltink, E. Kirkegaard and D.W. Skagen. 1989. The egg production and spawning stock size of the North Sea mackerel stocks in 1988. ICES, Doc. C.M.1989/H:16.

Lockwood, S.J., J.H. Nichols and W.A. Dawson. 1981. The estimation of mackerel (Scomber scombrus L.) spawning stock size by plankton survey. Journ. Plankton Res., 3(2).

Lucio, P. and B. Villamor. Spanish mackerel (Scomber japonicus) fishery in the Bay of Biscay (ICES Divisions VIIIb and VIIIc) in 1990. Working Document Mackerel Working Group.

Priede, I.G. 1990. Evaluation of the batch fecundity method for assessment of stocks of pelagic spawning fishes. Final Rep. of a study contract submitted to the Directorate-General for Fisheries (DGXIV) of the EC.

Walsh, M., P. Hopkins, M. Witthames, M. Greer-Walker and J. Watson. 1990. Estimation of total potential fecundity and atresia in the western mackerel stock. ICES, Doc. C.M.1990/H:31, 22 pp.

Table 3.1 Planned research vessel deployment for the 1992 Mackerel/Horse Mackerel Egg Surveys in the western and southern areas.

Area	Participating Country	Participating Ships	Coverage	Egg sampling week no's	Trawl sampling week no's	Latitude to be covered
WESTERN	Germany	"Walter Herwig"	1	14 - 16		44°N - 56°N
(Sub-area VI, VII	Scotland	"Scotia"	2	18 - 20		44°N - 58°N
and Div. VIIIa,b,d)	Ireland	Charter	3	22 - 24		52°N - 58°N
	England	"Cirolana"	3	22 - 24		48°30' - 52°N
	France	"Thalassa"	3	22 - 24		44°N - 48°30'N
	Spain	"Cornide de S."	3	22 - 24	22 - 24	44°N - 47°N
	Netherlands	"Tridens"	3		22 - 24	46°N - 52°30'N
	EC	Charter	3		22 - 24	50°N - 58°N
	Netherlands	"Tridens"	4	26 - 27		44°N - 49°N
	Scotland	Charter	4	26 - 27		49°N - 58°N
	Scotland	Charter	5	28		44°N - 56°N
SOUTHERN	Portugal	"Noruega"	peak-spawning	10 - 13	10 - 13	36°N - 42°N
(Div. VIIIc and IXa)	Spain	"Cornide de S."	peak-spawning	19 - 21	19 - 21	42°N - 44°N

Table 3.2 Estimates of total egg production and pre-spawning biomass of mackerel derived from the North Sea egg surveys by the total fecundity method.

Annual egg production

Year	Total egg production ($x\ 10^{-12}$)	Mackerel pre-spawning stock biomass ($x\ 10^{-3}$ t)	References
1982	126	190	(Iversen & Westgaard, 1984)
1983	160	240	(Iversen & Westgaard, 1984)
1984	78	118	(Iversen *et al*., 1985)
1986	30	45	(Iversen *et al*., 1987)
1988	25	37	(Iversen *et al*., 1989)
1989	36[1]	53	(Anon., 1990a)
1990	53	78	(Iversen *et al*., WD 1991).

[1] Only based on a single coverage at the peak of spawning.

Table 3.3 Estimates of mackerel egg production, of pre-spawning and spawning stock biomass of mackerel derived from the western egg surveys by annual and dfaily egg production methods (taken from Anon., 1990a).

	ANNUAL EGG PRODUCTION METHOD			DAILY EGG PRODUCTION METHOD		
Year	Total egg production ($x10^{-15}$)	Mackerel pre-spawning stock biomass ($x10^{-6}$t)	Mackerel spawning stock biomass ($x10^{-6}$t)	Daily egg production ($x10^{-13}$)	Mackerel pre-spawning stock biomass ($x10^{-6}$t)	Mackerel spawning stock biomass ($x10^{-6}$t)
1977	1.98	2.72	2.94	-	-	-
1980	1.84	2.53	2.73	-	-	-
1983	1.50	2.06	2.22	-	-	-
1986	1.17	1.60	1.73	-	-	-
1989	1.50	1.87	2.01	2.24	2.22	2.36[1]

[1] Revised.

Table 5.1 Mackerel abundance indices from the International Young Fish Surveys in the North Sea (hauls south of 59^0 N only). Values are mean numbers/10 hr.

	Age	
Year	1	2
1970	6536	13
1971	3250	576
1972	13	226
1973	28	2
1974	14	12
1975	26	1
1976	3	<0.5
1977	14	<0.5
1978	8	<0.5
1979	3	<0.5
1980	<0.5	<0.5
1981	1	<0.5
1982	1	1
1983	24	64
1984	1	2
1985	8	0
1986	6	1
1987	2	<0.5
1988	1	1
1989	13	21
1990	427	11
1991[1]	<0.5	*

[1] Provisional.
* Not yet available

Table 5.2 Western mackerel recruitment indices. Values are mean numbers/hr.

Year class	First winter	Second winter
1980	-	50
1981	125	78
1982	6	46
1983	4	8
1984	149	210
1985	37	37
1986	89	25
1987	110	225
1988	106	138
1989	162	399
1990	126	-

Table 6.1 Nominal catch (t) of MACKEREL in the North Sea, Skagerrak, and Kattegat (Sub-area IV and Division IIIa), 1981-1990. (Data submitted by Working Group members.)

Country	1981	1982	1983	1984	1985
Belgium	55	102	93	68	-
Denmark	9,982	2,034	11,285	10,088	12,424
Faroe Islands	-	720	-	-	1,356
France	3,755	3,041	2,248	-	322
Germany, Fed. Rep.	59	28	10	112	217
Ireland	733	-	-	-	-
Netherlands	1,706	390	866	340	726
Norway	28,341	27,966	24,464	27,311	30,835
Sweden	2,446	692	1,903	1,440	760
UK (England and Wales)	6,520	16	16	2	143
UK (Scotland)	10,575	44	4	13	7
UK (N. Ireland)	-	-	-	-	-
USSR	-	-	-	-	-
Unallocated + discards	3,216	450	96	202	3,656
Total	67,388	35,483	40,985	39,576	50,446

Country	1986	1987[1]	1988	1989	1990[2]
Belgium	49	14	20	37	-
Denmark	23,368	28,217	32,588	26,831	29,000
Faroe Islands	-	-	-	2,685	5,900
France	1,200	2,146	1,806	2,200	1,600
Germany, Fed. Rep.	1,853	474	177	6,312	3,500
Ireland	-	-	-	8,880	12,800
Netherlands	1,949	2,761	2,564	7,343	13,700
Norway	50,600	108,250	59,750	81,400	74,500
Sweden	1,300	3,162	1,003	6,601	6,400
UK (England and Wales)	18	94	160	5,618	1,300
UK (Scotland)	541	19,763	616	33,042	28,100
UK (N. Ireland)	-	-	100	-	1,400
USSR	-	-	-	-	-
Unallocated + discards	7,431	10,789	29,766	4,777[3]	4,300
Total	88,309	175,670	128,550	185,726	182,500

[1] May include catches taken in Division IIa.
[2] Preliminary.
[3] Unallocated: 2,587 t, discards 2,190 t.

Table 6.2 Nominal catches (t) of MACKEREL in the Norwegian Sea (Division IIa) and off the Faroes (Division Vb), 1981-1990.

Country	1981	1982	1983	1984	1985
Denmark[1]	801	1,008	10,427	11,787	7,610
Faroe Islands[1]	-	180	-	138	-
France[2]	6	8	-	-	16
Germany, Fed. Rep.[2]	51	-	5	-	-
German Dem. Rep.[2]	-	-	-	-	-
Norway[1]	12,941	34,540	38,453	82,005	61,065
Poland[2]	-	231	-	-	-
UK (England and Wales)[1]	255	-	-	-	-
UK (Scotland)[2]	968	-	-	-	-
USSR[2]	3,640	1,641	65	4,292	9,405
Total	18,662	37,608	48,950	98,222	78,096

Country	1986	1987[3]	1988[3]	1989	1990[4]
Denmark[1]	1,653	3,133	4,265	6,433	6,800
Faroe Islands[1]	-	-	22	1,247	3,100
France[2]	-	-	-	11	-
Germany, Fed. Rep.[2]	99	-	380	-	-
German Dem. Rep.[2]	16	292	-	2,409	-
Ireland	-	-	-	-	-
Norway[1]	85,400	25,000	86,400	68,300	77,200
Poland[2]	-	-	-	-	-
UK (England and Wales)[1]	-	-	-	-	+
UK (Scotland)[2]	2,131	157	1,413	-	400
USSR[2]	11,813	18,604	27,924	12,088	28,900
Discards	-	-	-	-	2,300
Total	101,112	47,186	120,404	90,488	118,700

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

Table 6.3 Nominal catch (tonnes) of MACKEREL in the Western area (Sub-areas VI and VII and Divisions VIIIa,b,d,e). (Data estimated by Working Group.)

Country	1981	1982	1983	1984	1985
Belgium	-	-	+	+	-
Denmark	13,464	15,000	15,000	200	400
Faroe Islands	9,070	11,100	14,900	9,200	9,900
France	14,829	12,300	11,000	12,500	7,400
Germany, Fed.Rep.	29,221	11,200	23,000	11,200	11,800
Ireland	92,271	109,700	110,000	84,100	91,400
Netherlands	88,117	67,200	73,600	99,000	37,000
Norway	21,610	19,000	19,900	34,700	24,300
Poland	1	-	-	-	-
Spain	1,365	-	-	100	+
UK (England + Wales)	75,722	82,900	62,000	30,000	9,600
UK (N. Ireland)	4,153	9,600	800	10,600	12,200
UK (Scotland)	109,153	147,400	120,100	157,700	184,100
USSR	-	-	+	200	+
Unallocated	140,322	97,300	105,500	18,000	75,100
Discard	42,300	24,900	11,300	12,100	4,500
Grand total	641,598	607,700	567,100	479,600	467,700

Country	1986	1987	1988[1]	1989[2]	1990[2]
Belgium	+	-	-	-	-
Denmark	300	100	-	1,000?	-
Faroe Islands	1,400	7,100	2,600	1,100	1,000
France	11,200	11,100	8,900	12,700	17,400
Germany, Fed.Rep.	7,700	13,300	15,900	16,200	18,100
Ireland	74,500	89,500	85,800	61,100	61,500
Netherlands	58,900	31,700	26,100	24,000	24,500
Norway	21,000	21,600	17,300	700	-
Poland	-	-	-	-	-
Spain	-	-	1,500	1,400	400
UK (Engl. + Wales)	9,100	25,200	24,100	14,700	19,200
UK (N. Ireland)	9,700	10,700	8,900	11,000	12,800
UK (Scotland)	137,500	164,800	175,400	123,400	130,700
USSR	-	-	+	-	-
Unallocated	51,000	25,800	4,700	16,700	6,000
Discard	-	-	5,800	4,900	11,300
Grand total	380,500	401,700	377,000	288,900	302,900

[1] Includes catches taken in Division IVa, but misreported to Division VIa.
[2] Preliminary.

Table 6.4 Catches of mackerel by division and sub-area in 1990. (Data submitted by Working Group members.)

Division/ Sub-area	Quarter 1	2	3	4	Total
IIa + Vb	-	-	84,300	32,500	116,800
IVa	40,000	100	60,700	189,700	290,500
IVb	+	700	3,800	1,000	5,500
IVc	100	400	200	500	1,200
IIIa	+	500	4,900	2,500	7,900
VI	105,200	700	1,200	13,600	120,600
VII	23,600	22,700	3,100	9,500	58,900
VIIIa,b,d,e	800	1,200	600	300	2,900
Sub-total	169,700	26,300	158,800	249,600	604,300
VIIIc	6,800	8,200	600	600	16,200
IXa	900	1,900	1,500	700	5,000
Grand total	174,400	36,400	160,900	250,800	625,500

Table 6.5 Actual catches of mackerel by sub-areas. Discards not estimated prior to 1978. (Data submitted by Working Group members.)

	Sub-area VI			Sub-area VII and Divisions VIIIa,b,d,e			Sub-area IV and Division IIIa			Divs.[1] IIa,Vb
Year	Landings	Discards	Catch	Landings	Discards	Catch	Landings	Discards[2]	Catch	
1969	4,800	-	4,800	66,300	-	66,300	739,182	-	739,182	+
1970	3,900	-	3,900	100,300	-	100,300	322,451	-	322,451	163
1971	10,200	-	10,200	122,600	-	122,600	243,673	-	243,673	358
1972	10,000	-	10,000	157,800	-	157,800	188,599	-	188,599	88
1973	52,200	-	52,200	167,300	-	167,300	326,519	-	326,519	21,600
1974	64,100	-	64,100	234,100	-	234,100	298,391	-	298,391	6,800
1975	64,800	-	64,80	416,500	-	416,500	263,062	-	263,062	34,700
1976	67,800	-	67,800	439,400	-	439,400	303,842	-	303,842	10,500
1977	74,800	-	74,800	259,100	-	259,100	258,131	-	258,131	1,400
1978	151,700	15,200	166,900	355,500	35,500	391,000	148,817	-	148,817	4,200
1979	203,300	20,300	223,600	398,000	39,800	437,800	152,323	500	152,823	7,000
1980	218,700	6,000	224,700	386,100	15,600	401,700	87,391	-	87,391	8,300
1981	335,100	2,500	337,600	274,300	39,800	314,100	64,172	3,216	67,388	18,700
1982	340,400	4,100	344,500	257,800	20,800	278,600	35,033	450	35,483	37,600
1983	315,100	22,300	337,400	245,400	9,000	254,400	40,889	96	40,985	49,000
1984	306,100	1,600	307,700	176,100	10,500	186,600	39,374	202	39,576	93,900
1985	388,140	2,735	390,875	75,043	1,800	76,843	46,168	3,656	50,124	78,000
1986	104,100	+	104,100	128,499	+	128,495	236,309	7,431	243,740	101,000
1987	183,700	+	183,700	100,300	+	100,300	290,829	10,789	301,612	47,000
1988	115,600	3,100	118,700	75,600	2,700	78,300	308.550	29,766	338,316	116,200
1989	121,300	2,600	123,900	72,900	2,300	75,200	279,410	2,190	281,600	86,900
1990	114,800	5,800	120,600	56,300	5,500	61,800	300,700	4,300	305,100	116,800

[1] Division IIa only 1976-1985. Divisions IIa+Vb 1986 1990.
[2] Includes unallocated as well as discards.

NB: Catches in Sub-area IV and Division IIIa are taken from 1978 Working Group report and Norwegian catches taken in Division IIa from 1973-1987.

Table 6.6 CATCH IN NUMBERS ('000) BY QUARTER, DIVISION,AND AGE IN 1990

FIRST QUATER

AGE	IIa,IVa,Vb	IIIa	IVb,c	VIa,b	VIIa,d-h	VIIb,c,j,k	VIIIa,b,d,e	TOTAL
0	0	0	0	0	0	0	0	0
1	0	1	217	612	5314	153	15	6312
2	1346	0	89	4380	27551	2272	26	35665
3	21661	0	179	39787	8555	11735	428	82345
4	18380	0	22	32862	520	7697	687	60167
5	14209	0	46	35593	648	7184	353	58034
6	19621	0	30	63487	92	11760	372	95362
7	3719	0	17	17073	29	959	147	21945
8	6357	0	2	13300	71	1240	151	21121
9	6946	0	8	25690	35	2820	245	35743
10	2912	0	12	6319	48	2125	32	11449
11	2188	0	2	4256	39	1314	51	7849
12	758	0	0	2470	0	516	13	3758
13	298	0	0	1282	9	117	0	1706
14	94	0	0	1367	0	664	0	2125
15	554	0	0	3785	5	593	0	4938
TOTAL	99045	3	625	252263	42917	51148	2519	448520
TONNES	41002	1	166	106219	5440	18222	804	171854

SECOND QUARTER

AGE	IIa,IVa,Vb	IIIa	IVb,c	VIa,b	VIIa,d-h	VIIb,c,j,k	VIIIa,b,d,e	TOTAL
0	0	0	0	0	0	0	0	0
1	0	637	628	23	2795	127	0	4210
2	0	211	287	109	14492	2690	82	17870
3	60	177	780	724	4500	19063	544	25848
4	30	37	268	423	273	13933	870	15835
5	60	45	397	198	341	8717	598	10357
6	60	45	438	460	49	15052	924	17028
7	30	94	166	44	15	1799	136	2286
8	0	86	34	21	37	2173	190	2542
9	30	86	170	39	18	2405	299	3048
10	0	37	65	55	25	336	82	600
11	0	50	34	43	20	510	0	658
12	0	12	0	6	0	451	27	496
13	0	13	0	12	5	144	0	174
14	0	57	0	0	0	420	0	477
15	0	19	0	18	3	212	0	251
TOTAL	272	1607	3267	2175	22574	68032	3752	101680
TONNES	112	531	1099	672	2862	19829	1244	26349

..cont'd

Table 6.6 (cont'd)

THIRD QUARTER

AGE	IIa,IVa,Vb	IIIa	IVb,c	VIa,b	VIIa,d-h	VIIb,c,j,k	VIIIa,b,d,e	TOTAL
0	0	0	0	0	0	0	0	0
1	236	22251	3973	34	1438	0	0	27932
2	25268	15973	2976	1108	639	0	171	46134
3	108815	1697	2334	1132	2865	53	341	117238
4	42125	198	1103	1228	744	210	341	45949
5	31131	122	1051	526	1637	106	171	34743
6	50972	70	653	531	1376	26	341	53970
7	6695	186	540	6	211	26	171	7835
8	7514	99	784	6	353	53	171	8980
9	17191	87	539	12	335	26	171	18361
10	6791	47	390	13	236	79	0	7555
11	1487	12	196	10	43	53	0	1800
12	469	6	38	2	0	26	0	542
13	693	6	94	0	0	0	0	793
14	103	99	93	0	0	0	0	295
15	2481	6	2	0	31	0	0	2520
TOTAL	301972	40857	14765	4607	9908	659	1877	374646
TONNES	144614	7552	4141	1208	2953	187	583	161238

FOURTH QUARTER

AGE	IIa,IVa,Vb	IIIa	IVb,c	VIa,b	VIIa,d-h	VIIb,c,j,k	VIIIa,b,d,e	TOTAL
0	0	0	0	0	5352	0	0	5352
1	17146	77	766	30238	21926	0	0	70154
2	75898	632	606	18773	6750	0	0	102660
3	168651	2174	1311	7036	3160	43	292	182668
4	77426	894	571	2502	1457	175	292	83316
5	46448	694	379	407	618	87	292	48925
6	77750	1604	304	120	946	22	292	81038
7	8105	31	49	2	341	22	0	8549
8	10674	231	26	54	1309	43	0	12337
9	21924	324	18	56	488	22	0	22832
10	11090	185	44	3	514	65	0	11901
11	4727	15	6	2	783	43	0	5577
12	2304	77	1	0	1	22	0	2405
13	1541	0	3	0	0	0	0	1544
14	909	0	3	0	0	0	0	912
15	3452	108	0	0	475	0	0	4035
								0
TOTAL	528045	7048	4086	59195	44121	542	1168	644204
TONNES	219993	3078	1341	12690	8892	154	348	246496

Table 6. 7 MEAN WEIGHT (G) BY QUARTER, DIVISION,AND AGE IN 1990

FIRST QUATER

AGE	IIa,IVa	IIIa	IVb,c	VIa,b	VIIa,d-h	VIIb,c,j,k	VIIIa,b,d,e	MEAN
0								
1		136	189	63	88	68	55	88
2	183	222	239	150	120	127	187	127
3	265	318	287	273	159	235	241	253
4	347	342	288	345	205	309	260	339
5	401	432	352	396	183	341	313	388
6	447	466	426	429	251	395	381	428
7	520	633	361	497	227	490	394	500
8	549	599	630	516	250	482	420	522
9	564	603	608	571	275	515	399	564
10	630	617	311	546	236	544	370	565
11	672	741	611	549	227	578	432	586
12	755	718		688		645	526	695
13	700	720		562	282	582		586
14	738	588		610		633		623
15	849	753		761	282	694		762
MEAN	412	331	266	421	127	356	317	383
TONNES	41002	1	166	106163	5441	18200	799	171581

SECOND QUARTER

AGE	IIa,IVa	IIIa	IVb,c	VIa,b	VIIa,d-h	VIIb,c,j,k	VIIIa,b,d,e	MEAN
0								
1		136	189	111	88	53		109
2		222	232	197	120	123	202	124
3	275	318	284	255	159	214	236	209
4	358	342	345	288	205	271	281	273
5	401	432	388	344	183	320	313	319
6	433	466	437	361	251	352	361	355
7	518	633	476	395	227	387	389	404
8		599	630	403	250	402	429	412
9	600	603	608	472	275	409	478	434
10		617	437	425	236	420	507	439
11		741	611	462	227	391		429
12		718		592		460	540	473
13		720		481	282	531		535
14		588				535		541
15		753		684	282	598		612
MEAN	410	331	336	310	127	291	331	259
TONNES	112	532	1099	674	2862	19821	1244	26342

continued

Table 6.7 (cont'd)

THIRD QUARTER

AGE	IIa,IVa	IIIa	IVb,c	VIa,b	VIIa,d-h	VIIb,c,j,k	VIIIa,b,d,e	MEAN
0								
1	223	155	183	197	151			160
2	308	201	227	217	230		161	262
3	396	261	290	252	307	204	214	388
4	452	278	332	278	343	247	262	440
5	503	398	372	283	320	260	317	485
6	550	437	402	310	350	252	369	539
7	650	631	438	428	341	252	397	620
8	697	425	355	463	353	351	422	644
9	716	536	395	455	391	383	432	697
10	718	459	372	448	300	349		681
11	684	701	334	428	640	314		633
12	810	717	537	417		371		767
13	702	717	431					670
14	820	562	439					613
15	857	725	809		704			854
MEAN	479	185	280	262	298	282	311	430
TONNES	144614	7551	4141	1209	2952	186	583	161208

FOURTH QUARTER

AGE	IIa,IVa	IIIa	IVb,c	VIa,b	VIIa,d-h	VIIb,c,j,k	VIIIa,b,d,e	MEAN
0					61			61
1	225	231	188	170	160			181
2	292	293	265	243	217			278
3	366	362	338	282	272	204	230	361
4	401	395	404	322	335	247	265	397
5	452	433	428	266	365	260	325	448
6	497	492	487	386	344	252	369	494
7	563	507	324	503	449	252		556
8	616	616	352	437	377	351		588
9	648	652	390	373	397	383		642
10	634	646	298	540	345	349		619
11	629	524	328	549	493	314		607
12	692	692	534		503	371		689
13	776		427					775
14	723		439					722
15	793	866			586			771
MEAN	417	437	328	214	201	282	297	383
TONNES	219993	3078	1341	12687	8889	153	347	246477

Table 6.8. Annual length distriubtion (percent) of mackerel catches by fleet and country in 1990.

