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International Council for the Exploration of the Sea

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# *REPORT OF THE MACKEREL WORKING GROUP*

Copenhagen, 16 - 25 February 1987



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# 1 INTRODUCTION

## 1.1 Terms of Reference

At the 74th Statutory Meeting in Copenhagen, it was decided (C.Res.1986/2:5:4) that the Mackerel Working Group (Chairman: Mr S.A. Iversen) should meet at ICES headquarters from 16-25 February 1987 to:

a) consider the report of the Mackerel Egg Production Workshop;

b) consider the report of the *ad hoc* Multispecies Assessment Working Group;

c) assess the status of and provide catch options for 1988 within safe biological limits for the mackerel stocks and management units in Sub-areas II-VII and Divisions VIIIa,b;

d) 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;

e) 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 1986 as input for the Multispecies VPA, and provide information on the likely level of Western stock mackerel which are seasonally present in the North Sea.

In the minutes of the ACFM meeting (30 October - 6 November 1986) the different working groups were asked "to produce stock-recruitment plots for each stock and to attempt to define alternative biological reference points ($F_{high}$, $F_{med}$, and $F_{low}$)". The definitions of these reference points are given in Anon. (1983).

## 1.2 Participation

The Working Group met in Copenhagen with the following participants:

| | |
|---|---|
| R.S. Bailey | UK (Scotland) |
| J. Casey | UK (England and Wales) |
| W. Dawson | UK (England and Wales) |
| A. Eltink | Netherlands |
| S.A. Iversen (Chairman) | Norway |
| E. Kirkegaard | Denmark |
| J. Molloy | Ireland |
| T. Westgård | Norway |

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

## 2 REVIEW OF THE MACKEREL EGG PRODUCTION REPORT

The final version of the report from the Mackerel Egg Production Workshop (Anon.,1987) was available for the Working Group.

New data about fecundity from the Western mackerel demonstrate a rather similar fecundity-length relation as given for the North Sea stock in Iversen and Adoff (1983). However, both the new and earlier investigations deal with the potential fecundity, i.e., the maximum numbers of oocytes which might become fully developed and be shed in the current season. Due to atresia and the possibility of oocyte development during the spawning period, the potential fecundity may not be an exact estimate of the actual number of eggs shed. More information on the atresia problem is available, but uncertainties still continue as to its duration and possible differences between levels of atresia in first-time spawners, which can be very high, and return spawners. The Working Group, therefore, strongly stresses the need for further investigations to quantify the atresia in different age and length groups of the spawning population.

The total egg production in the North Sea in 1986 was estimated at $30 \times 10^{12}$ eggs and for the Western mackerel stock $1.165 \times 10^{15}$ eggs. Data on egg mortality obtained during the survey of the spawning area of the Western stock indicate a daily mortality of about 13%. If this mortality is assumed to be representative and constant, the overall stage 1 production estimates could be increased by about 10% to estimate the total number of eggs spawned.

The North Sea egg estimates are based on stage 1 eggs which range from newly spawned to 2 days old depending on temperature. The survey did not cover Skagerrak and the egg production there is, therefore, not included in the North Sea estimate. Some data from earlier years (Iversen, 1977) indicate that the Skagerrak might contribute about 5-10% of the North Sea egg production.

Neither of the two estimates are compensated for egg mortality and no adjustment for the Skagerrak production has been done for the North Sea estimate.

There is evidence from earlier work that mackerel spawn outside the areas covered in 1986, e.g., outside the limits of the continental shelf west of Scotland and in the western English Channel (Walsh, 1976).

It was pointed out in a working paper presented to the Working Group (Walsh and Hopkins, 1987) that the method of calculating the number of females spawning at each point in the spawning season is conceptually inaccurate because it assumes that all stage 6 females in the relevant period spawn all their eggs in one batch. In reality, the number of females spawning in any given period will be much higher, but the number of eggs spawned by each will be lower than the total fecundity of an individual female. An alternative approach is to apply a fecundity-weight relationship to the total egg production thereby giving a total biomass of females (referred to the maturity stage at which fecundity is estimated) which can be converted to number by using a mean weight of females at the appropriate stage for the season as a whole.

Using weight data not available at the Workshop, it has now been found that a good straight-line relationship exists between fecundity and weight of females, the line passing close to the origin and not differing significantly from it. Using a regression forced through the origin, an estimated 1,457 eggs were produced per gram of female mackerel at maturity stage 4. At a mean weight of 382 g, estimated by weighting mean weights in each survey period by the egg production during that period, and assuming a 1:1 sex ratio, the spawning biomass is estimated to be $1.6 \times 10^6$ t, and the number of spawning fish $4,188 \times 10^6$. This is 8.5% lower than the Workshop estimate of $4,578 \times 10^6$ spawning fish. While the methodology used clearly affects the estimate of the number of spawning fish, the alternative method described here requires a reliable estimate of the mean weight of stage 4 females over the entire spawning season.

In view of the fact that most of the potential causes of inaccuracy or imprecision listed above have not been quantified, the present Working Group adopted the estimate of the number of spawning fish in 1986 given by the Workshop.

The report from the Egg Production Workshop lists several important objectives to improve both the mackerel egg production and spawning stock estimates. The Mackerel Working Group wishes to emphasize the most important ones:

- Extend the areas investigated to include the Skagerrak in the North Sea survey and Division VIa, the eastern Celtic Sea, and the western English Channel in the western survey.

- Improve the staging of older eggs so they can be used in the production estimates.

- Further investigations of ovaries to quantify atresia, threshold of vitellogenesis, proliferation of primary oocytes over the annual cycle, and their recruitment to vitellogenesis during spawning. Investigate batch fecundity.

In addition, the Working Group stresses the need for better sampling of the spawning population over the entire spawning period.

A further North Sea egg survey is planned for 1988. To ensure full coverage of the area and spawning season, it is essential that the survey be coordinated, and the Working Group recommends that survey plans be conveyed to a coordinator (S. A. Iversen) as soon as possible. Time for the formulation of final plans should be made available at the Working Group meeting in 1988.

## 3 SAFE BIOLOGICAL LIMITS

In it last report (Anon., 1986), the Working Group had a thorough discussion on safe biological limits of the Western and North Sea mackerel stocks. The conclusions from this discussion remain the same, i.e., that:

1) Since 1974, the North Sea mackerel spawning stock has decreased from one million t to less than one tenth of that level. Throughout this period, the average level of recruitment has been insufficient to maintain the spawning stock even in the absence of exploitation.

2) The Western spawning stock is at its lowest recorded level in the period 1972-1986.

3) The general trend is for a continuing decline in the spawning stock biomass of both the North Sea and Western stocks.