Length	Denmark	Ireland	Netherlands		Norway		UK (England)		UK (Scotland)			Spain			Portugal		
(cm)	P. seine	Pr trawl	Bot/Beam Trl	Pel Trwl	P Seine	Artisan	Pel Trwl	Handline	P. Seine	2-Bt Pel	1-Bt Pel	P. Seine	Trawl	Artisan*	P Seine	Trawl	Artisan
15												0	0				
16												2	1				
17												2	1				
18												1	7				
19		0		1								1	2				
20		0		2			0					5	2			0	0
21		0		1			1					10	2			0	0
22		0		0		0	1		0			7	9			1	0
23		0		0		0	1	0	0			3	16			4	0
24		0		0		1	3	2	0			7	15			9	3
25		0		1		2	11	3	0			10	10			9	5
26		1	2	2		5	21	5	0	0		5	4	0		11	3
27		1	6	3	0	5	21	11	0	1		2	2	0		12	4
28		1	17	1	0	4	11	10	1	1		3	2	0		12	11
29		2	10	2	0	2	11	10	2	4	1	3	2	1	6	15	22
30	0	3	8	4	2	2	5	10	3	6	3	2	1	1	6	13	22
31	0	5	6	5	4	3	3	9	5	9	4	2	1	1	9	7	11
32	0	8	8	8	8	5	3	12	8	11	10	1	2	1	22	2	7
33	0	10	11	8	10	7	2	9	11	11	10	1	2	2	25	2	3
34	0	11	10	8	14	11	2	8	12	13	15	2	2	3	9	2	2
35	0	11	6	8	14	11	1	5	12	10	14	1	2	4	9	0	1
36	0	10	7	10	12	10	1	2	10	11	10	3	2	6	6	0	1
37	1	9	3	9	10	9	0	2	10	6	11	4	3	10	3	0	1
38	1	8	4	8	8	6	0	1	7	8	7	4	3	12	0	0	1
39	1	6	1	7	5	5	0	0	5	2	7	5	2	13	3	0	1
40	2	4	1	3	5	4	0	0	4	4	3	4	2	15	0	0	0
41	3	3	0	3	3	3	0	0	4	1	2	4	2	13	0		1
42	5	2	1	3	2	2	0	0	2	0	1	3	2	10	0		1
43	8	1		1	1	1	0	0	1	1	1	2	1	6	0		1
44	10	1		1	1	1	0	0	1	1	1	1	1	3	0		1
45	11	1		0	0	0	0	0	0		0	0	0	0	0		0
46	11	0			0	0	0	0	0			0	0	0	0		0
47	10	0			0	0						0	0	0	0		
48	9				0	0						0	0		0		
49	8				0	0						0					
50	6				0	0						0					
51	4																
52	3																
53	2																
54	1																
55	1																
56	1																
57	0																
58	0																
SUM	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* Handline and gillnet

Table 6.9 Estimates spawning stock size (number x 10^6) and total stock of North Sea mackerel at time of spawning 1990 (Iversen et al., WD, 1991)

Age	Spawning Stock	Total Stock
1	0	73.9
2	76.6	95.7
3	109.8	109.8
4	29.3	29.3
5	8.5	8.5
6	4.8	4.8
7	1.0	1.0
8	4.1	4.1
9	2.4	2.4
10	2.7	2.7
11	0.1	0.1
12	1.4	1.4
13	0.3	0.3
14	+	+
15+	2.0	2.0

Table 6.10 VIRTUAL POPULATION ANALYSIS

Mackerel in the Western Area (Fishing Areas VI, VII and VIII)

CATCH IN NUMBERS UNIT: millions

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	2	0	1	1	34	2	10	80	20	38	2	0
1	12	34	87	53	279	154	31	351	485	266	203	44
2	12	49	24	104	185	290	564	62	469	506	436	713
3	29	64	124	95	322	154	425	603	75	225	484	445
4	508	116	109	306	171	166	244	366	381	32	184	392
5	0	582	192	192	289	51	258	217	282	175	25	130
6	0	0	567	144	119	140	72	233	145	159	137	20
7	0	0	0	1246	280	64	152	87	158	100	109	91
8	0	0	0	0	439	89	57	154	52	117	85	71
9	0	0	0	0	0	159	83	71	140	35	87	47
10	0	0	0	0	0	0	211	75	44	139	24	49
11	0	0	0	0	0	0	0	189	48	29	90	19
12+	0	0	0	0	0	0	0	0	115	176	148	126
TOTAL	563	845	1103	2141	2117	1268	2107	2486	2414	1997	2012	2147

	1984	1985	1986	1987	1988	1989	1990
0	1	0	18	2	0	24	5
1	15	234	26	23	99	43	109
2	80	16	398	148	127	307	202
3	662	49	30	654	175	203	408
4	375	420	64	52	505	163	205
5	238	243	332	79	67	356	152
6	92	158	194	237	78	46	247
7	16	59	120	149	179	54	41
8	51	16	38	84	112	106	45
9	39	42	11	33	52	67	80
10	25	33	29	18	19	31	32
11	21	20	20	25	12	14	16
12+	44	80	60	61	52	35	27
TOTAL	1659	1371	1339	1565	1478	1449	1569

Table 6.11 SUM OF PRODUCTS CHECK

Mackerel in the Western Area (Fishing Areas VI, VII and VIII)
CATEGORY: TOTAL

MEAN WEIGHT AT AGE IN THE CATCH UNIT: kilogram

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.066	.066	.066	.066	.066	.066	.000	.000	.066	.066	.066	.066
1	.137	.137	.137	.137	.137	.137	.137	.137	.131	.131	.131	.178
2	.158	.158	.158	.158	.158	.158	.158	.158	.248	.248	.248	.216
3	.241	.241	.241	.241	.241	.241	.241	.241	.283	.283	.283	.270
4	.416	.314	.314	.314	.314	.314	.314	.314	.343	.343	.343	.306
5	.000	.437	.334	.334	.334	.334	.334	.334	.373	.373	.373	.383
6	.000	.000	.472	.398	.398	.398	.398	.398	.455	.455	.455	.425
7	.000	.000	.000	.480	.410	.410	.410	.410	.497	.497	.497	.430
8	.000	.000	.000	.000	.508	.503	.503	.503	.508	.508	.508	.491
9	.000	.000	.000	.000	.000	.511	.511	.511	.539	.539	.539	.542
10	.000	.000	.000	.000	.000	.511	.511	.511	.573	.573	.573	.608
11	.000	.000	.000	.000	.000	.000	.000	.511	.573	.573	.573	.608
12	.000	.000	.000	.000	.000	.000	.000	.000	.573	.573	.573	.608
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.573	.573	.608
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.573	.608
15+	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.608

	1984	1985	1986	1987	1988	1989	1990
0	.069	.000	.000	.049	.071	.061	.061
1	.137	.151	.166	.176	.157	.154	.167
2	.176	.273	.245	.222	.260	.238	.234
3	.294	.349	.339	.318	.326	.321	.337
4	.324	.418	.421	.399	.390	.377	.380
5	.341	.416	.473	.478	.462	.434	.425
6	.429	.434	.444	.513	.537	.455	.469
7	.538	.520	.456	.492	.567	.546	.530
8	.468	.544	.541	.496	.563	.596	.558
9	.561	.562	.593	.577	.568	.579	.612
10	.619	.627	.546	.635	.617	.582	.611
11	.636	.666	.692	.634	.627	.649	.592
12	.636	.683	.692	.707	.686	.655	.683
13	.636	.694	.692	.704	.659	.728	.669
14	.636	.693	.692	.662	.666	.784	.636
15+	.636	.727	.692	.751	.754	.778	.782

Table 6.12 VIRTUAL POPULATION ANALYSIS

Mackerel in the Western Area (Fishing Areas VI, VII and VIII)

MEAN WEIGHT AT AGE OF THE STOCK UNIT: kilogram

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
1	.113	.113	.113	.113	.113	.113	.095	.095	.095	.070	.070	.070
2	.131	.131	.131	.131	.131	.131	.150	.150	.150	.172	.108	.156
3	.201	.201	.201	.201	.201	.201	.215	.215	.215	.241	.202	.220
4	.380	.251	.251	.251	.251	.251	.275	.275	.275	.300	.260	.261
5	.000	.410	.264	.264	.264	.264	.320	.320	.320	.300	.379	.322
6	.000	.000	.440	.316	.316	.316	.355	.355	.355	.359	.329	.360
7	.000	.000	.000	.470	.380	.380	.380	.380	.380	.401	.388	.384
8	.000	.000	.000	.000	.490	.412	.400	.400	.400	.412	.417	.420
9	.000	.000	.000	.000	.000	.511	.420	.420	.420	.427	.425	.497
10	.000	.000	.000	.000	.000	.511	.485	.485	.485	.413	.460	.453
11	.000	.000	.000	.000	.000	.000	.000	.485	.485	.509	.513	.550
12+	.000	.000	.000	.000	.000	.000	.000	.000	.485	.509	.513	.550

	1984	1985	1986	1987	1988	1989	1990
0	.000	.000	.000	.000	.000	.000	.000
1	.070	.070	.070	.070	.070	.070	.070
2	.187	.150	.164	.139	.146	.176	.128
3	.246	.292	.261	.233	.233	.238	.213
4	.283	.300	.290	.268	.302	.299	.280
5	.305	.328	.345	.363	.327	.342	.331
6	.379	.366	.337	.371	.434	.363	.365
7	.429	.421	.395	.392	.455	.419	.405
8	.421	.440	.467	.402	.436	.468	.393
9	.465	.448	.441	.459	.460	.441	.420
10	.515	.554	.451	.483	.528	.451	.514
11	.497	.579	.472	.442	.606	.496	.514
12+	.547	.601	.612	.559	.684	.585	.514

Table 6.13

Title : Mackerel in the Western Area (Fishing Areas VI, VII and VIII)
At 15.45.21 30 APRIL 1991
from 72 to 90 on ages 0 to 11
with Terminal F of .275 on age 5 and Terminal S of 1.000

Initial sum of squared residuals was 466.447 and
final sum of squared residuals is 105.509 after 123 iterations

Matrix of Residuals

Years / Ages	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80
0/ 1	.663	-4.349	.087	-1.958	1.408	1.012	.120	1.535
1/ 2	.249	1.902	1.512	.310	.777	.359	.857	.937
2/ 3	-.921	-.239	-.573	-.484	.076	.359	.531	.080
3/ 4	-.897	-.130	-.414	-.249	.252	-.017	.429	.408
4/ 5	.233	-.217	-.195	.268	.664	-.128	.248	.055
5/ 6	.169	.112	.454	.473	-.044	-.246	.008	-.039
6/ 7	.179	.093	-.616	-.675	-.156	.018	-.287	-.062
7/ 8	.092	.005	.082	.942	.278	.136	-.207	-.041
8/ 9	.084	-.003	.076	-.106	.151	.075	-.414	-.449
9/10	.105	.019	.098	-.083	-.843	-.258	-.062	-.042
10/11	.026	-.058	.023	-.154	-.919	-.046	-.132	-.149
	.000	.000	.000	.000	.000	.000	.000	.000
WTS	.001	.001	.001	.001	.001	.001	.001	.001

Years / Ages	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90		WTS
0/ 1	.553	1.666	.225	-3.075	-2.838	-3.400	3.351	-.215	-1.637	1.906	.000	.087
1/ 2	1.012	.732	-.054	.488	1.146	.760	-.270	-.354	.119	-.265	.000	.298
2/ 3	.851	.341	.254	.241	.761	-.250	.067	.264	-.151	.069	.000	.409
3/ 4	.658	.181	.172	.031	.433	-.182	-.292	.375	.071	.027	.000	.496
4/ 5	.426	.089	.167	.224	.287	.187	-.092	-.269	.207	-.034	.000	.768
5/ 6	-.013	-.142	-.203	-.149	.041	-.043	.244	-.230	-.001	.030	.000	.898
6/ 7	-.215	-.012	-.003	-.235	.081	.017	.175	.032	-.007	-.215	.000	.775
7/ 8	-.384	-.322	-.074	-.018	-.499	.074	.172	-.055	.060	-.250	.000	.595
8/ 9	-.299	-.197	.080	-.005	-.260	.016	-.037	.138	.042	-.158	.000	1.000
9/10	-.662	-.096	.096	.057	-.266	.046	-.645	.215	.050	.337	.000	.584
10/11	-.346	-.108	-.308	.181	-.306	.078	-.088	-.016	-.169	.198	.000	.744
	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	2.554	
WTS	.001	.001	.001	.001	.001	1.000	1.000	1.000	1.000	1.000		

Fishing Mortalities (F)

	72	73	74	75	76	77	78	79	80
F-values	.0657	.0927	.1239	.1886	.2576	.1631	.2432	.3245	.3188

	81	82	83	84	85	86	87	88	89	90
F-values	.2620	.2544	.2406	.2018	.1876	.1917	.2397	.2664	.2654	.2750

Selection-at-age (S)

	0	1
S-values	.0022	.0730

	2	3	4	5	6	7	8	9	10	11
S-values	.3122	.5609	.7811	1.0000	1.0576	1.1360	1.1199	1.0937	1.0901	1.0000

Table 6.14 VIRTUAL POPULATION ANALYSIS

Mackerel in the Western Area (Fishing Areas VI, VII and VIII)

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	.016	.004	.006	.002	.000
1	.003	.022	.025	.019	.075	.040	.044	.144	.119	.064	.038	.039
2	.007	.014	.019	.036	.081	.099	.189	.110	.275	.167	.133	.172
3	.013	.045	.041	.091	.141	.085	.194	.299	.179	.194	.225	.185
4	.069	.062	.095	.128	.223	.095	.177	.241	.296	.101	.228	.271
5	.000	.100	.132	.230	.162	.091	.198	.224	.279	.203	.101	.236
6	.000	.000	.127	.131	.205	.104	.170	.261	.217	.237	.229	.107
7	.000	.000	.000	.423	.380	.155	.149	.300	.268	.214	.239	.223
8	.000	.000	.000	.000	.243	.189	.188	.210	.281	.305	.268	.229
9	.000	.000	.000	.000	.000	.123	.254	.354	.282	.293	.370	.222
10	.000	.000	.000	.000	.000	.000	.226	.358	.364	.471	.319	.345
11	.000	.000	.000	.000	.000	.000	.000	.306	.387	.421	.605	.418
12+	.000	.000	.000	.000	.000	.000	.000	.306	.387	.421	.605	.418
(4- 8)U	.014	.033	.071	.182	.243	.127	.176	.247	.268	.212	.213	.213
(4- 8)W	.069	.091	.123	.269	.231	.113	.177	.240	.273	.217	.224	.243

	1984	1985	1986	1987	1988	1989	1990
0	.000	.000	.007	.000	.000	.002	.001
1	.023	.043	.014	.010	.022	.020	.011
2	.089	.029	.091	.101	.070	.085	.119
3	.225	.069	.066	.200	.157	.144	.147
4	.222	.206	.114	.147	.222	.203	.201
5	.249	.207	.236	.192	.269	.228	.278
6	.246	.246	.240	.250	.277	.284	.232
7	.106	.233	.280	.277	.287	.297	.411
8	.179	.146	.221	.306	.325	.258	.406
9	.181	.205	.134	.284	.296	.310	.299
10	.168	.215	.199	.313	.252	.278	.223
11	.236	.189	.188	.249	.346	.268	.209
12+	.236	.189	.188	.249	.346	.268	.209
(4- 8)U	.200	.208	.218	.234	.276	.254	.306
(4- 8)W	.224	.217	.223	.239	.250	.233	.244

Table 6.15 VIRTUAL POPULATION ANALYSIS

Mackerel in the Western Area (Fishing Areas VI, VII and VIII)

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	1981	1982	1983
0	1907	4397	3536	4829	4966	902	3277	5466	5419	6853	1411	836
1	4553	1640	3784	3042	4156	4243	775	2811	4631	4646	5863	1213
2	1828	3907	1380	3177	2570	3318	3510	638	2094	3538	3752	4858
3	2425	1562	3317	1165	2638	2041	2588	2499	492	1370	2576	2826
4	8167	2060	1285	2741	915	1972	1614	1834	1595	354	971	1771
5	0	6559	1666	1006	2076	630	1544	1164	1241	1021	275	665
6	0	0	5106	1257	688	1519	495	1090	801	808	717	214
7	0	0	0	3870	949	482	1178	360	723	555	549	491
8	0	0	0	0	2182	558	356	873	229	476	386	372
9	0	0	0	0	0	1473	398	254	609	149	302	254
10	0	0	0	0	0	0	1121	266	153	395	96	179
11	0	0	0	0	0	0	0	770	160	92	213	60
12+	0	0	0	0	0	0	0	0	385	549	347	396
TOTAL NO	18879	20125	20075	21087	21139	17139	16854	18024	18533	20805	17458	14134
SPS NO	10674	11210	10921	10355	9588	9672	9692	7956	6655	6960	7636	8544
TOT.BIOM	4345	4217	4284	4164	3761	3632	3571	3259	2941	2938	2762	3021
SPS BIOM	3342	3384	3345	3065	2696	2657	2797	2450	1996	1997	1825	2193

	1984	1985	1986	1987	1988	1989	1990	1991
0	6932	2284	2784	5614	2675	12297	9722	0
1	719	5966	1966	2379	4830	2302	10562	8363
2	1003	605	4918	1669	2027	4065	1942	8990
3	3522	790	506	3865	1299	1626	3215	1484
4	2022	2420	634	408	2722	956	1212	2390
5	1162	1394	1694	487	303	1876	671	853
6	452	780	975	1152	346	199	1285	437
7	166	304	525	660	772	226	129	878
8	338	128	207	342	431	499	145	74
9	255	243	95	143	217	268	332	83
10	175	183	171	72	93	139	169	212
11	109	127	127	120	45	62	90	116
12+	226	502	378	296	192	159	153	170
TOTAL NO	17082	15727	14981	17207	15951	24674	29627	
SPS NO	7472	6591	5541	7219	6780	7368	7923	
TOT.BIOM	2802	2978	2888	2728	2854	2896	3164	
SPS BIOM	2218	2178	1807	2050	2028	2082	1990	

Table 6.16

Analysis by RCRTINX2 of data from file RTINX for age 1
WESTERN MACKEREL

Data for 1 surveys over 10 years
REGRESSION TYPE = C
TAPERED TIME WEIGHTING NOT APPLIED
PRIOR WEIGHTING NOT APPLIED
FINAL ESTIMATES SHRUNK TOWARDS MEAN
ESTIMATES WITH S.E.'S GREATER THAN THAT OF MEAN INCLUDED
MINIMUM S.E. FOR ANY SURVEY TAKEN AS .20
MINIMUM OF 5 POINTS USED FOR REGRESSION

Yearclass = 1990

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
0/1 GP	4.8442	.612	5.547	.8930	7	8.5116	.31147	.34709	.84845
MEAN						7.8419	.82124	.82124	.15155

Yearclass		Weighted Average Prediction	Internal Standard Error	External Standard Error	Virtual Population Analysis	Ext.SE/ Int.SE
1990	8.41	4492.14	.32	.24		.75

Table 6.17

Analysis by RCRTINX2 of data from file RTINX2 for age 2
WESTERN MACKEREL

Data for 2 surveys over 10 years
REGRESSION TYPE = C
TAPERED TIME WEIGHTING NOT APPLIED
PRIOR WEIGHTING NOT APPLIED
FINAL ESTIMATES SHRUNK TOWARDS MEAN
ESTIMATES WITH S.E.'S GREATER THAN THAT OF MEAN INCLUDED
MINIMUM S.E. FOR ANY SURVEY TAKEN AS .20
MINIMUM OF 5 POINTS USED FOR REGRESSION

Yearclass = 1989

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
1/2 GP	5.9915	1.006	3.833	.6850	7	9.8578	.59950	.84667	.14188
0/1 GP	5.0937	.598	5.411	.8928	6	8.4564	.32500	.38064	.70197
MEAN						7.6534	.80706	.80706	.15615

Yearclass		Weighted Average Prediction	Internal Standard Error	External Standard Error	Virtual Population Analysis	Ext.SE/ Int.SE
1989	8.53	5063.63	.32	.43		1.36

Table 6.18

List of input variables for the ICES prediction program.

WESTERN MACKEREL
The reference F is the mean F (non-weighted) for the age group range from 4 to 8

The number of recruits per year is as follows:

Year	Recruitment
1991	3300.0
1992	3300.0
1993	3300.0

Proportion of F (fishing mortality) effective before spawning: .4000
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	3300.0	.00	.15	.00	.061	.000
1	4500.0	.02	.15	.08	.168	.070
2	5000.0	.09	.15	.60	.234	.147
3	1534.0	.15	.15	.90	.338	.229
4	2372.0	.22	.15	.97	.381	.287
5	841.0	.27	.15	.97	.425	.341
6	439.0	.29	.15	.99	.470	.383
7	827.0	.31	.15	1.00	.529	.418
8	81.0	.31	.15	1.00	.559	.425
9	92.0	.30	.15	1.00	.612	.445
10	211.0	.30	.15	1.00	.608	.494
11	108.0	.27	.15	1.00	.591	.515
12+	159.0	.27	.15	1.00	.683	.586

For data that can be entered by file or manually by screen the following table gives the method of input by age group. The identifiers in the table are to be interpreted as:

space: not defined or set by the program
M : manual input by screen
F : data read from a file

age	F at age	M at age	maturity ogive	weight in the catch	weight in the stock
0	M	F	F	F	F
1	M	F	F	F	F
2	M	F	F	F	F
3	M	F	F	F	F
4	M	F	F	F	F
5	M	F	F	F	F
6	M	F	F	F	F
7	M	F	F	F	F
8	M	F	F	F	F
9	M	F	F	F	F
10	M	F	F	F	F
11	M	F	F	F	F
12+	M	F	F	F	F
proportion of F before spawning: F					
proportion of M before spawning: F					

The data from the files were selected as follows:

M at age:	year 1990 from file NATMOR
Maturity ogive:	year 1990 from file MORPROP
Catch weight:	year 1990 from file WECA
Stock weight:	mean values for years 1987 - 1990 from file WEST
Proportions of F and M:	from file MORPROP

Table 6.19

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

WESTERN MACKEREL

Year 1991					Year 1992					Year 1993	
factor	ref. F	stock biomass	sp.stock biomass	catch	factor	ref. F	stock biomass	sp.stock biomass	catch	stock biomass	sp.stock biomass
.9	.25	3213	2233	605	.6	.18	3373	2535	495	3511	2732
					.7	.20		2519	545	3471	2680
					.9	.25		2479	674	3367	2548
					1.0	.28		2460	733	3318	2488
1.0	.28	3213	2214	668	.6	.18	3322	2491	485	3469	2695
					.7	.20		2476	534	3429	2645
					.9	.25		2437	661	3327	2515
					1.0	.28		2418	720	3279	2456

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 1993 has been calculated with the same fishing mortality as for 1992.
The reference F is the mean F (non-weighted) for the age group range from 4 to 8

Table 6.20

Results

15.38.22 30 APRIL 1991
WESTERN MACKEREL

* Year 1991. F-factor 1.000 and reference F .2802 *

age	absolute F	catch in numbers	catch in weight	stock size	stock biomass	at 1 January sp.stock size	at 1 January sp.stock biomass	at spawning time sp.stock size	at spawning time sp.stock biomass
0	.0010	3.06	.187	3300.0	.00	.00	.00	.00	.00
1	.0200	82.77	13.905	4500.0	315.00	360.00	25.20	336.33	23.54
2	.0860	383.03	89.628	5000.0	736.25	3000.00	441.75	2729.76	401.96
3	.1540	203.71	68.853	1534.0	351.67	1380.60	316.50	1222.52	280.26
4	.2150	427.27	162.790	2372.0	681.36	2300.84	660.92	1988.29	571.14
5	.2750	188.41	80.074	841.0	286.57	815.77	277.97	688.24	234.52
6	.2910	103.30	48.552	439.0	168.25	434.61	166.56	364.33	139.63
7	.3120	206.63	109.307	827.0	345.48	827.00	345.48	687.46	287.19
8	.3080	20.02	11.189	81.0	34.40	81.00	34.40	67.44	28.65
9	.3010	22.29	13.641	92.0	40.94	92.00	40.94	76.81	34.18
10	.3000	50.97	30.992	211.0	104.23	211.00	104.23	176.24	87.06
11	.2750	24.20	14.299	108.0	55.57	108.00	55.57	91.12	46.88
12+	.2750	35.62	24.329	159.0	93.09	159.00	93.09	134.14	78.54
Total		1751.27	667.746	19464.0	3212.81	9769.82	2562.63	8562.68	2213.54

* Year 1992. F-factor 1.000 and reference F .2802 *

age	absolute F	catch in numbers	catch in weight	stock size	stock biomass	at 1 January sp.stock size	at 1 January sp.stock biomass	at spawning time sp.stock size	at spawning time sp.stock biomass
0	.0010	3.06	.187	3300.0	.00	.0	.00	.00	.00
1	.0200	52.19	8.768	2837.5	198.62	227.0	15.89	212.08	14.85
2	.0860	290.83	68.055	3796.5	559.03	2277.9	335.42	2072.70	305.21
3	.1540	524.39	177.244	3948.9	905.29	3554.0	814.76	3147.09	721.47
4	.2150	203.89	77.681	1131.9	325.13	1097.9	315.38	948.78	272.54
5	.2750	368.90	156.781	1646.6	561.09	1597.2	544.26	1347.53	459.17
6	.2910	129.38	60.808	549.8	210.72	544.3	208.61	456.30	174.88
7	.3120	70.57	37.332	282.4	117.99	282.4	117.99	234.79	98.08
8	.3080	128.75	71.971	521.0	221.31	521.0	221.31	433.81	184.26
9	.3010	12.41	7.597	51.2	22.80	51.2	22.80	42.78	19.04
10	.3000	14.16	8.608	58.6	28.95	58.6	28.95	48.95	24.18
11	.2750	30.14	17.813	134.5	69.22	134.5	69.22	113.51	58.40
12+	.2750	39.11	26.709	174.6	102.20	174.6	102.20	147.27	86.22
Total		1867.78	719.555	18433.6	3322.36	10520.8	2796.79	9205.57	2418.29

* Year 1993. F-factor 1.000 and reference F .2802 *

age	absolute F	catch in numbers	catch in weight	stock size	stock biomass	at 1 January sp.stock size	at 1 January sp.stock biomass	at spawning time sp.stock size	at spawning time sp.stock biomass
0	.0010	3.06	.187	3300.0	.00	.0	.00	.00	.00
1	.0200	52.19	8.768	2837.5	198.62	227.0	15.89	212.08	14.85
2	.0860	183.39	42.912	2393.9	352.50	1436.3	211.50	1306.95	192.45
3	.1540	398.17	134.581	2998.4	687.38	2698.6	618.64	2389.58	547.81
4	.2150	524.85	199.969	2913.7	836.97	2826.3	811.86	2442.39	701.58
5	.2750	176.03	74.813	785.7	267.74	762.2	259.71	643.02	219.11
6	.2910	253.32	119.060	1076.5	412.58	1065.8	408.45	893.40	342.40
7	.3120	88.39	46.756	353.8	147.78	353.8	147.78	294.06	122.84
8	.3080	43.97	24.581	177.9	75.58	177.9	75.58	148.16	62.93
9	.3010	79.85	48.867	329.6	146.66	329.6	146.66	275.17	122.45
10	.3000	7.88	4.794	32.6	16.12	32.6	16.12	27.26	13.47
11	.2750	8.37	4.947	37.4	19.23	37.4	19.23	31.53	16.22
12+	.2750	45.27	30.921	202.1	118.32	202.1	118.32	170.49	99.82
Total		1864.74	741.156	17439.2	3279.49	10149.5	2849.75	8834.09	2455.92

Table 7.1 Landings (tonnes) of Mackerel in Divisions VIIIc, and IXa, 1977-1990. (Data submitted by Working members.)

Division VIIIc

Country	1977	1978	1979	1980	1981	1982	1983
Spain	19,852	18,543	15,013	11,316	12,834	15,621	10,390
Total	19,852	18,543	15,013	11,316	12,834	15,621	10,390

Country	1984	1985	1986	1987	1988	1989	1990
Spain	13,852	11,810	16,533	15,982	16,844	13,446	16,086
Total	13,852	11,810	16,533	15,982	16,844	13,446	16,086

Division IXa

Country	1977	1978	1979	1980	1981	1982	1983
Portugal	1,743	1,555	1,071	1,929	3,108	3,018	2,239
Spain	2,935	6,221	6,280	2,719	2,111	2,437	2,224
Poland	8	-	-	-	-	-	-
USSR	2,879	189	111	-	-	-	-
Total	7,565	7,965	7,462	4,648	5,219	5,455	4,463

Country	1984	1985	1986	1987	1988	1989	1990
Portugal	2,250	4,178	6,419	5,650	4,150	3,016	3,509
Spain	4,206	2,123	1,837	491	3,540	1,763	1,406
Poland	-	-	-	-	-	-	-
USSR	-	-	-	-	-	-	-
Total	6,456	6,301	8,256	6,141	7,690[2]	4,779[2]	4,915[2]

Table 7.2 Spanish and Portuguese landings of Mackerel by gear (tonnes) in Divisions VIIIc, and IXa 1985-1990. (Data submitted by Working Group members.)

Division VIIIc

Gear	1985	1986	1987	1988	1989	1990
Purse seine	4,208	2,105	4,277	7,413	5,659	5,370
Trawl	1,135	2,850	1,900	2,321	2,273	3,842
Hook	6,371	11,323	9,739	6,799	5,208	6,532
Gillnet	96	255	66	312	306	343
Total	11,810	16,533	15,982	16,845	13,446	16,086

Division IXa

Gear	1985	1986	1987	1988	1989	1990
Spain	2,123	1,837	491[1]	3,540	1,763	1,406
Purse seine	1,221	1,436	254[1]	2,644	1,151	910
Trawl	902	401	237[1]	896	612	496
Artisanal	-	-	-	-	-	-
Portugal	4,178	6,419	5,650	4,150	3,016	3,509
Purse seine	13	1,511	1,564	1,623	1,458	1,470
Trawl	3,658	3,544	2,776	1,656	1,312	1,650
Artisanal	507	1,364	1,310	871	246	389

[1] Estimated catch does not include Riveira landing port.

Table 7.3 MACKEREL in Division IXa (Portugal). Catch in numbers ('000) by age group in 1981-1990.

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
0	7,861	10,964	4,500	20,801	37,264	4,773	2,110	77,652	7,792	1,902
1	7,298	6,631	5,351	1,705	44,234	21,929	12,983	8,924	7,170	5,783
2	2,539	7,894	2,893	2,059	3,316	7,078	4,595	1,388	2,406	3,644
3	878	1,264	1,296	1,169	594	3,046	2,128	1,357	987	435
4	158	298	159	255	218	431	535	448	608	95
5	66	71	43	63	57	194	771	155	142	39
6	52	47	11	17	39	76	55	39	20	18
7	25	68	11	6	3	48	60	6	5	29
8	15	41	8	9	3	3	48	18	9	1
9	10	24	7	10	3	1	3	6	6	0
10+	56	101	14	8	11	14	48	2	4	0
Tonnes	3,108	3,018	2,239	2,250	4,178	6,419	5,650	4,150	3,016	3,509

<u>Table 7.4</u> Mackerel in Divisions VIIIc and IXa (Spain). Catch in numbers ('000) by age group and division in 1982 - 1990.

Age	Divisions VIIIc + IXa						Division VIIIc			Division IXa			Age
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1988	1989	1990	
0	2	7	271,337	61,231	20,859	2,449	459	7,320	7,438	40,274	30,957	5,980	0
1	7	694	13,928	4,643	12,903	4,149	5,951	1,667	17,051	29,438	7,992	5,451	1
2	348	1,581	2,149	383	3,224	3,509	1,908	2,742	2,222	841	486	1,134	2
3	1,745	4,894	7,669	1,508	1,134	8,495	4,648	2,367	1,785	359	75	347	3
4	1,321	5,046	4,500	10,319	2,177	4,162	9,003	3,025	2,453	93	34	175	4
5	929	968	6,425	3,284	9,038	8,769	2,923	5,922	4,509	36	46	84	5
6	1,628	313	1,630	2,012	2,606	6,973	5,433	2,501	6,505	51	25	79	6
7	4,607	409	926	720	179	1,652	12,785	3,998	1,882	183	40	16	7
8	3,859	2,230	1,575	522	1,096	1,776	5,508	4,885	4,679	77	78	35	8
9	2,676	1,676	1,532	1,022	448	1,079	1,785	1,833	5,426	31	22	38	9
10+	11,694	3,350	2,546	3,468	6,475	3,801	530	578	1,522	45	11	9	10
							284	150	692	-	4	5	11
							752	112	594	-	-	2	12
							713	240	57	-	6	-	13
							124	58	135	-	1	1	14
							931	330	145	-	4	-	15+
Tonnes	18,058	12,614	18,058	13,933	18,370	16,473	16,884	13,446	16,086	3,540	1,763	1,406	

Table 7.5. Catch in numbers ('000) by quarter, geographical area, and age, in 1990 for Divisions VIIIc and IXa.

FIRST QUARTER

	VIIIc								IXa	
AGE	EAST. C(n)	part W(g)	CENTR. C(n)	part W(g)	WEST. C(n)	part W(g)	TOTAL C(n)	MEAN W(g)	NORTH. C(n)	part W(g)
0	0		0		0		0		0	
1	0	155	3265	54	9219	93	12484	83	480	96
2	313	207	167	174	306	152	786	178	312	175
3	475	249	158	251	155	236	788	247	128	219
4	583	298	189	299	149	302	921	299	70	260
5	1019	366	355	366	257	352	1631	364	63	330
6	1499	407	496	415	365	387	2360	406	65	380
7	517	480	210	486	71	454	798	480	15	463
8	1326	500	564	512	167	475	2056	501	31	461
9	1553	524	731	533	138	502	2422	526	35	494
10	439	512	192	522	50	496	681	513	8	476
11	179	569	97	581	12	516	288	571	4	542
12	177	541	80	556	19	532	276	545	2	499
13	10	691	18	749	1	688	29	727		
14	42	553	18	553	2	553	62	553	1	553
15+	41	726	36	765	1	688	78	743		
TOTAL	8173	434	6575	254	10912	132	25659	259	1214	196
TONNES	3516		1796		1459		6772		237	

SECOND QUARTER

	VIIIc								IXa	
AGE	EAST. C(n)	part W(g)	CENTR. C(n)	part W(g)	WEST. C(n)	part W(g)	TOTAL C(n)	MEAN W(g)	NORTH. C(n)	part W(g)
0	0		0		0		0		0	
1	1	139	1893	55	701	113	2595	70	3839	79
2	48	226	295	186	204	150	547	176	434	155
3	290	275	316	252	102	250	708	261	105	201
4	721	323	495	313	156	312	1372	318	38	239
5	1513	368	956	363	296	363	2765	366	18	285
6	2265	400	1394	396	431	399	4090	399	14	305
7	593	472	328	466	143	484	1064	472	1	464
8	1438	485	780	483	397	514	2615	489	3	472
9	1628	518	852	517	525	549	3004	523	3	498
10	468	498	240	498	133	525	841	502	1	491
11	202	570	100	566	83	600	386	576	0	508
12	168	525	88	537	62	565	318	536	0	520
13	3	721	17	755	9	688	28	730	0	
14	38	553	20	553	14	553	73	553	0	553
15+	2	696	49	744	13	703	64	734	0	
TOTAL	9377	434	7823	325	3270	368	20469	382	4459	93
TONNES	4166		2717		1285		8168		411	

continued

Table 7.5 continued

THIRD QUARTER

AGE	VIIIc EAST. C(n)	part W(g)	CENTR. C(n)	part W(g)	WEST. C(n)	part W(g)	TOTAL C(n)	MEAN W(g)	IXa NORTH. C(n)	part W(g)
0	2	123	107	76	3188	71	3297	71	5059	86
1	9	147	6	177	1046	148	1061	148	966	134
2	4	172	4	207	456	152	463	152	331	144
3	8	267	13	277	138	223	159	230	96	202
4	7	283	13	292	54	294	74	292	57	216
5	7	355	16	379	47	371	69	371	2	283
6	2	428	5	428	29	458	36	452	0	
7	1	431	3	459	9	448	13	449	0	
8	0	371	0	371	5	576	6	551	0	
9	0		0		0		0		0	
10	0		0		0		0		0	
11	2	285	2	285	7	285	10	285	1	285
12	0		0		0		0		0	
13	0		0		0		0		0	
14	0		0		0		0		0	
15+	0		0	820	3	843	3	842	0	
TOTAL	42	256	169	163	4982	108	5192	111	6511	99
TONNES	10		27		540		577		643	

FOURTH QUARTER

AGE	VIIIc EAST. C(n)	part W(g)	CENTR. C(n)	part W(g)	WEST. C(n)	part W(g)	TOTAL C(n)	MEAN W(g)	IXa NORTH. C(n)	part W(g)
0	0		3800	66	341	109	4141	69	921	86
1	0	200	20	134	890	150	911	150	167	134
2	0	252	9	153	418	159	427	159	57	144
3	1	323	34	307	95	213	130	239	18	203
4	2	350	28	327	56	231	85	265	11	217
5	2	418	33	365	9	269	43	348	0	282
6	2	415	18	443	0		20	440	0	
7	1	435	7	432	0		8	433	0	
8	0	518	2	371	0		2	397	0	
9	0		0		0		0		0	
10	0		0		0		0		0	
11	0	285	6	285	2	285	8	285	0	285
12	0		0		0		0		0	
13	0		0		0		0		0	
14	0		0		0		0		0	
15+	0		0	820	0		0	820	0	
TOTAL	8	390	3957	75	1809	151	5774	99	1174	99
TONNES	3		292		276		571		115	

Table 8.1 VIRTUAL POPULATION ANALYSIS

Mackerel in the Western Area (combined western and southern catches)

CATCH IN NUMBERS UNIT: millions

	1984	1985	1986	1987	1988	1989	1990
0	293	99	44	7	59	71	21
1	31	283	61	40	143	60	137
2	84	20	408	157	131	312	209
3	670	51	34	664	182	207	411
4	379	431	66	57	515	167	208
5	245	296	341	89	70	363	157
6	94	179	197	244	83	48	254
7	16	60	120	150	192	58	43
8	53	17	39	86	117	111	50
9	41	43	12	34	53	69	85
10	28	36	35	22	23	33	35
11	28	24	27	31	17	19	24
12+	58	95	79	77	72	48	40
TOTAL	2019	1633	1462	1658	1657	1564	1672

Table 8.2

Title : Mackerel in the Western Area (combined western and southern catches)
At 14.10.58 29 APRIL 1991
from 84 to 90 on ages 0 to 11
with Terminal F of .275 on age 5 and Terminal S of 1.000

Initial sum of squared residuals was 31.438 and
final sum of squared residuals is 12.243 after 92 iterations

Matrix of Residuals

Years / Ages	84/85	85/86	86/87	87/88	88/89	89/90		WTS
0/ 1	.511	.984	.825	-2.314	.501	.003	.000	.074
1/ 2	1.216	.422	.074	-.208	.020	-.310	.000	.163
2/ 3	.740	-.276	.018	.303	-.184	.139	.000	.247
3/ 4	.400	-.273	-.292	.410	.052	.103	.000	.295
4/ 5	.096	.111	-.188	-.169	.197	.050	.000	.574
5/ 6	-.113	.013	.167	-.172	-.071	.062	.000	.731
6/ 7	.051	.032	.127	.027	-.048	-.138	.000	1.000
7/ 8	-.478	-.018	.132	-.023	.083	-.174	.000	.410
8/ 9	-.270	-.080	-.073	.183	.053	-.084	.000	.597
9/10	-.237	-.118	-.727	.247	.131	.467	.000	.216
10/11	-.222	-.026	.020	.076	-.172	.102	.000	.687
	.000	.000	.000	.000	.000	.000	1.693	
WTS	.001	1.000	1.000	1.000	1.000	1.000		

Fishing Mortalities (F)

	84	85	86	87	88	89	90
F-values	.2032	.1889	.1789	.2157	.2507	.2436	.2750

Selection-at-age (S)

	0	1
S-values	.0570	.1168

	2	3	4	5	6	7	8	9	10	11
S-values	.3280	.5730	.7832	1.0000	.9925	1.0117	.9674	.8996	.9486	1.0000

Table 8.3 VIRTUAL POPULATION ANALYSIS

Mackerel in the Western Area (combined western and southern catches)

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

	1984	1985	1986	1987	1988	1989	1990
0	.043	.040	.017	.002	.018	.014	.016
1	.040	.050	.030	.019	.038	.022	.032
2	.082	.031	.090	.095	.074	.104	.095
3	.206	.062	.065	.196	.144	.152	.184
4	.196	.188	.102	.140	.217	.181	.212
5	.223	.219	.210	.182	.240	.221	.243
6	.212	.238	.209	.217	.244	.248	.225
7	.085	.192	.235	.232	.250	.254	.338
8	.142	.110	.177	.249	.269	.211	.339
9	.145	.156	.098	.217	.229	.236	.236
10	.157	.176	.174	.256	.207	.203	.170
11	.203	.189	.180	.217	.306	.248	.209
12+	.203	.189	.180	.217	.306	.248	.209
(4- 8)U	.172	.189	.187	.204	.244	.223	.272
(4- 8)W	.195	.202	.194	.208	.232	.213	.235

Table 8.4 VIRTUAL POPULATION ANALYSIS

Mackerel in the Western Area (combined western and southern catches)

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

	1984	1985	1986	1987	1988	1989	1990	1991
0	7542	2696	2764	4760	3484	5496	1431	0
1	840	6220	2229	2338	4090	2945	4665	1212
2	1150	694	5091	1862	1975	3388	2479	3888
3	3865	912	579	4004	1458	1579	2627	1940
4	2286	2707	738	467	2832	1087	1167	1881
5	1315	1617	1931	574	350	1962	781	813
6	527	906	1118	1347	412	237	1354	527
7	218	367	614	781	933	277	159	930
8	430	173	261	418	533	626	185	98
9	326	321	133	188	281	350	436	113
10	204	243	236	104	130	192	238	297
11	164	150	175	171	69	91	135	173
12+	338	591	513	423	295	234	229	254
TOTAL NO	19205	17596	16384	17437	16843	18463	15886	
SPS NO	8676	7636	6484	8158	7467	7601	7726	
TOT.BIOM	3270	3431	3326	3111	3161	3092	2913	
SPS BIOM	2622	2558	2168	2389	2345	2263	2087	

Table 8.5

List of input variables for the ICES prediction program.

WESTERN MACKEREL COMBINED ASSESSMENT
The reference F is the mean F (non-weighted) for the age group range from 4 to 8

The number of recruits per year is as follows:

Year	Recruitment
1991	4100.0
1992	4100.0
1993	4100.0

Proportion of F (fishing mortality) effective before spawning: .4000
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	4100.0	.02	.15	.00	.061	.000
1	3800.0	.03	.15	.08	.168	.070
2	4200.0	.09	.15	.60	.234	.147
3	1950.0	.16	.15	.90	.338	.229
4	1931.0	.22	.15	.97	.381	.287
5	810.0	.27	.15	.97	.425	.341
6	511.0	.27	.15	.99	.470	.383
7	887.0	.28	.15	1.00	.529	.418
8	104.0	.27	.15	1.00	.559	.425
9	122.0	.25	.15	1.00	.612	.445
10	293.0	.26	.15	1.00	.608	.494
11	158.0	.27	.15	1.00	.591	.515
12+	238.0	.27	.15	1.00	.683	.586

Table 8.6

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

WESTERN MACKEREL COMBINED ASSESSMENT

Year 1991					Year 1992					Year 1993	
factor	ref. F	stock biomass	sp.stock biomass	catch	factor	ref. F	stock biomass	sp.stock biomass	catch	stock biomass	sp.stock biomass
.9	.24	3192	2290	626	1.0	.26	3293	2400	720	3280	2412

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 1993 has been calculated with the same fishing mortality as for 1992.
The reference F is the mean F (non-weighted) for the age group range from 4 to 8

Table 9.1 Estimated catch in numbers ('000) of North Sea mackerel stock in 1988-1990 by quarter.

	1988					1989					1990				
Quarter	1	2	3	4	Sum	1	2	3	4	Sum	1	2	3	4	Sum
%	2.8	0.4	25.5	71.3		5.5	0.6	36.4	57.5		13.2	0.6	22.8	63.4	
Age															
1	81	12	741	2,072	2,906	115	13	746	1,206	2,098	172	8	297	825	1,302
2	87	12	795	2,224	3,118	449	49	2,969	4,689	8,156	571	26	986	2,740	4,323
3	94	13	859	2,402	3,368	445	49	2,947	4,654	8,095	2,795	127	4,829	13,429	21,180
4	53	8	486	1,358	1,905	129	14	854	1,349	2,346	744	34	1,286	3,576	5,640
5	11	2	99	276	388	73	8	482	760	1,323	216	10	374	1,040	1,640
6	45	6	414	1,158	1,623	16	1	103	162	282	121	6	209	581	917
7	27	4	243	678	952	62	7	411	649	1,129	26	1	44	123	194
8	30	4	274	768	1,076	37	4	245	387	673	105	5	181	503	794
9	1	+	9	25	35	41	4	270	426	741	60	3	104	291	458
10	15	2	139	391	547	2	+	13	20	35	70	3	121	335	529
11	3	+	31	88	123	21	2	142	223	388	2	+	4	12	18
12	1	+	5	12	18	5	1	32	51	88	35	2	60	168	265
13	4	1	36	101	142	1	+	7	10	18	7	+	12	34	53
14	2	+	22	61	85	3	+	21	36	59	+	+	+	1	1
15	16	2	146	403	567	27	3	178	280	488	51	2	89	246	388

Table 9.2 Mean weight at age (g) by quarter in the North Sea mackerel stock and mean weight in catch.

	Quarter[1]				
Age	1	2	3	4	Mean weight in catch
1	180	140	180	180	180
2	210	255	240	210	215
3	240	330	280	240	250
4	260	395	330	260	275
5	300	450	375	300	320
6	325	500	420	325	350
7	355	540	465	355	380
8	380	570	510	380	410
9	410	605	550	410	445
10	435	635	585	435	470
11	465	670	620	465	500
12	500	700	650	500	535
13	530	730	680	530	565
14	560	765	705	560	595
15	590	790	720	590	620

[1] Data from Anon. (1990).

Table 9.3 Percentages of each mackerel stock assumed present in the North Sea during each quarter of 1990.

	North Sea Stock				Western Stock			
Age	1	2	3	4	1	2	3	4
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

Table 10.1 Summary of commercial fishery samples taken by quarter and division during 1990.

Division	Quarter	1990 Catch ('000 t)	Number of commercial samples Total	Number of commercial samples Per 1000t	Number measured Total	Number measured Per 1000t	Number measured Per sample	Number aged Total	Number aged Per 1000t	Number aged Per sample
IIa,Vb	1									
	2									
	3	84.3	90	1.1	4000	47.4	44	900	10.7	10
	4	32.5	54	1.7	2400	73.8	44	500	15.4	9
	1-4	116.8	144	1.2	6400	54.8	44	1400	12	10
IIIa	1	+	0		0			0		
	2	0.5	12	24	600	1200	50	100	200	8
	3	4.9	22	4.5	1100	224.5	50	200	40.8	9
	4	2.5	6	2.4	300	120	50	0	0	0
	1-4	7.9	40	5.1	2000	253.2	50	300	38	8
IV	1	40.1	5	0.1	303	7.6	61	125	3.1	25
	2	1.2	0	0	0	0		0	0	
	3	64.7	130	2	6571	101.6	51	1929	29.8	15
	4	191.2	156	0.8	11940	62.4	77	3678	19.2	24
	1-4	297.2	291	1	18814	63.3	65	5732	19.3	20
VI	1	105.2	33	0.3	3076	29.2	93	1370	13	42
	2	0.7	10	14.3	1497	2138.6	150	752	1074.3	75
	3	1.2	9	7.5	892	743.3	99	243	202.5	27
	4	13.5	19	1.4	2327	172.4	122	665	49.3	35
	1-4	120.6	71	0.6	7792	64.6	110	3030	25.1	43
VII	1	23.6	19	0.8	1650	69.9	87	1229	52.1	65
	2	22.7	13	0.6	954	42	73	544	24	42
	3	3.1	4	1.3	27	8.7	7	161	51.9	40
	4	9.5	19	2	848	89.3	45	397	41.8	21
	1-4	58.9	55	0.9	3479	59.1	63	2331	39.6	42
VIIIa,b,d,e	1	0.8	13	16.3	1343	1678.8	103	421	526.3	32
	2	1.2	3	2.5	344	286.7	115	228	190	76
	3	0.6	0	0	0	0		0	0	
	4	0.3	0	0	0	0		0	0	
	1-4	2.9	16	5.5	1687	581.7	105	649	223.8	41
VIIIc-IXa	1	7.9	120	15.2	8420	1065.8	70	645	81.6	5
	2	9.9	135	13.6	9041	913.2	67	651	65.8	5
	3	2.1	88	41.9	6923	3296.7	79	126	60	1
	4	1.3	62	47.7	4515	3473.1	73	156	120	3
	1-4	21.2	405	19.1	28899	1363.2	71	1578	74.4	4
Grand total 1990		625.5	1022	1.6	69071	110.4	68	15020	24	15

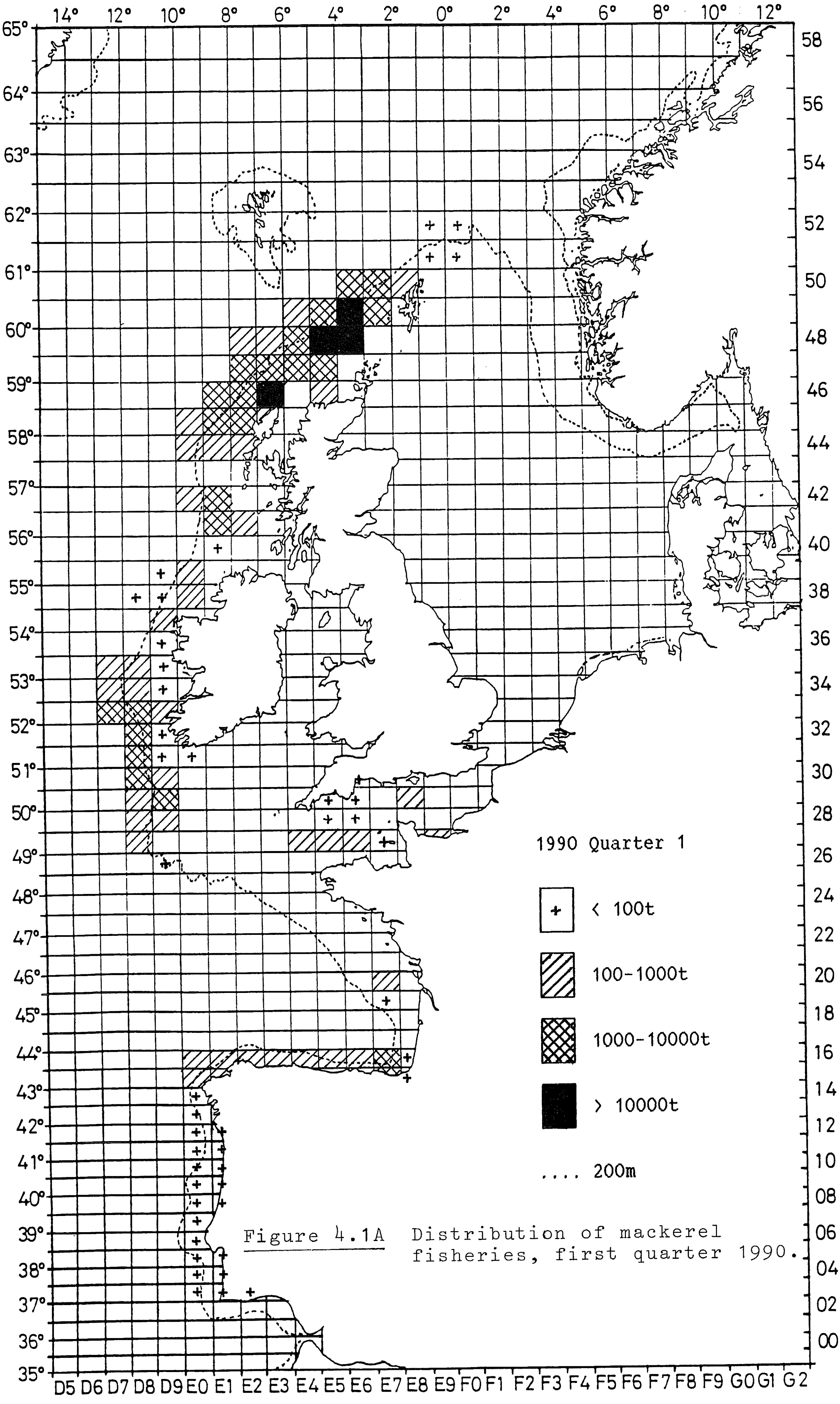


Figure 4.1A Distribution of mackerel fisheries, first quarter 1990.

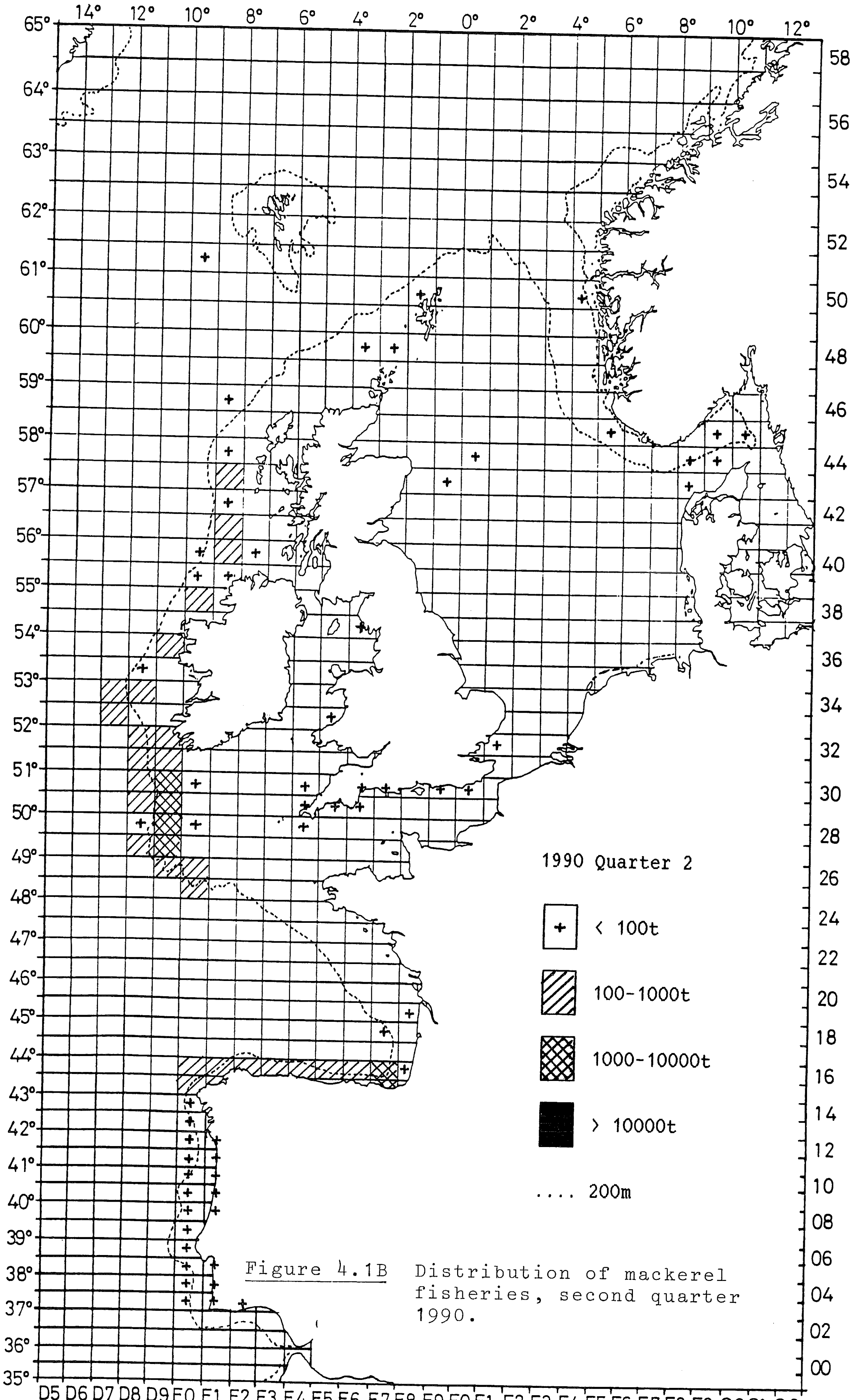


Figure 4.1B Distribution of mackerel fisheries, second quarter 1990.

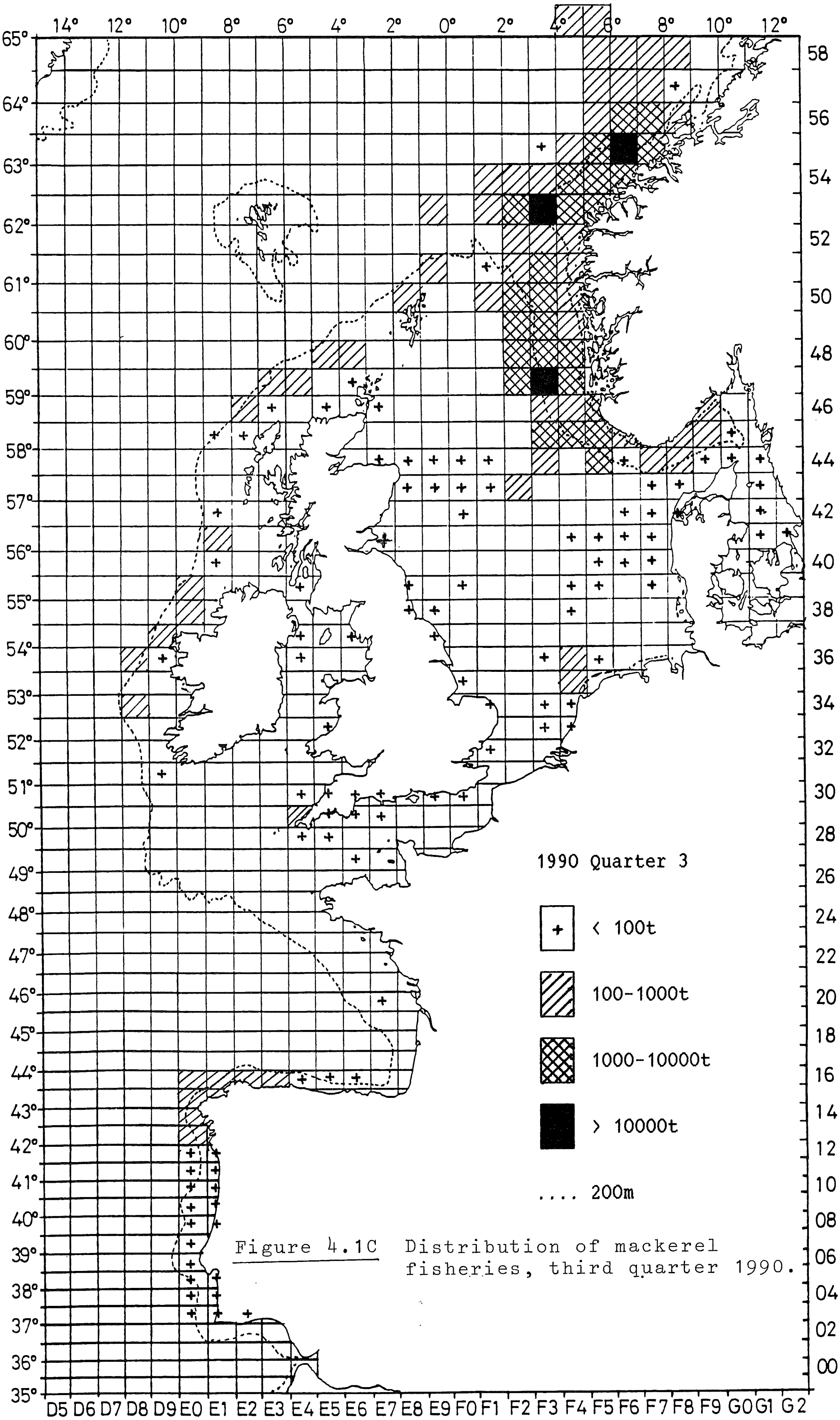


Figure 4.1C Distribution of mackerel fisheries, third quarter 1990.

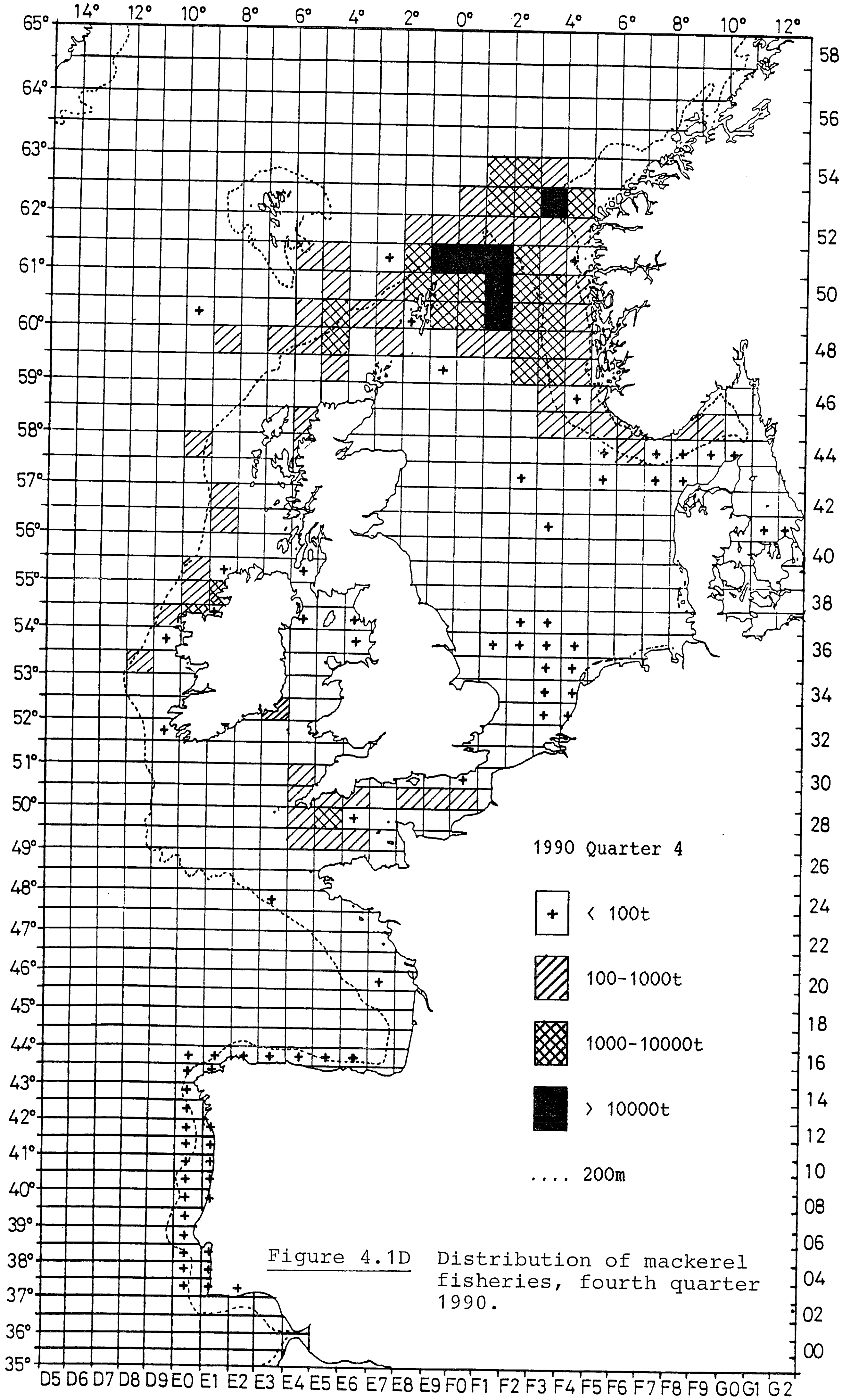


Figure 4.1D Distribution of mackerel fisheries, fourth quarter 1990.

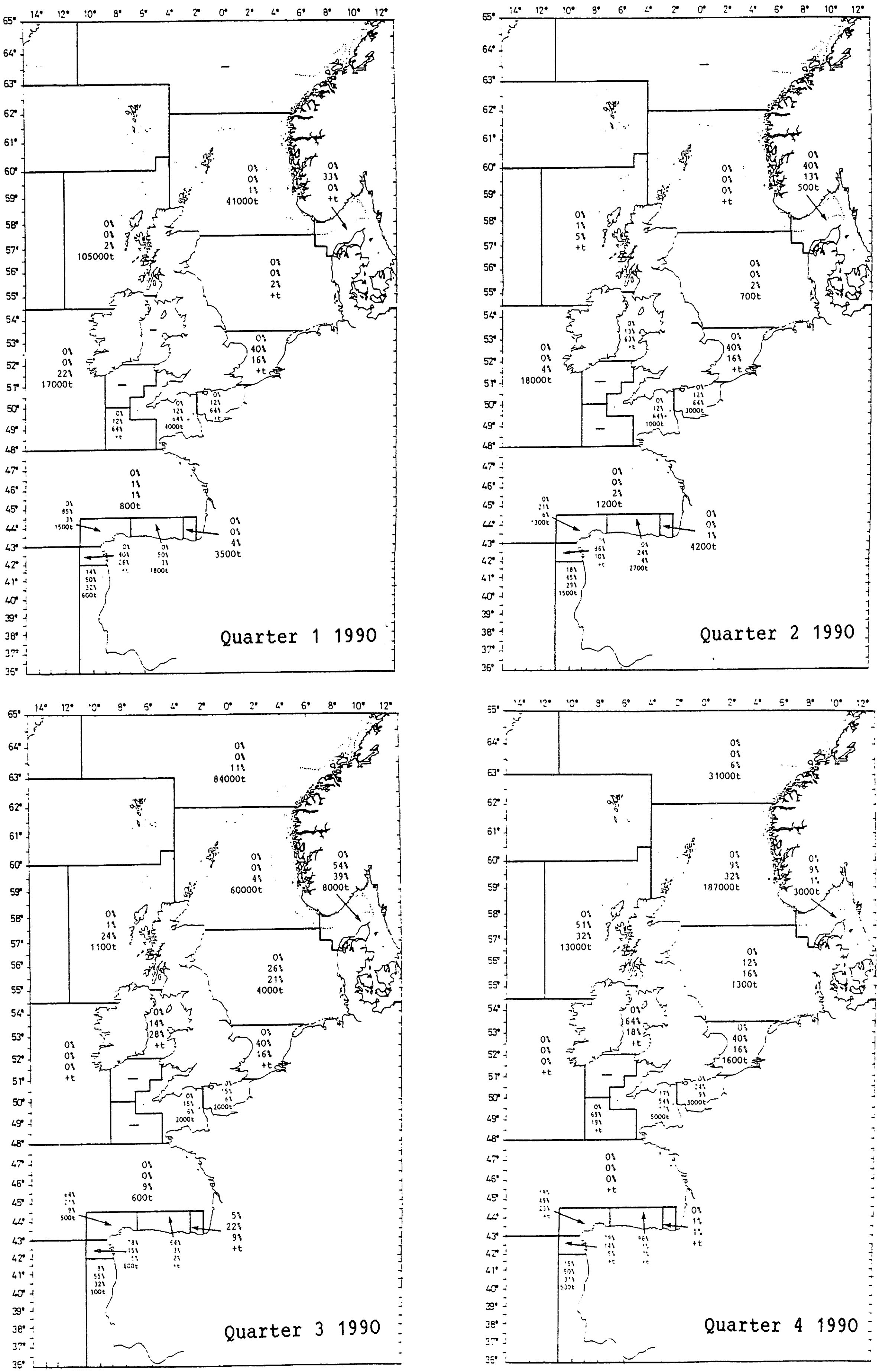


Figure 4.2 The occurrence of juvenile mackerel expressed as a percentage by numbers in the commercial catches that could be allocated to ICES divisions or sub-divisions in 1990. Values in each area are expressed from top to bottom as; 0-group; 1-group; 2-group; tonnage (+ = less than 500 t).

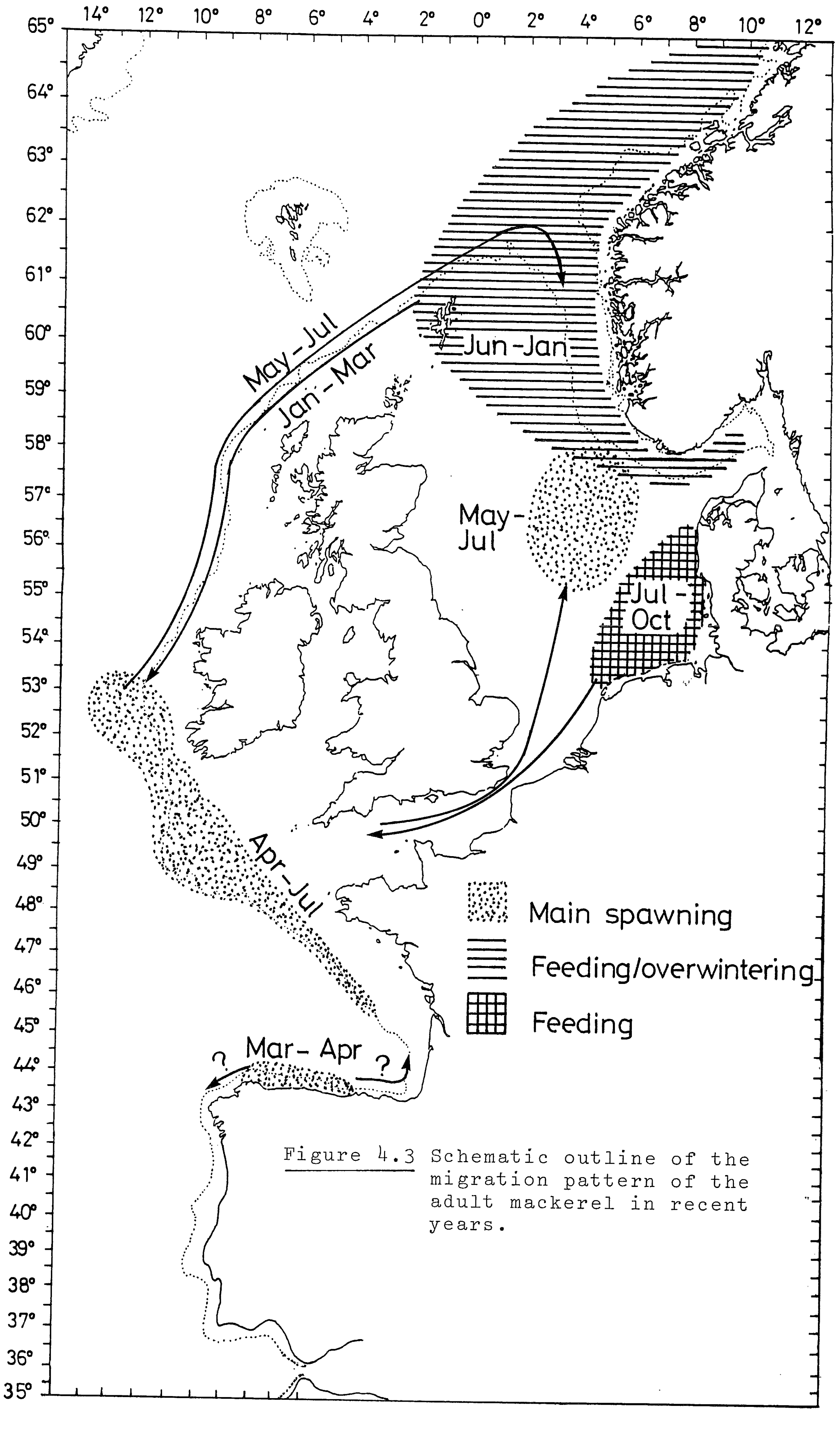


Figure 4.3 Schematic outline of the migration pattern of the adult mackerel in recent years.

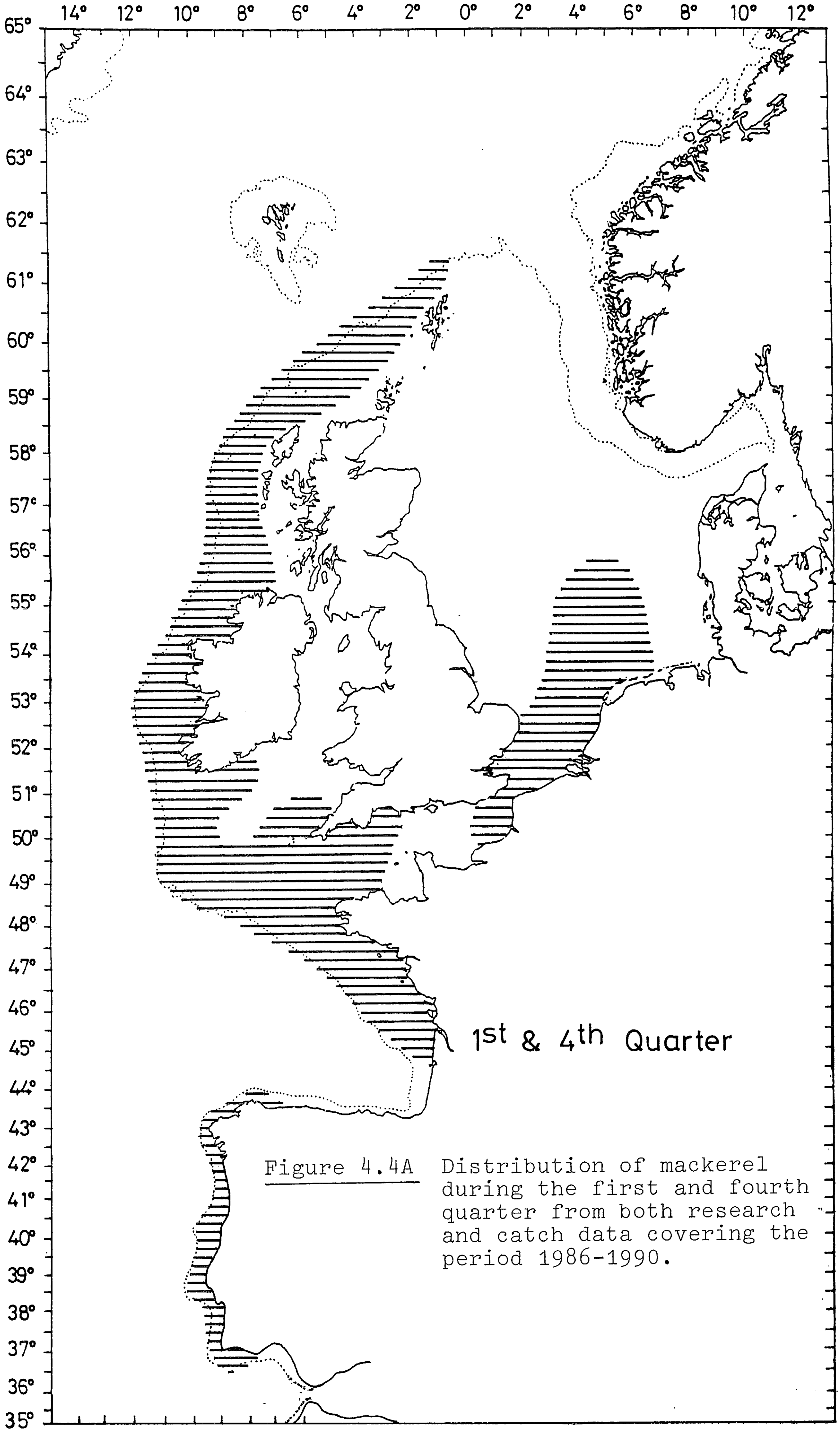
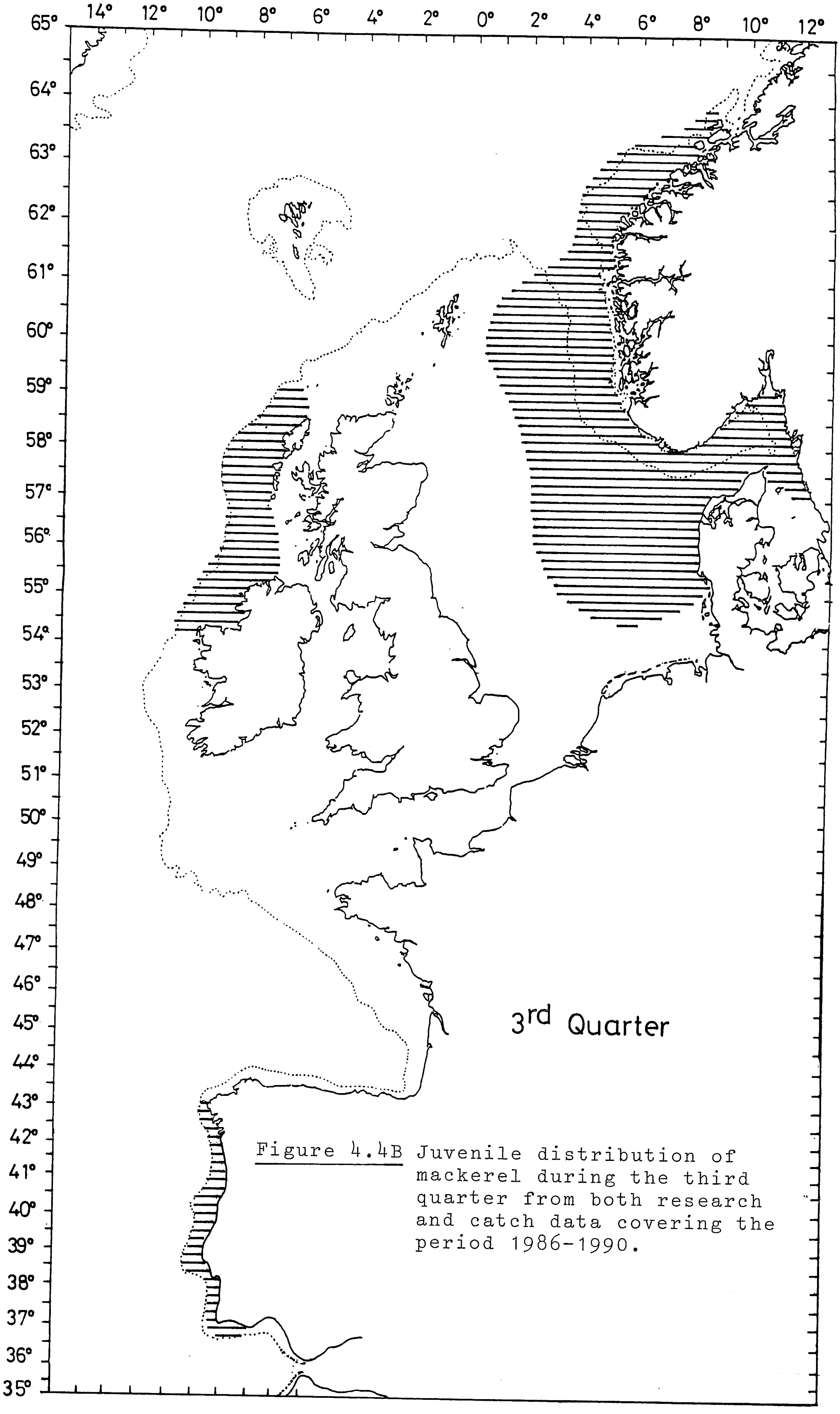


Figure 4.4A Distribution of mackerel during the first and fourth quarter from both research and catch data covering the period 1986-1990.



<u>Figure 4.4B</u> Juvenile distribution of mackerel during the third quarter from both research and catch data covering the period 1986-1990.

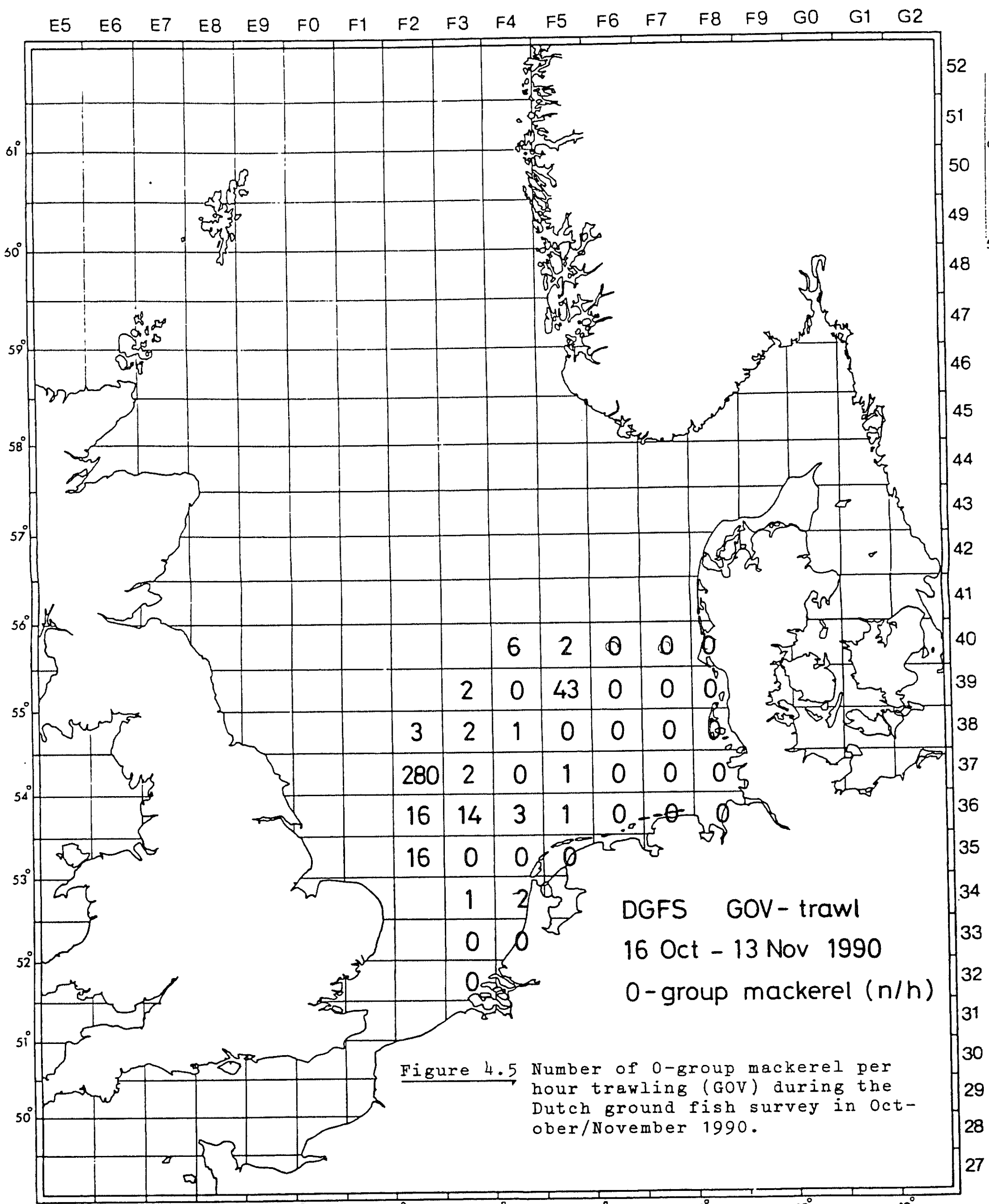


Figure 4.5 Number of 0-group mackerel per hour trawling (GOV) during the Dutch ground fish survey in October/November 1990.

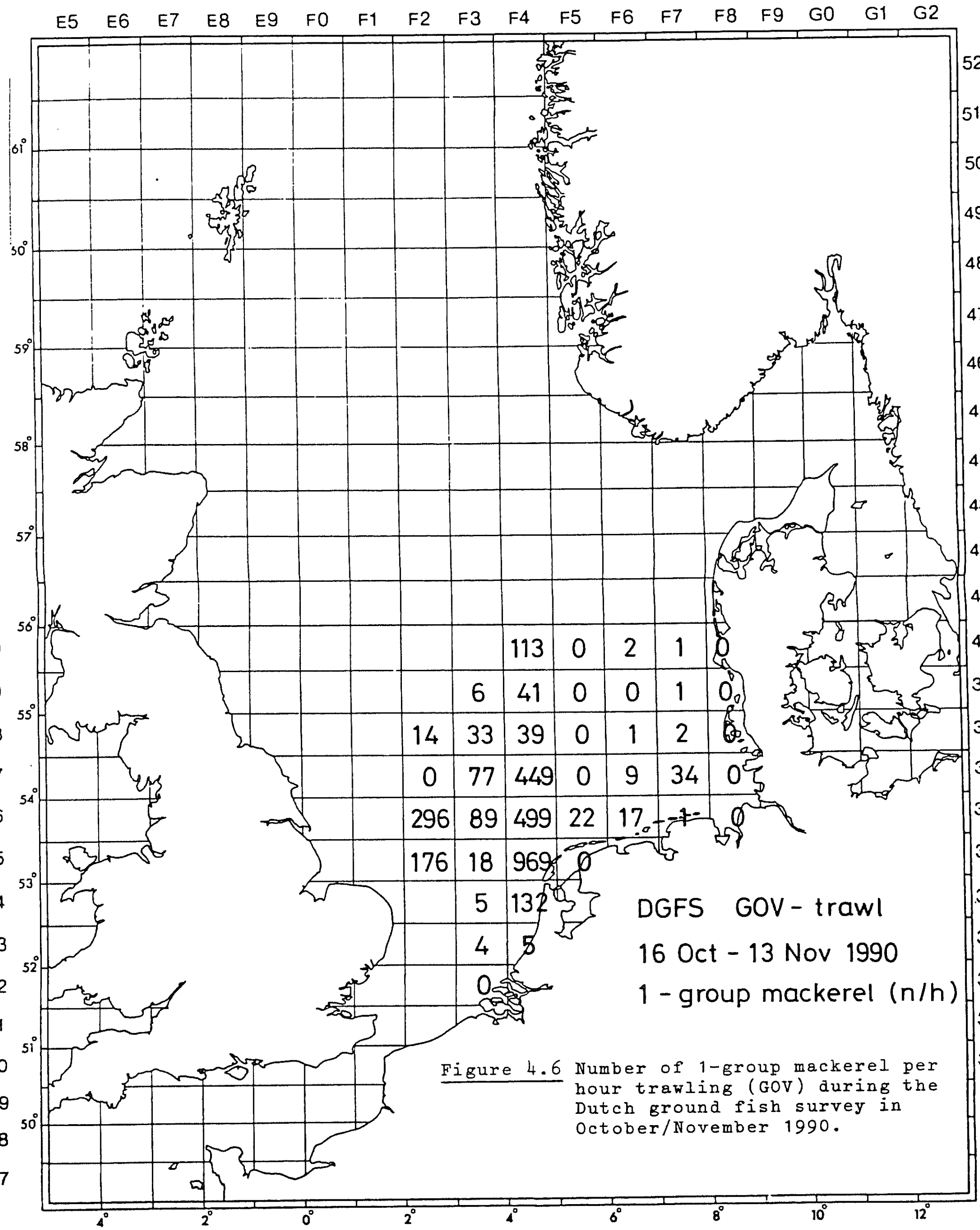
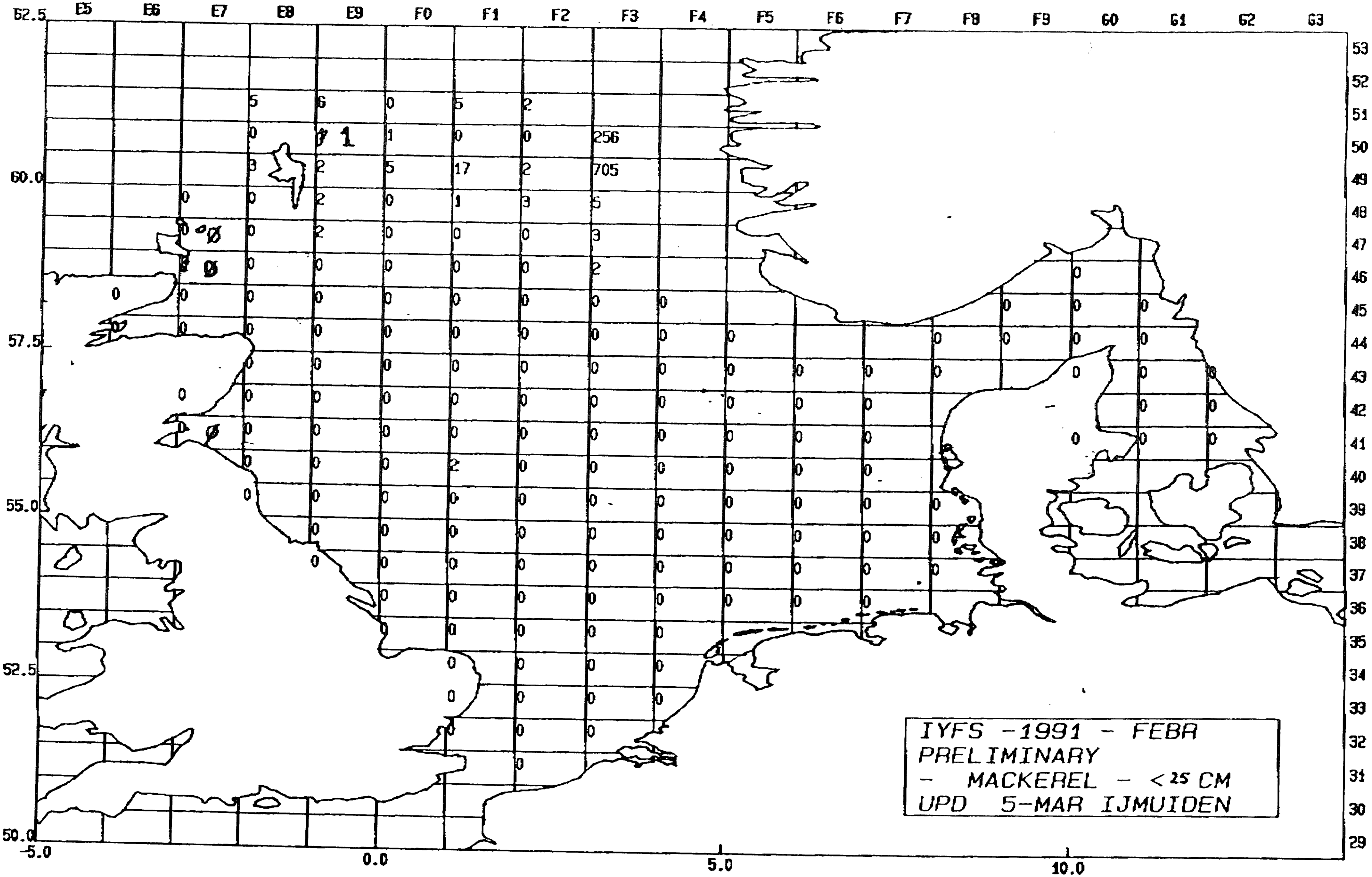


Figure 4.6 Number of 1-group mackerel per hour trawling (GOV) during the Dutch ground fish survey in October/November 1990.

Figure 5.1 Catch in numbers per hour of the 1990 year class during the 1991 International Young Fish Survey in the North Sea and Division IIIa.



1st Winter Mackerel (Yr Class 1990) Nos/Hr Trawled 10/90 - 3/91

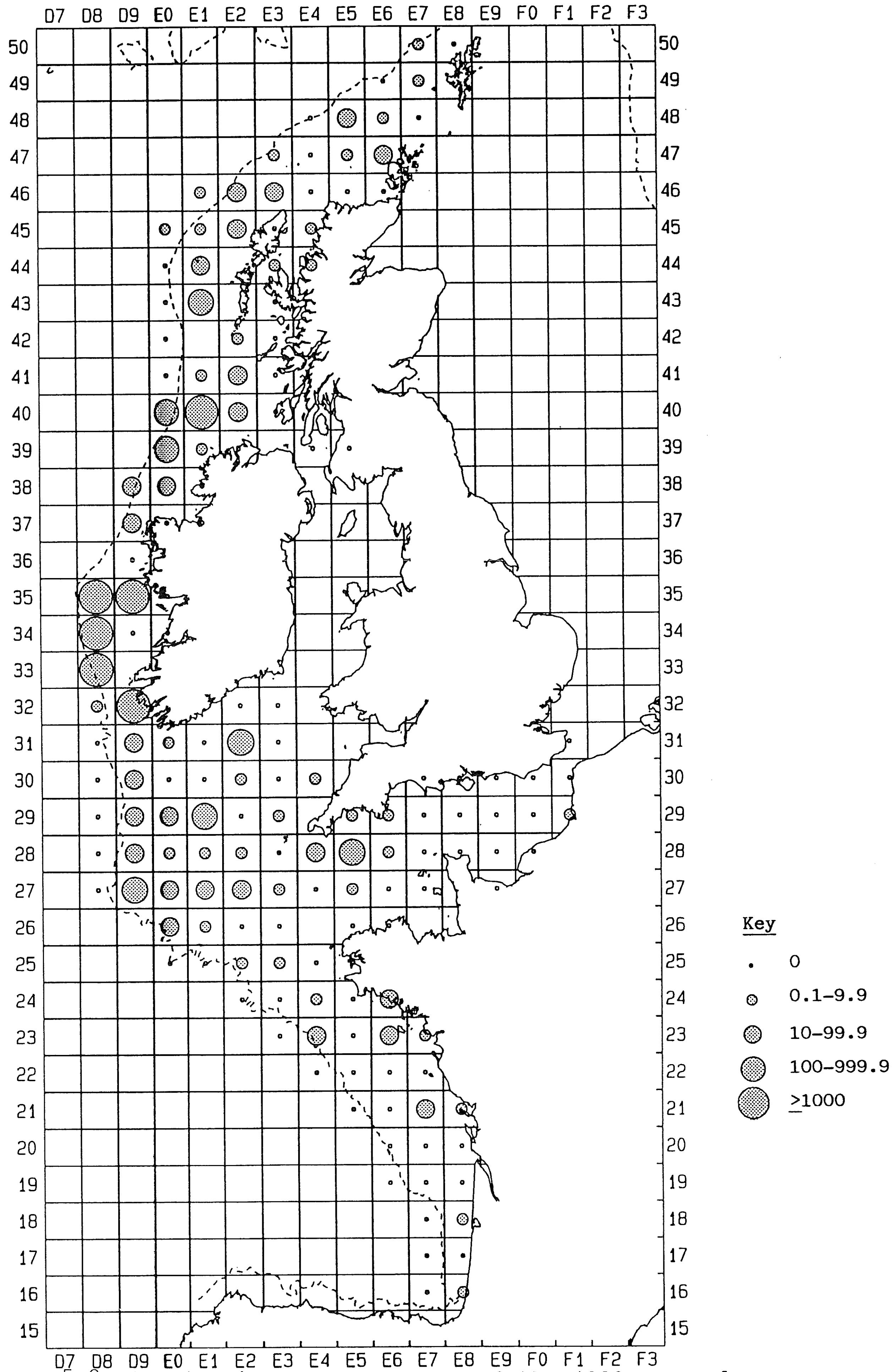


Figure 5.2 Distribution and abundance of the 1990 year class in the western area between October 1990 and March 1991.

2nd Winter Mackerel (Yr Class 1989) Nos/Hr Trawled 10/90 - 3/91

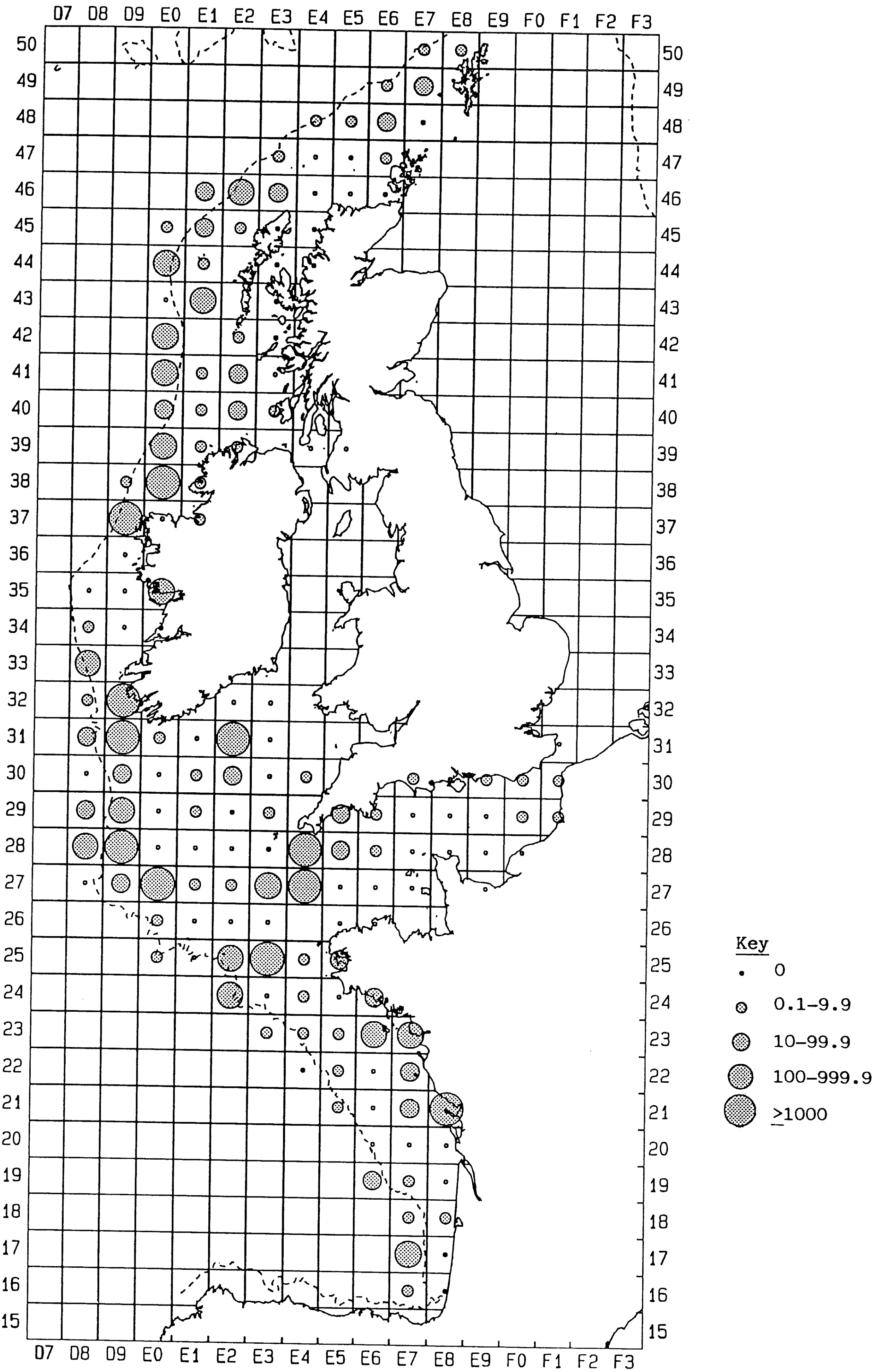


Figure 5.3 Distribution and abundance of the 1989 year class in the western area between October 1990 and March 1991.

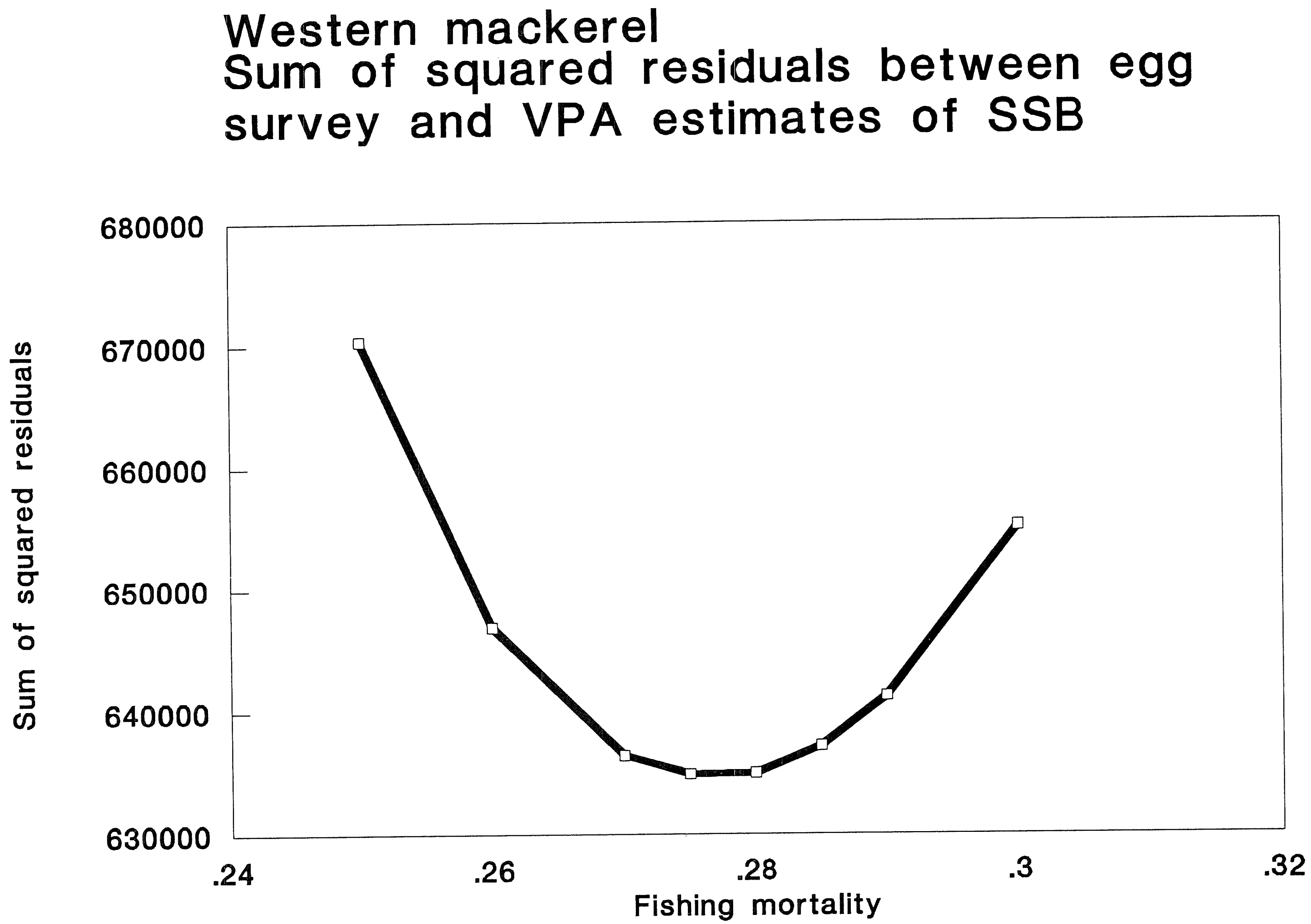
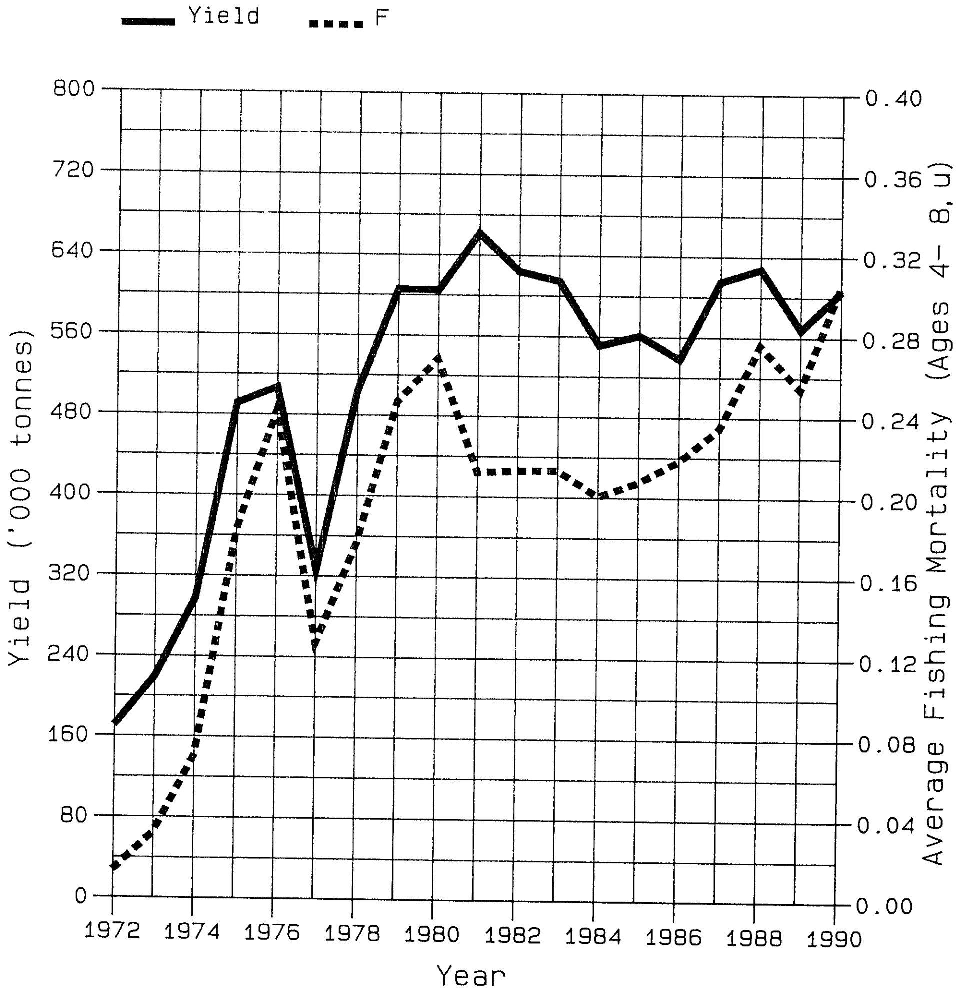

Western mackerel
Sum of squared residuals between egg survey and VPA estimates of SSB
680000
670000
660000
650000
640000
630000
Sum of squared residuals
.24
.26
.28
.3
.32
Fishing mortality

Figure 6.1

FISH STOCK SUMMARY
Mackerel in the Western Area
30-04-1991

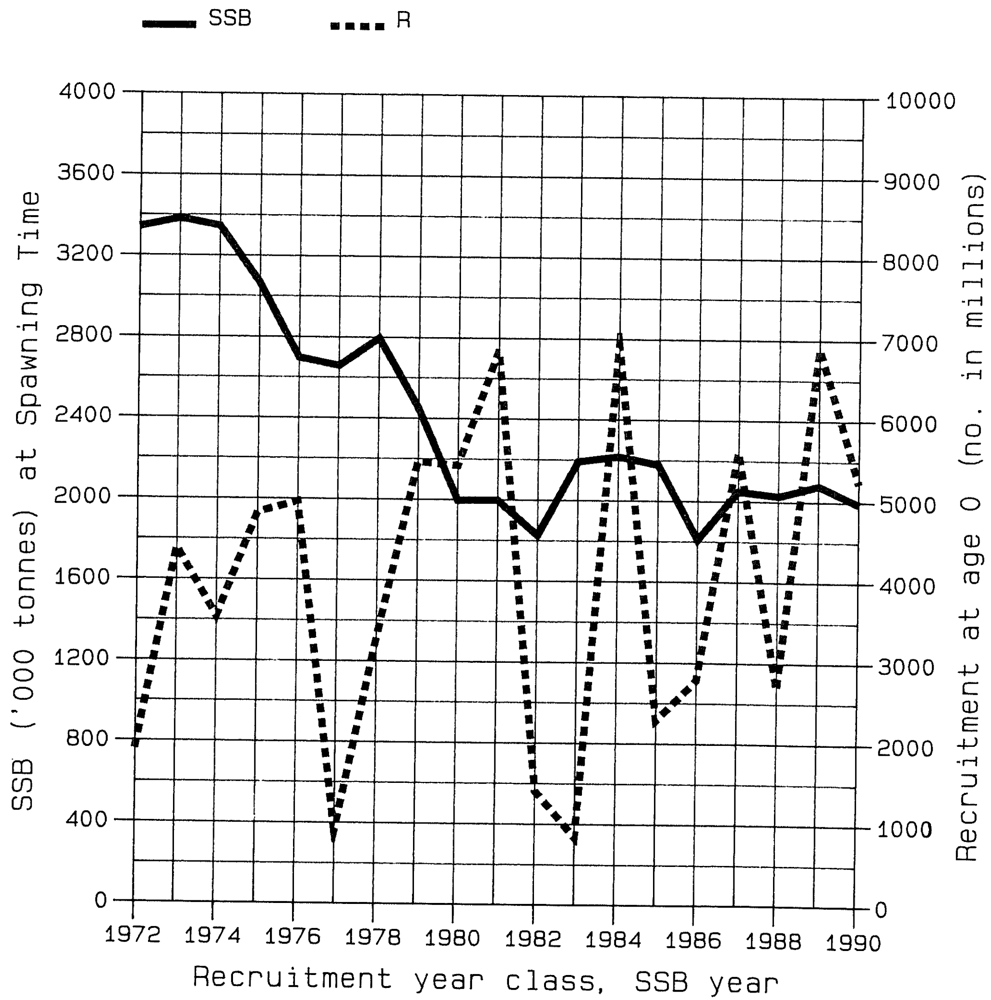
Figure 6.2

Trends in yield and fishing mortality (F)



A

Trends in spawning stock biomass (SSB) and recruitment (R)



B

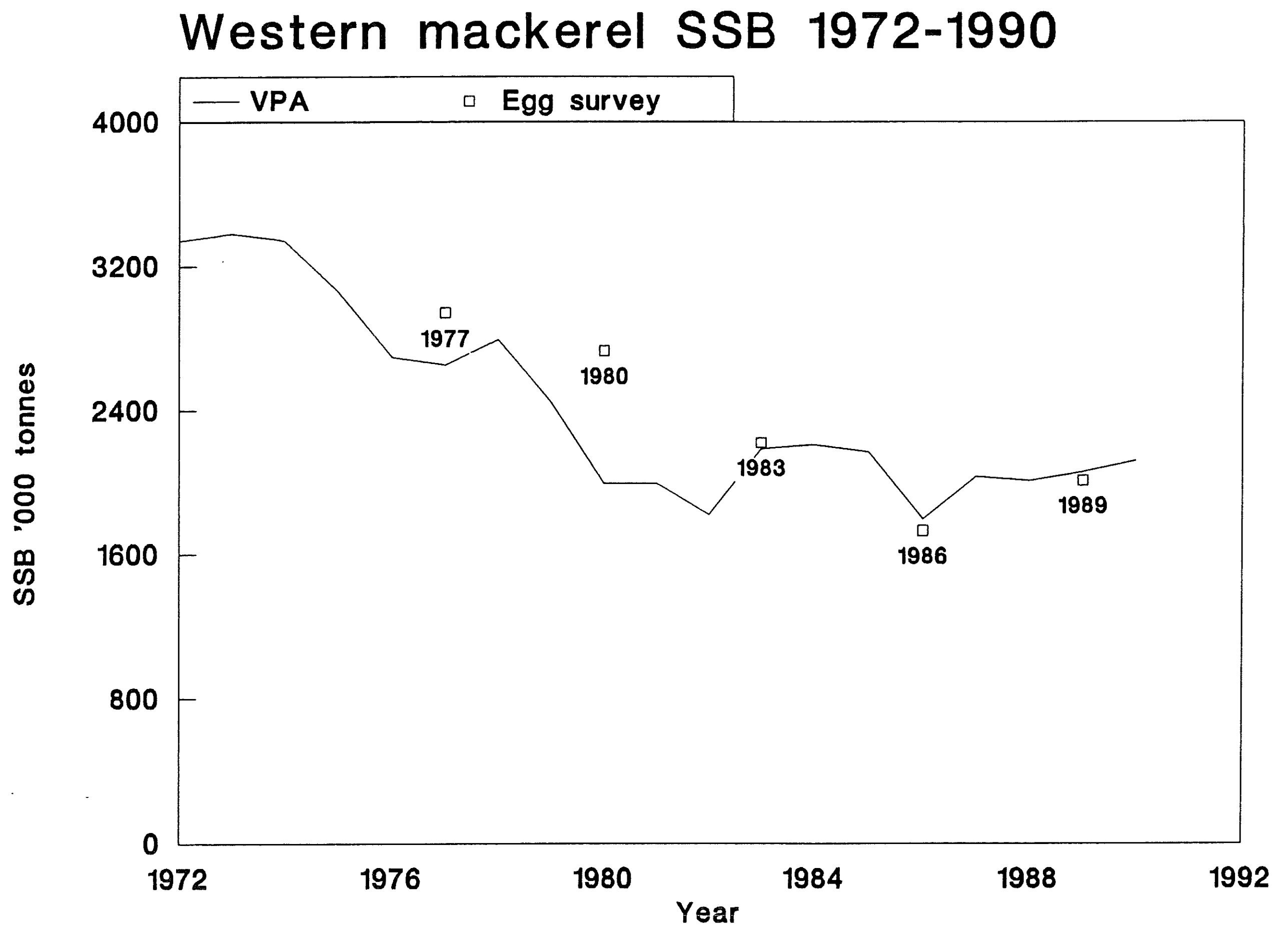


Figure 6.3 Spawning stock biomass at spawning time estimated from VPA and from egg survey.

Figure 6.4

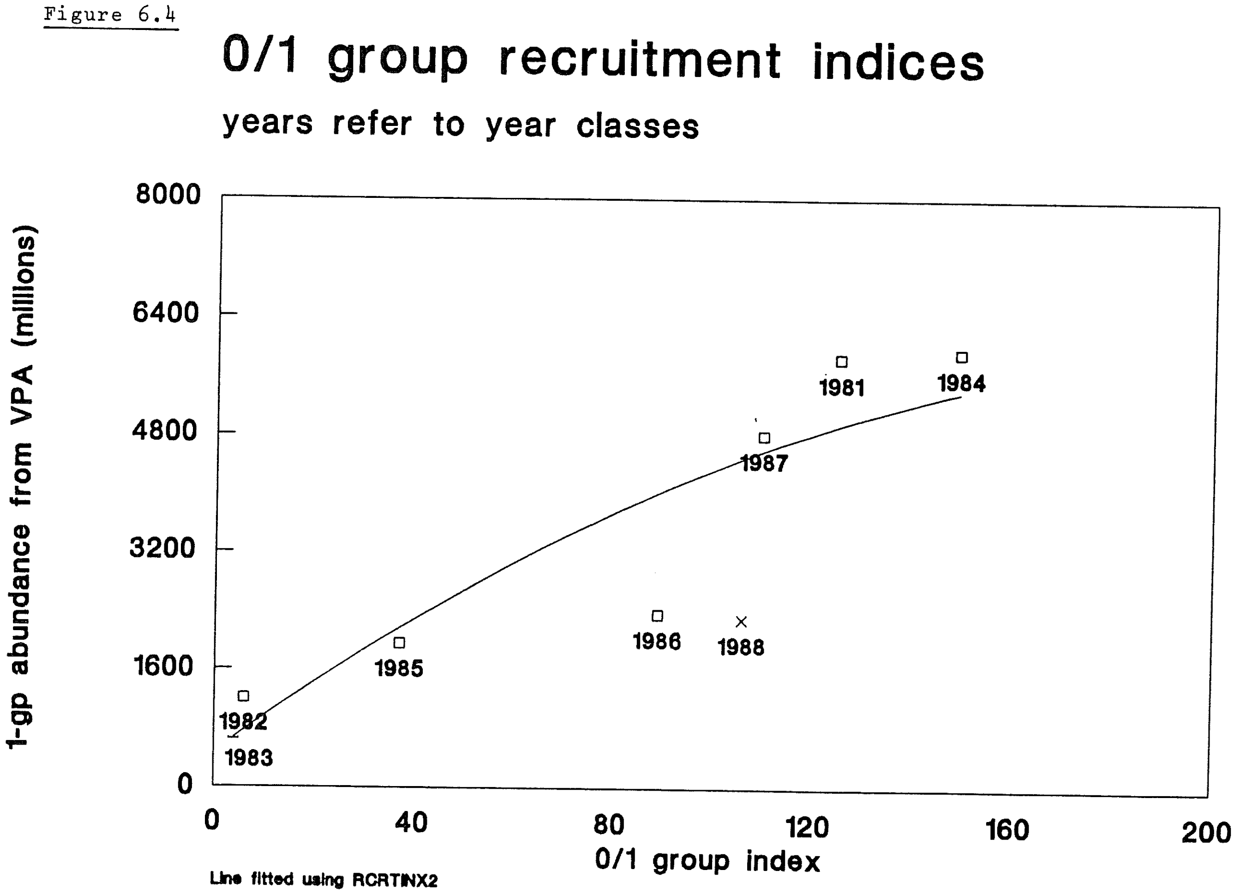


Figure 6.5

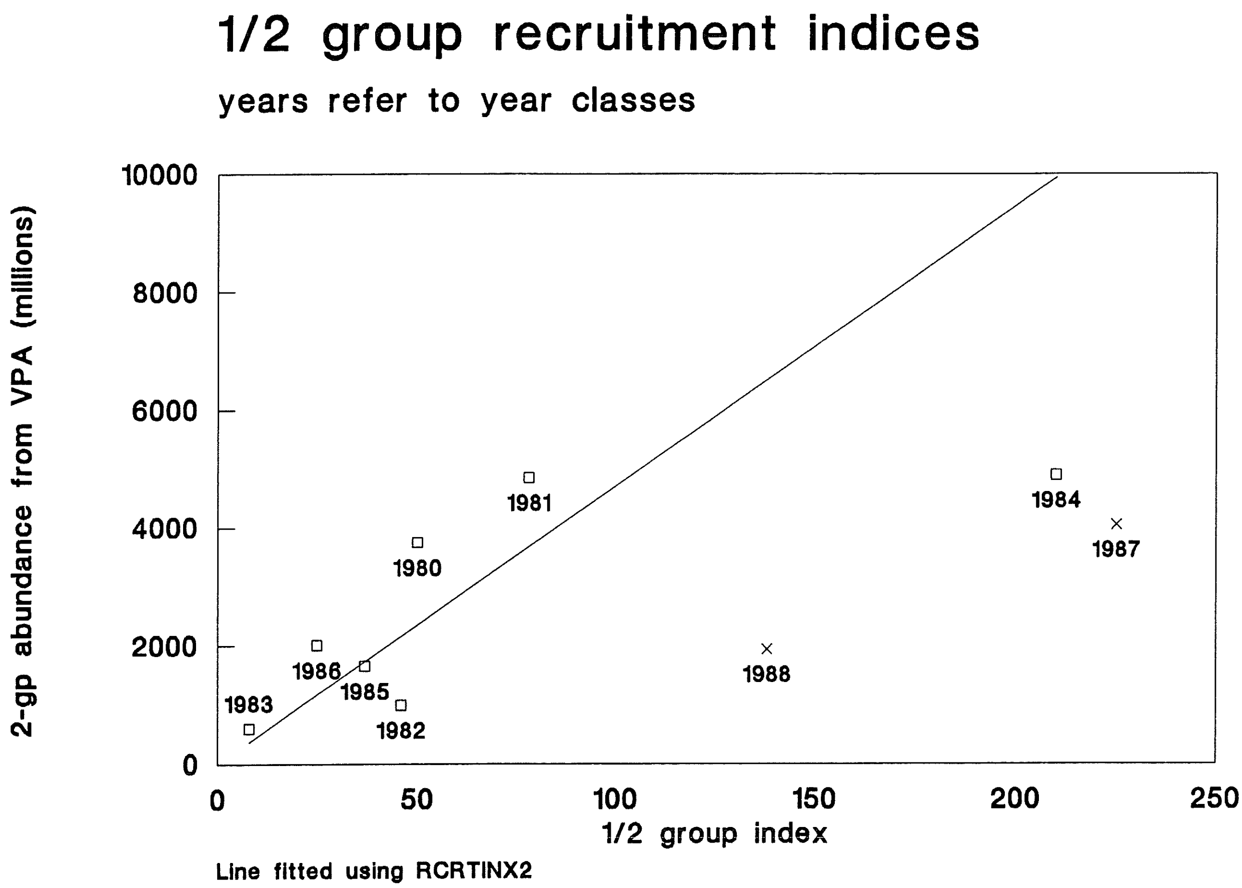


Figure 6.6

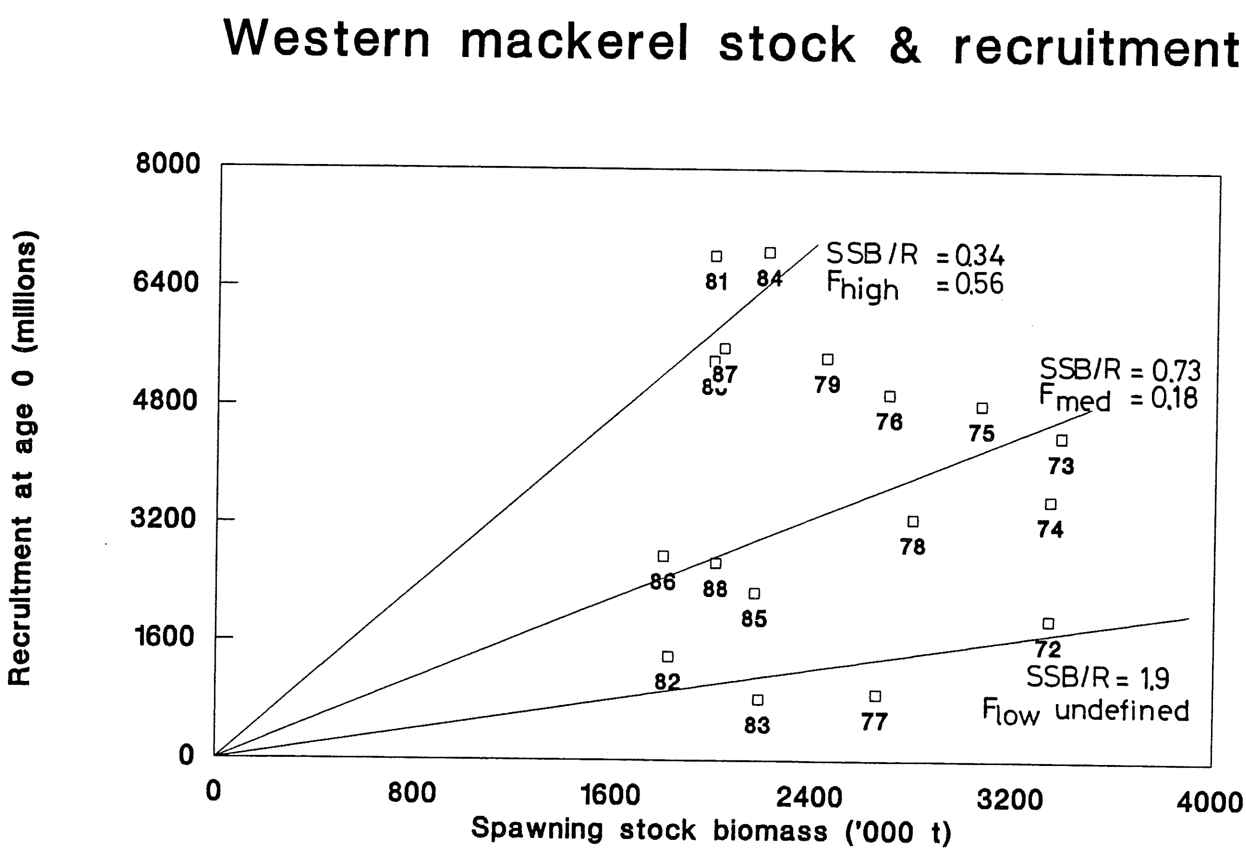
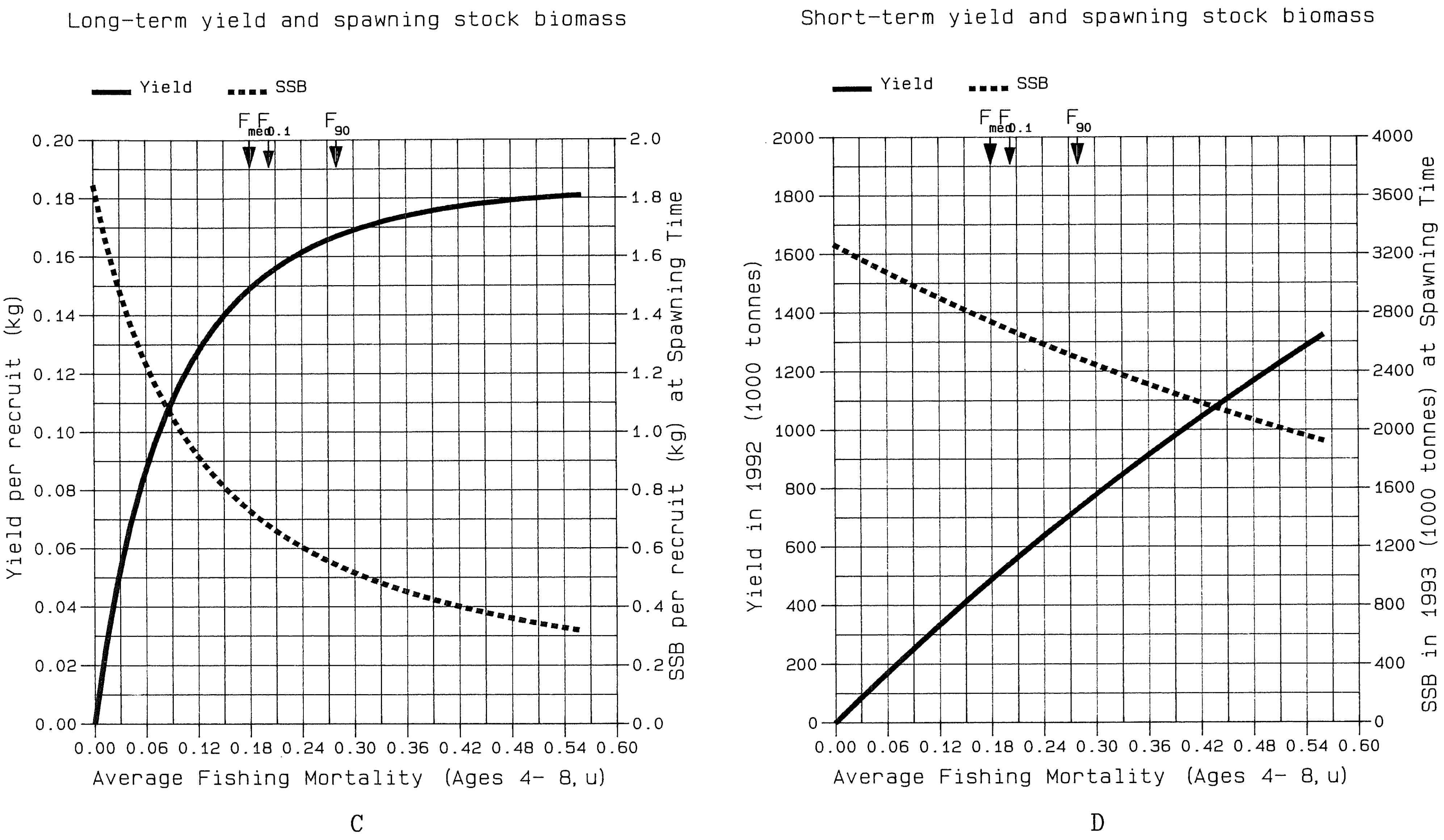
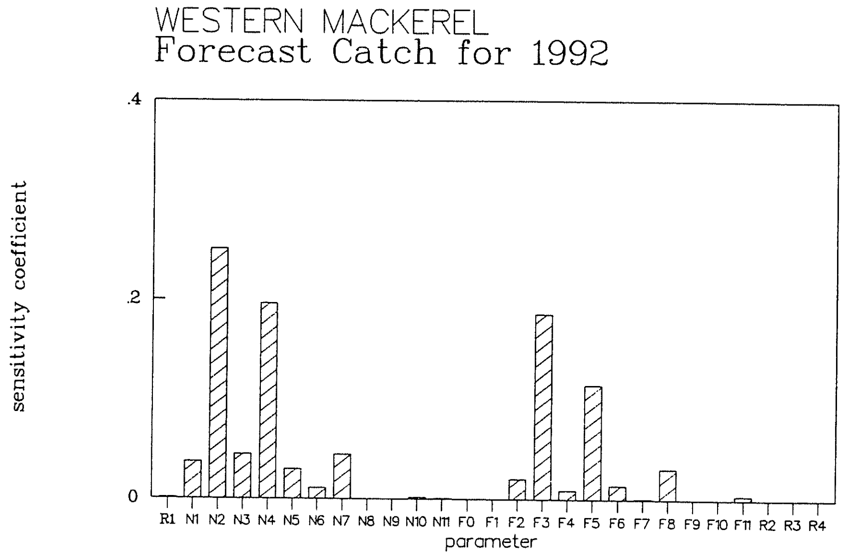
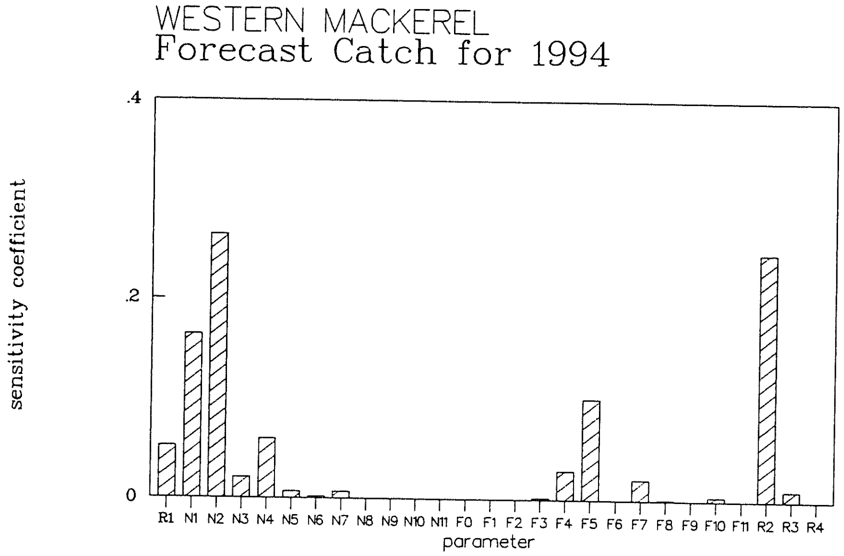


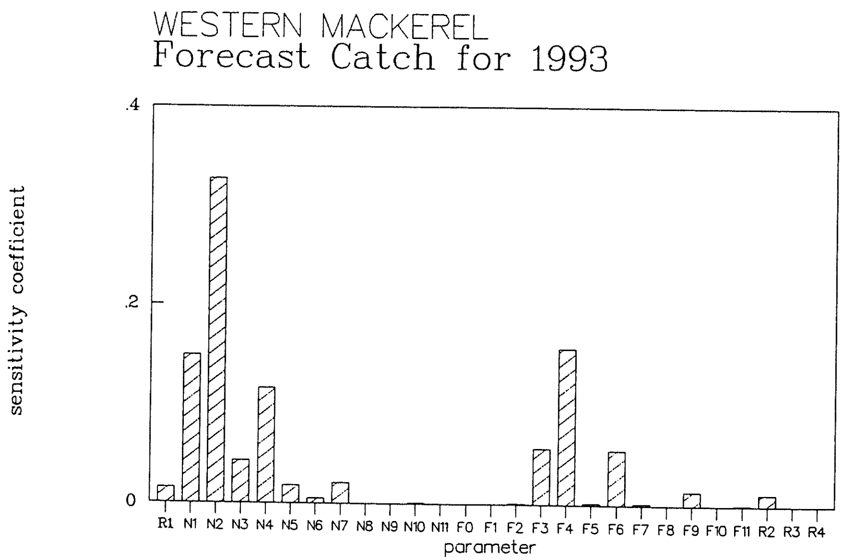
Figure 6.7

FISH STOCK SUMMARY
Western Mackerel
01-05-1991









PARAMETER KEY

N1=Number at age 1 in 1991
N2=Number at age 2 in 1991
N3 etc

F0=Fishing mortality age 0 in all years
F1=Fishing mortality at age 1 in all years
F3 etc

R1=Recruitment at age 0 in 1991
R2=Recruitment at age 0 in 1992
R3=Recruitment at age 0 in 1993
R4=Recruitment at age 0 in 1994

Figure 6.8 Results of the sensitivity analysis given the sensitivity and the forecast to the population in 1991, the baseline for the forecast.

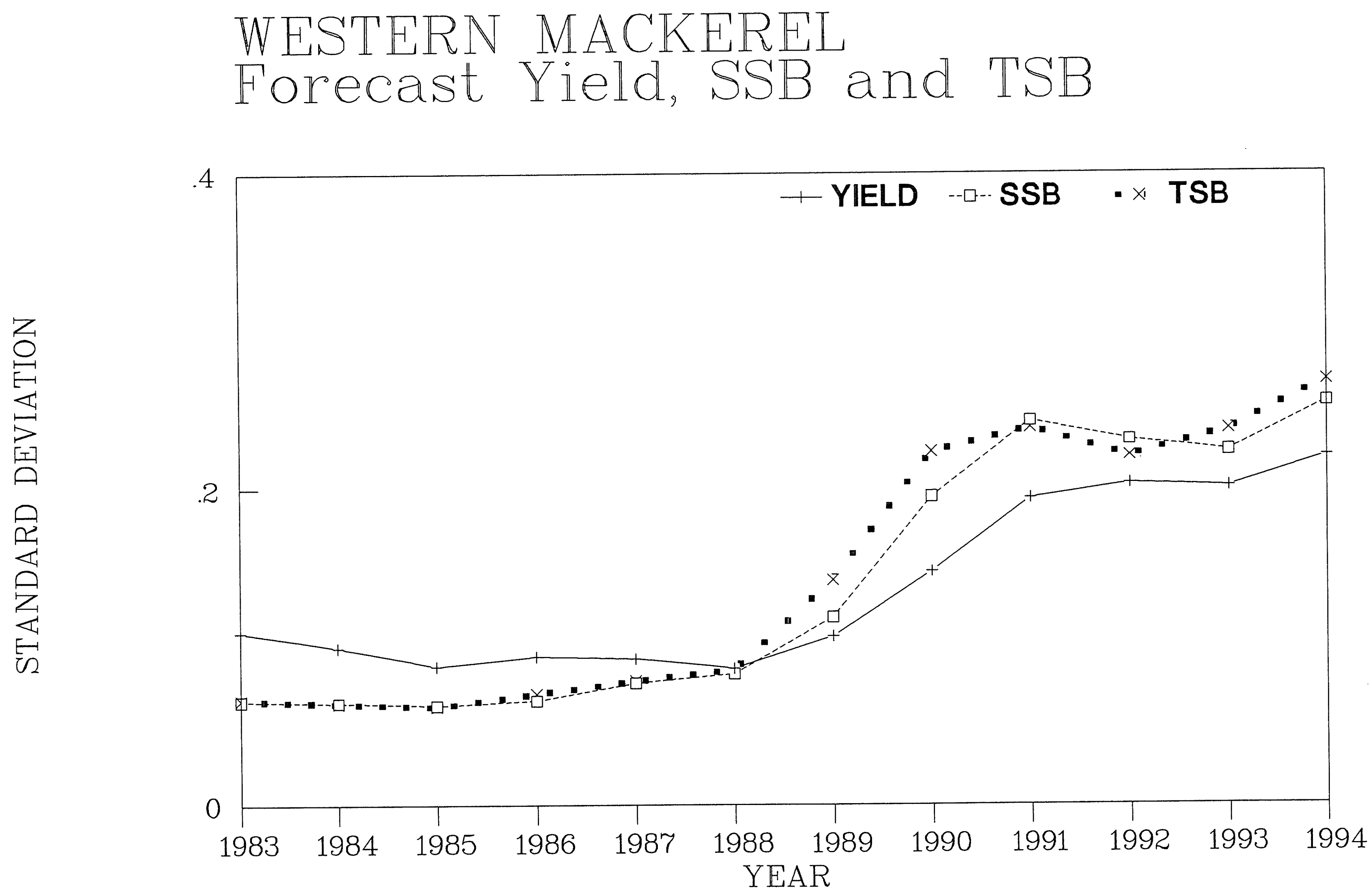
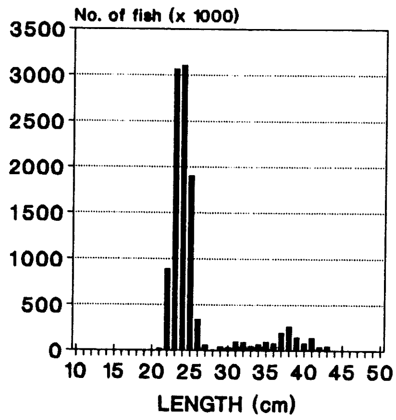
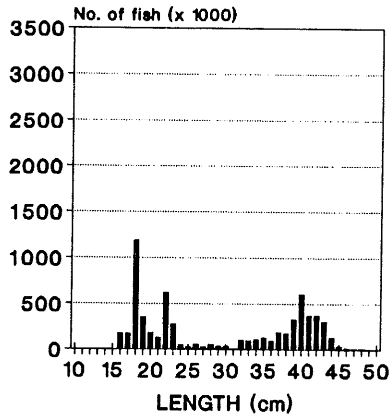


Figure 6.9 Estimated standard deviation of log yield, log SSB and log TSB as calculated from the integrated analysis.

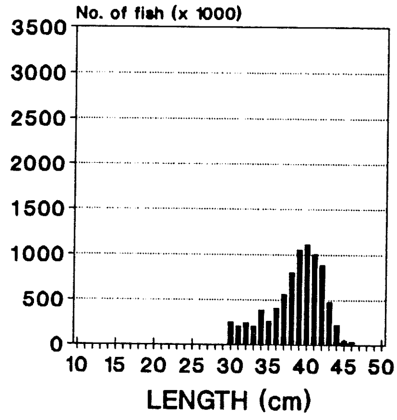
West. part VIIIc



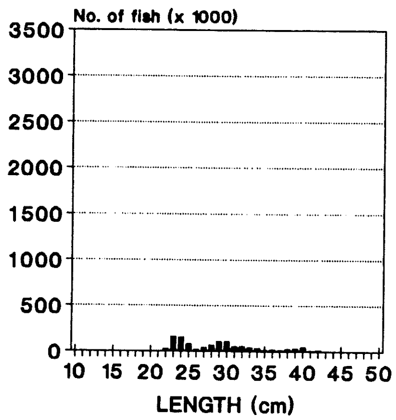
Cent. part VIIIc



East. part VIIIc



Nort. part IXa



Cent.+Sout.part IXa

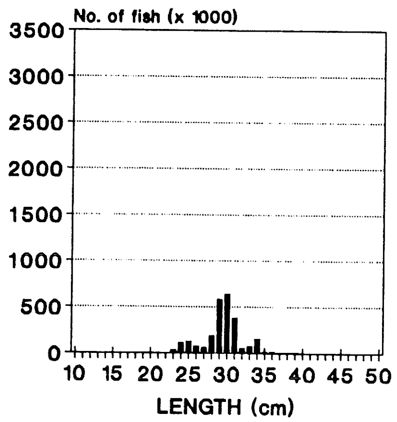
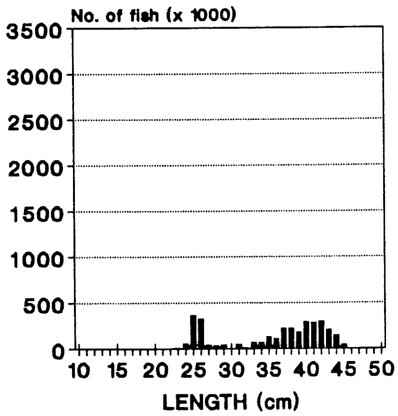


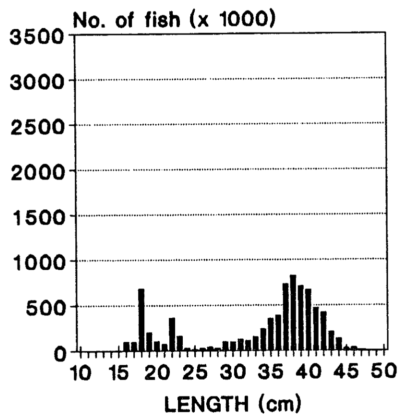
Figure 7.1a. Mackerel quartely length distributions (x 1000) from commercial catches, by geographical areas of Divisions VIIIc and IXa.

1st QUARTER - 1990

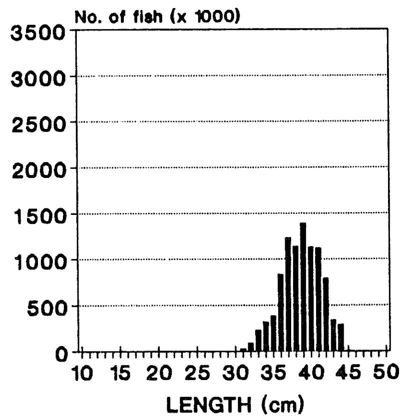
West. part VIIIc



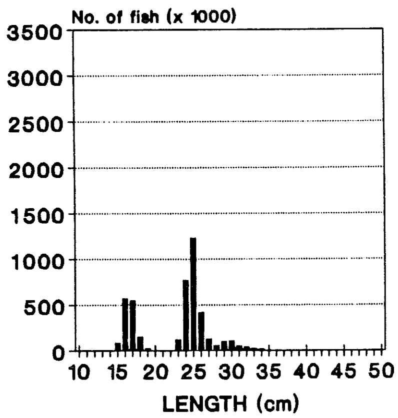
Cent. part VIIIc



East. part VIIIc



Nort.part IXa



Cent.+Sout.part IXa

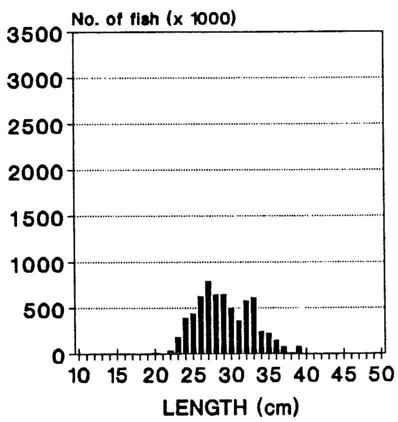
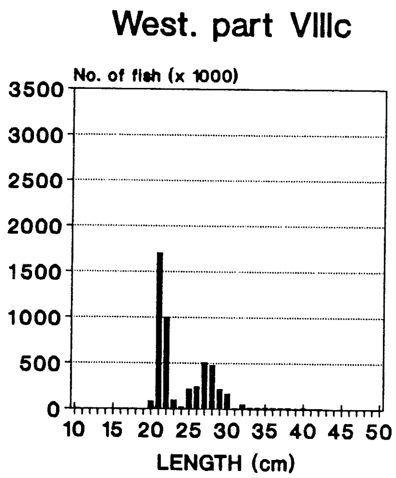
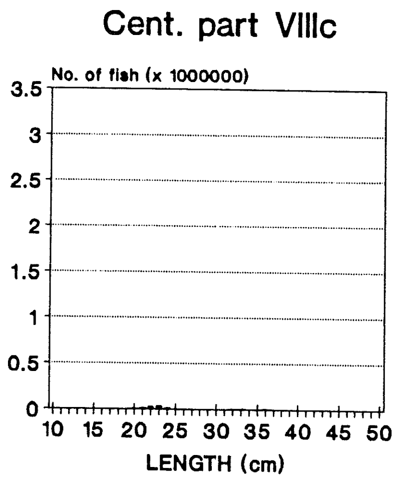
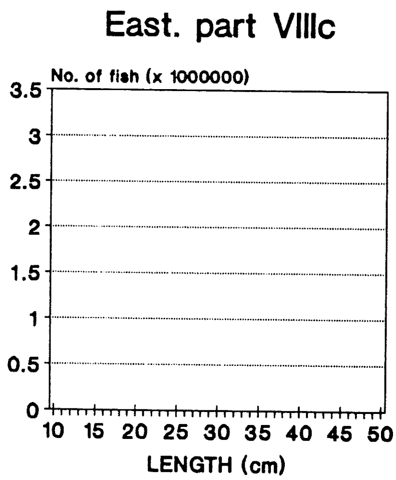


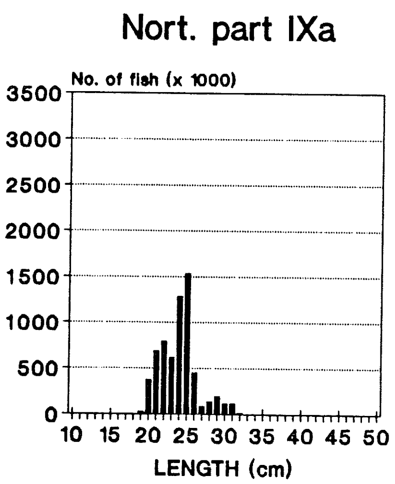
Figure 7.1b. Mackerel quarterly length distributions (x 1000) from commercial catches, by geographical areas of Divisions VIIIc and IXa.

2nd QUARTER - 1990









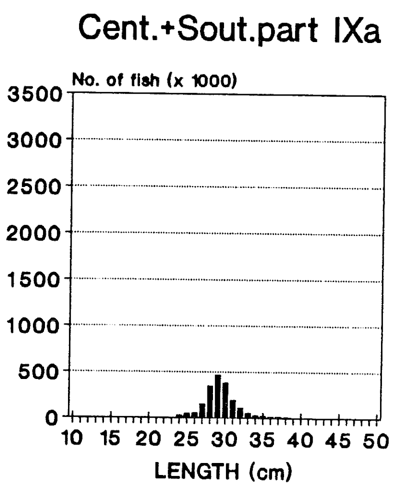
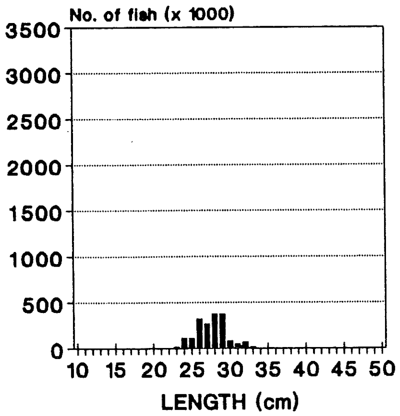


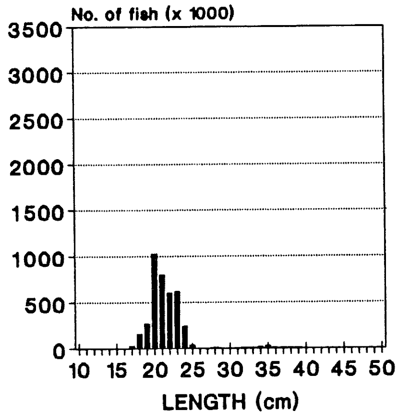
Figure 7.1c. Mackerel quarterly length distributions (x 1000) from commercial catches, by geographical areas of Divisions VIIIc and IXa.

3rd QUARTER - 1990

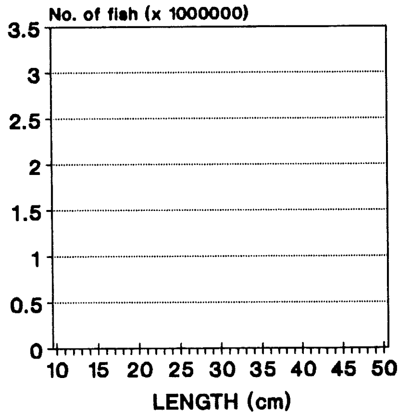
West. part VIIIc



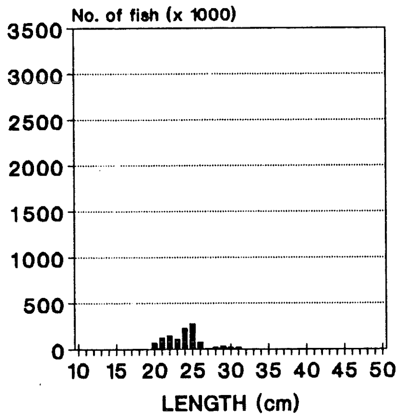
Cent. part VIIIc



East. part VIIIc



Nort. part IXa



Cent.+Sout.part IXa

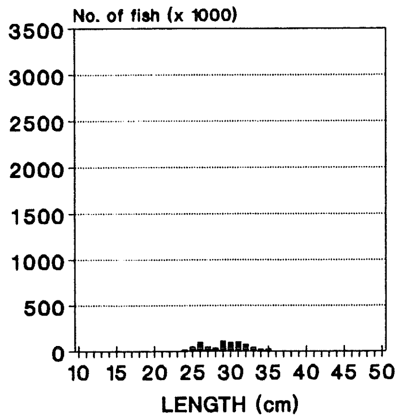


Figure 7.1d. Mackerel quarterly length distributions (x 1000) from commercial catches, by geographical areas of Divisions VIIIc and IXa.

4th QUARTER - 1990

Figure 8.1 Plot of recruitment estimates (1-group) from the western assessment and the combined assessment against 0/1-group recruitment indices for the western stock.

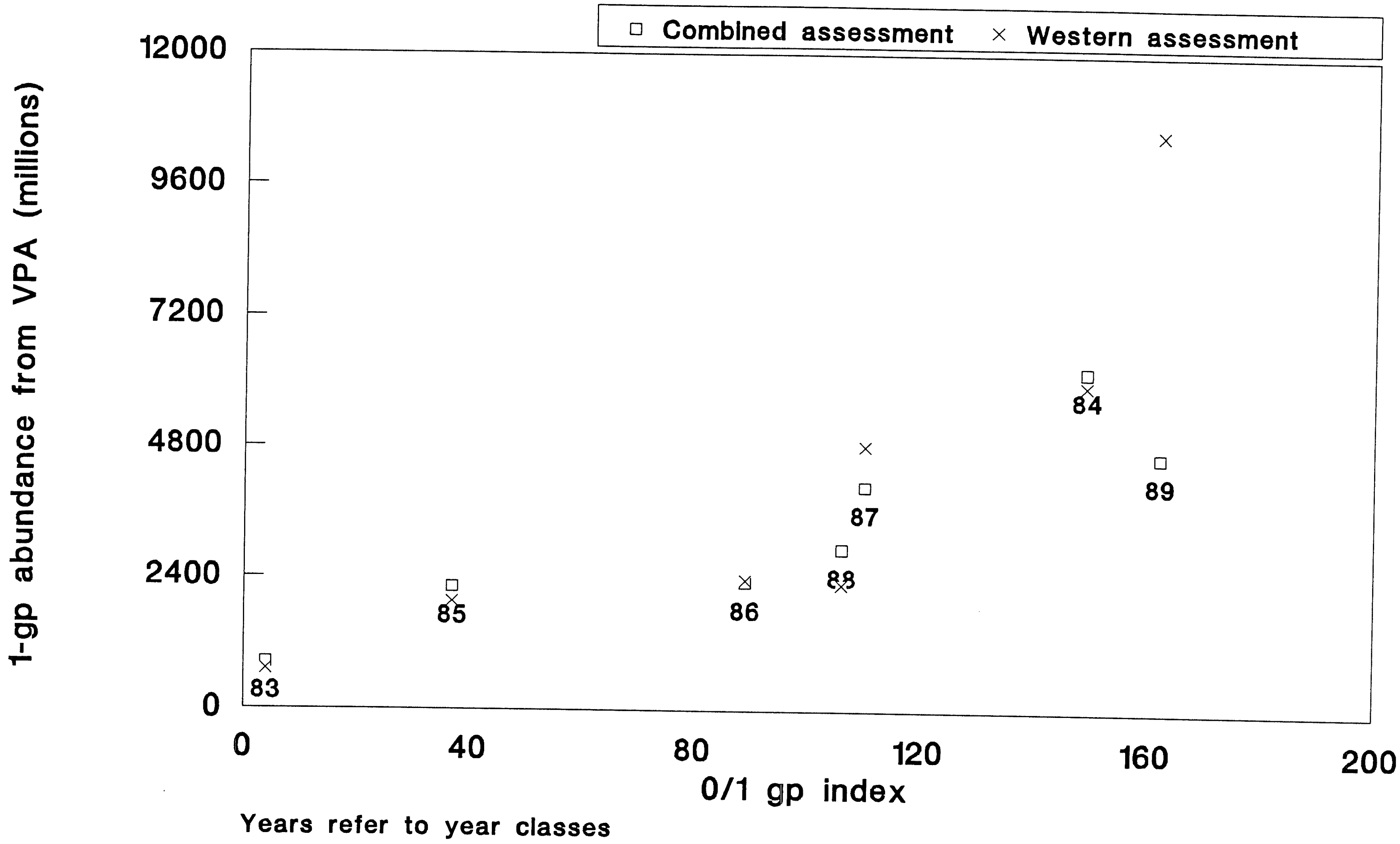
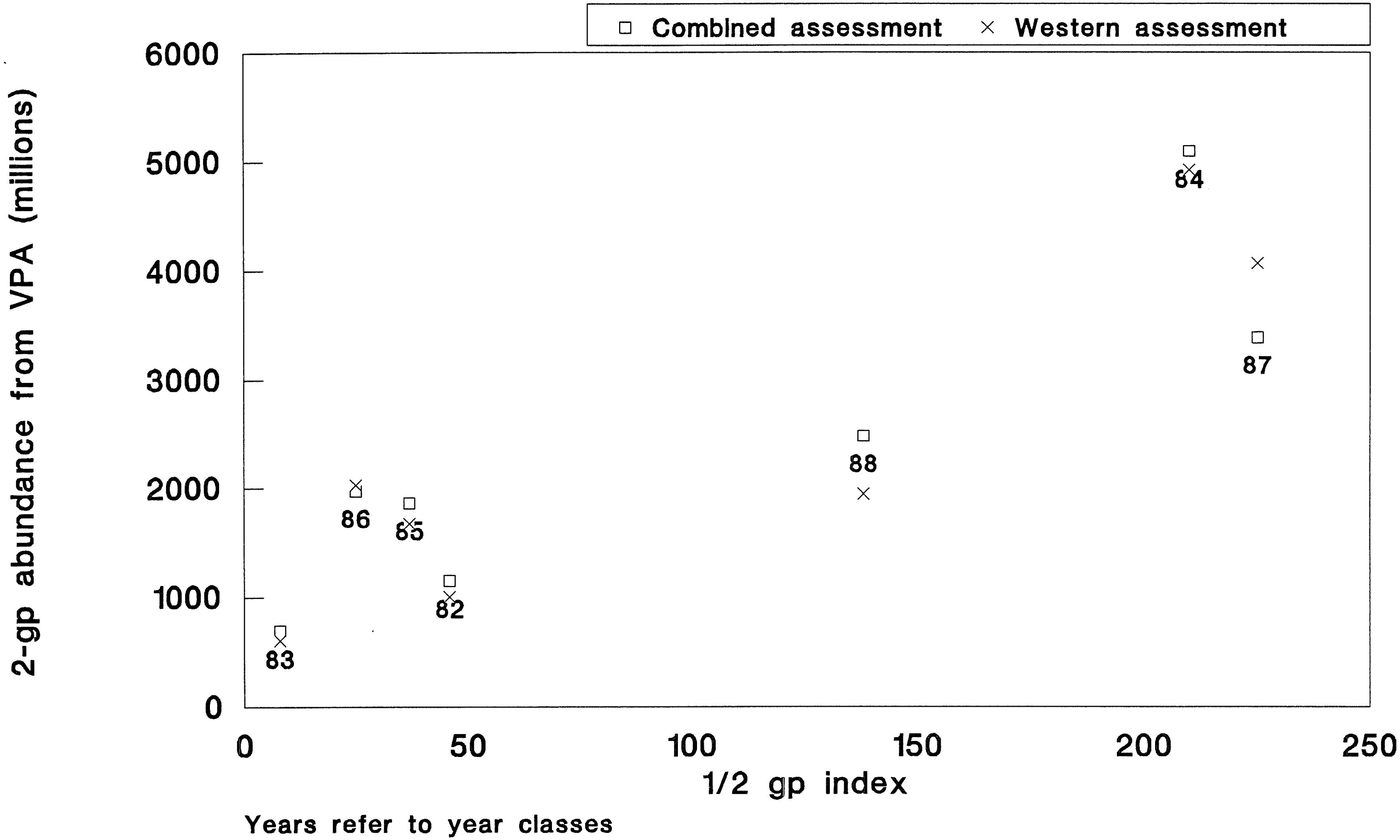


Figure 8.2 Plot of recruitment estimates (2-group) from the western assessment and the combined assessment against 1/2 group recruitment indices for the western stock.



APPENDIX I

INTEGRATED SEPARABLE ANALYSIS

1 INTRODUCTION

At present, the analysis of catch-at-age data for the western stock involves three stages. Firstly, separable VPAs are run for a variety of terminal Fs. Secondly, the terminal populations from SVPA are used to initiate standard VPAs from which SSBs can be calculated. Finally the sum of squares of residuals between the VPA estimated SSBs and the SSB as calculated from the egg surveys is calculated. The VPA generated from the SVPA which gives the lowest sum of squares is then selected as the final VPA. Thus two sets of sums of squares are being minimised; one minimises the log catch residuals (ie the SVPA) and the other the SSB residuals. In principle it is quite possible to minimise the SSB residuals within the separable analysis which would avoid the need to manually iterate the SSB calculations and the analysis would automatically be "tuned". In fact this might be a better procedure since minimising the two sets of SSQs separately does not necessarily produce a global minimum for all the data. This section describes an analysis which attempts to fit the separable model to the catch-at-age data and auxilliary data in much the same way as is done by CAGEAN (Deriso *et al*., 1985).

2. ANALYSIS WITH AUXILLIARY DATA

Three types of data are available for the estimation of population sizes and fishing mortality rates. These are the catch-at-age, egg survey (SSB) and recruitment data. The conventional separable VPA minimises the SSQ;

$$\min \Sigma[\ln(C)-\ln(C')]^2$$

where C' is the fitted catch derived from the separable model. It is straight forward to extend this to the sum;

$$\min \Sigma[n(C)-\ln(C')]^2 + \lambda_1\Sigma[\ln(SSB)-\ln(SSB')]^2 + \lambda_2\Sigma[\ln(R)-\ln(R')]^2$$

where R is the recruitment index and the prime (') indicates a fitted value from the separable model. The quantities λ_1 and λ_2 are weights reflecting the relative error in the SSB and recruitment data compared to the catch data.

The inclusion of the additional data means that some of the required input "guesstimates" to conventional SVPA are not required. In particular, it is not necessary to input terminal F since it can be estimated from the model.

3. RESULTS FROM THE ANALYSIS

The method was applied to the western mackerel stock using an extended version of RCSEP (Cook *et al*. 1991). This is very similar to the ICES separable VPA program and differs mainly in the provision of estimates of the variances of the estimated parameters. The model was fitted to the catch-at-age data for 1983-1990 and ages 2-10. λ_1 and λ_2 were estimated by examining the residual variance of the SSBs from the standard VPA runs (Section 6) and the residual variance of the plot of the recruitment index on VPA. This is rather crude and a more considered approach would be desirable in the future.

The estimated numbers-at-age and F-at-age from the integrated analysis are shown in Table A1. The results for 1990 from the final VPA are shown on the table for comparison. It can be seen that the results are very similar.

4. IS THE SEPARABLE MODEL THE CORRECT ONE?

It was not possible at the meeting to undertake detailed analysis of the results. Figure A1 shows the residuals from the model plotted against the fitted catch and recruitment. There is some evidence from these plots that larger residuals are related to small year classes. This would indicate that the separable assumption may be violated since it would suggest that fishermen selectively avoid small year classes. This effect is also evident from the standard VPA. Figure A2 shows F for ages 4, 5, 6, and 7 plotted against year class strength at age 0. It appears the the mortality rate on small year classes is consistently lower than on large year classes. If so this would suggest the separable hypothesis needs to be considered more carefully in relation to this stock.

5. CONCLUSION

Preliminary results from this analysis suggest that an integrated analysis can readily produce the same results as the _ad hoc_ method currently used very simply. However, there must be some doubt that the separable model is the correct one and this may lead to distorted estimates of year class strength and exploitation pattern. It is, however, quite possible to tune a standard VPA by minimising the SSQs on the SSB and recruitment data alone and this approach should be investigated.

REFERENCES

Cook, R.M., P.A. Kunzlik and R. Fryer. 1991. On the quality of North Sea cod stock forecasts. ICES Journal of Marine Science, in press.

Deriso, R., T. Quinn and P. Neal. 1985. Analysis of catch-at-age analysis with auxilliary information. Can. J. Fish. Aquat. Sci., 42:815-824.

TABLE A1

RESULTS FROM INTEGRATED SEPARABLE ANALYSIS

Year	SSB(obs)	SSB(fit)
1983	2220.00	2260.48
1986	1730.00	2089.20
1989	2010.00	2115.20

year	Robs	Rfit
1983	125	83.9
1984	6	25.8
1985	4	16.7
1986	149	88.0
1987	37	35.1
1988	89	39.4
1989	110	79.3
1990	106	49.0

F-at-age

Age	1983	1984	1985	1986	1987	1988
2	.0827	.0725	.0793	.0786	.0874	.0931
3	.1356	.1190	.1300	.1290	.1433	.1527
4	.1862	.1634	.1785	.1771	.1968	.2096
5	.2214	.1942	.2122	.2106	.2339	.2492
6	.2242	.1967	.2149	.2133	.2370	.2525
7	.2439	.2140	.2337	.2320	.2577	.2746
8	.2492	.2186	.2389	.2370	.2634	.2806
9	.2466	.2164	.2364	.2346	.2606	.2777
10	.2500	.2193	.2396	.2378	.2642	.2815

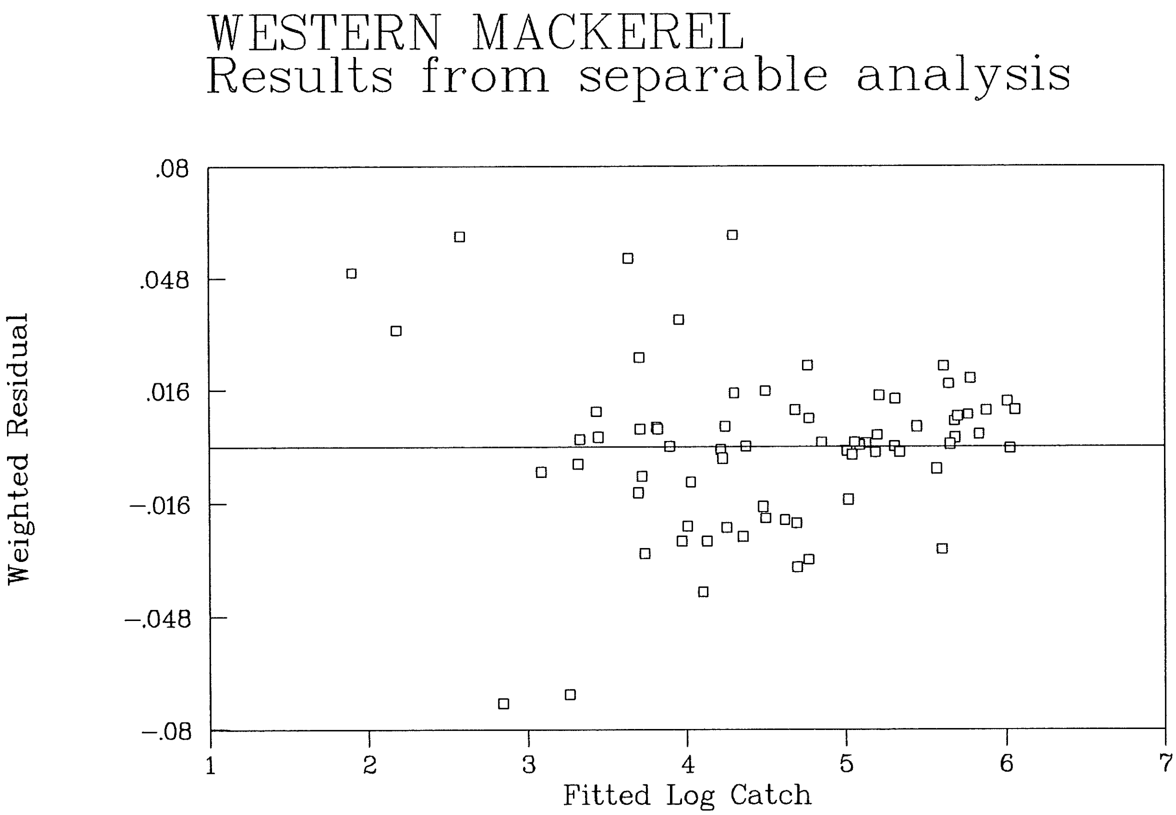
Age	1989	1990	**1990(VPA)**
2	.0913	.1085	**.0857**
3	.1497	.1780	**.1542**
4	.2055	.2444	**.2147**
5	.2443	.2906	**.2750**
6	.2475	.2943	**.2907**
7	.2692	.3201	**.3125**
8	.2751	.3271	**.3078**
9	.2722	.3237	**.3007**
10	.2759	.3281	**.2996**

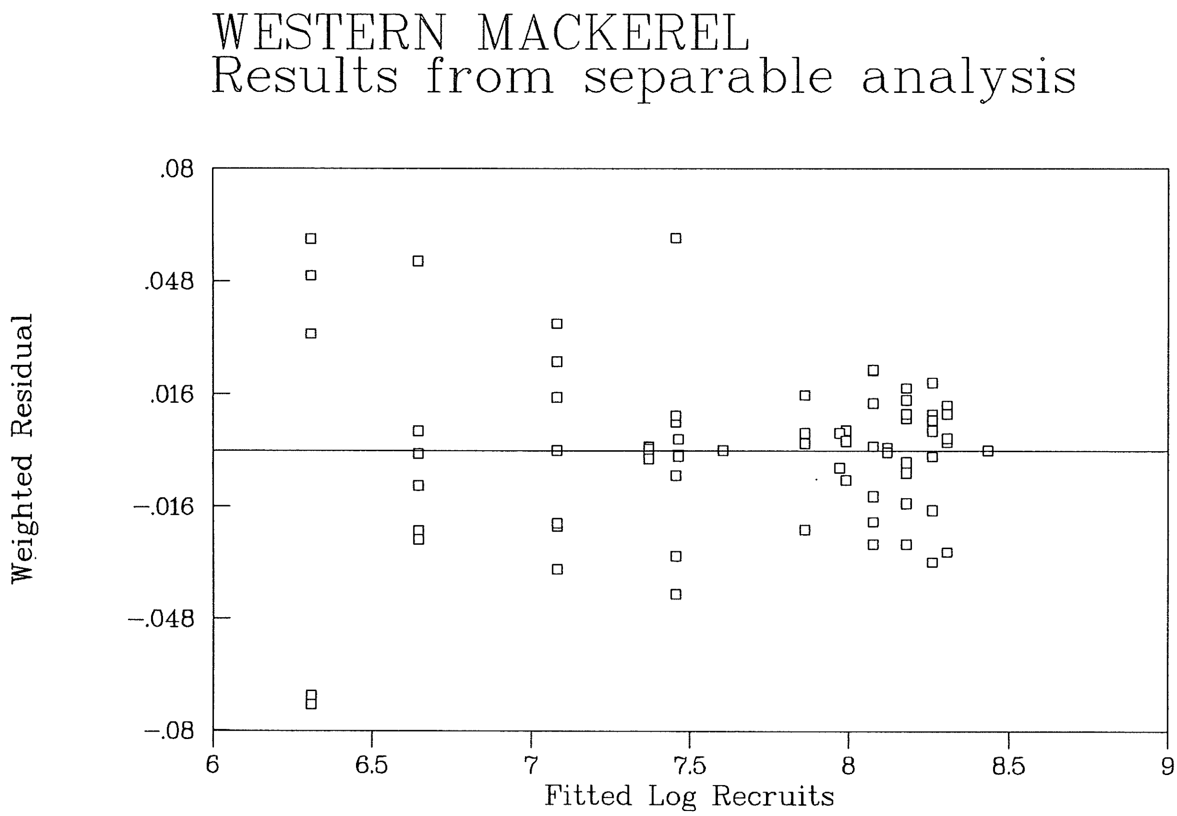
Fitted N-at-age

Age	1983	1984	1985	1986	1987	1988
2	3877.8	1191.4	773.2	4073.7	1623.4	1818.0
3	2687.0	3072.8	953.7	614.8	3241.1	1280.3
4	1730.4	2019.4	2348.1	720.8	465.1	2417.1
5	639.1	1236.4	1476.1	1690.7	519.7	328.8
6	139.6	440.8	876.3	1027.6	1178.9	354.0
7	444.6	96.0	311.7	608.4	714.6	800.6
8	340.0	299.9	66.7	212.3	415.2	475.3
9	224.4	228.1	207.4	45.2	144.2	274.6
10	242.0	150.9	158.1	140.9	30.8	95.6

Age	1989	1990	**1990(VPA)**
2	3662.1	2265.7	**1937**
3	1425.7	2877.1	**3194**
4	946.0	1056.5	**1198**
5	1687.0	662.9	**663**
6	220.6	1137.2	**1266**
7	236.7	148.2	**127**
8	523.6	155.7	**142**
9	309.0	342.3	**326**
10	179.1	202.6	**166**

Figure A1 The residuals from the integrated separable analysis plotted against the fitted catch and recruitment.





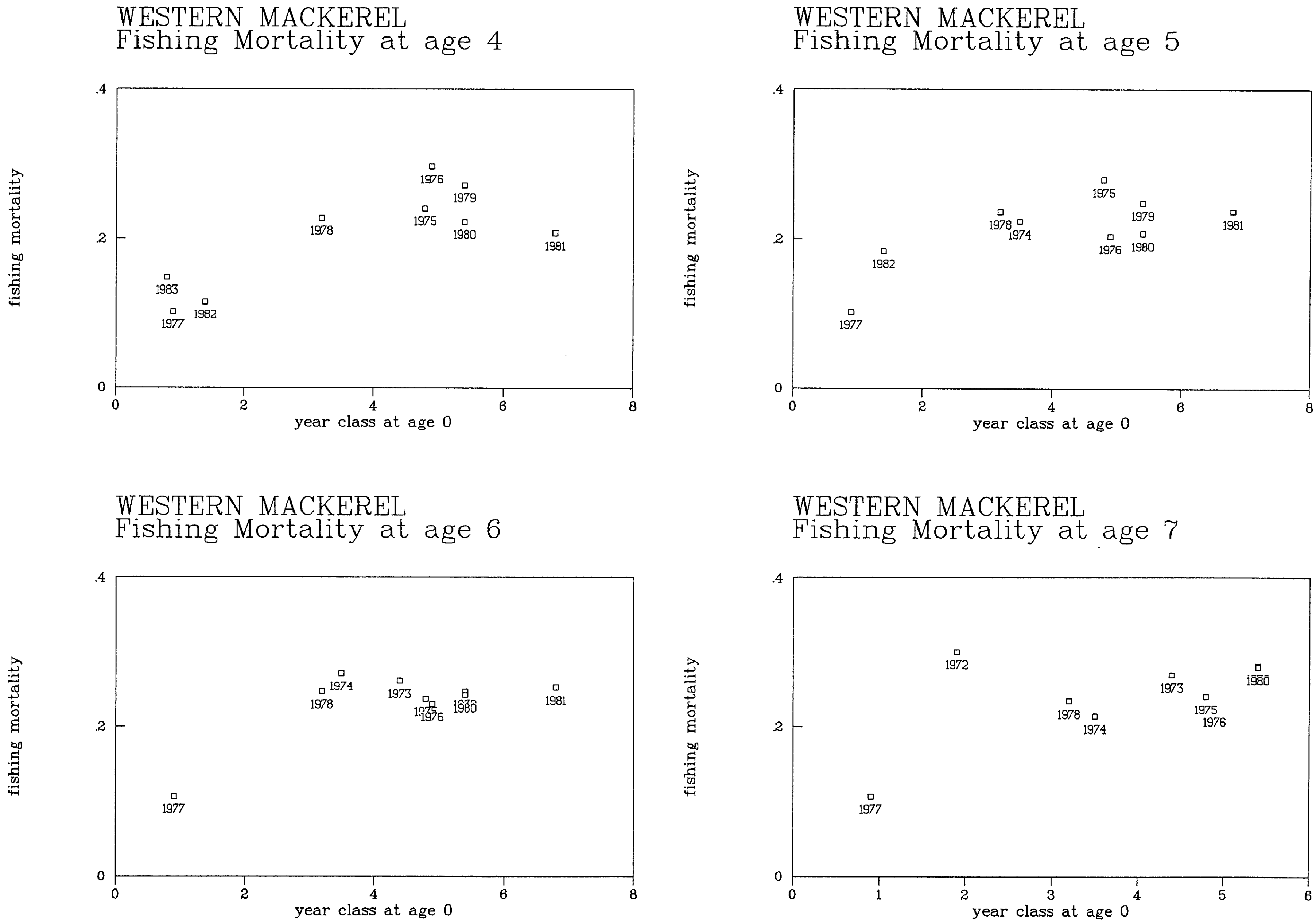


Figure A2 F for ages 4, 5, 6 and 7 plotted against year class strength at age 0.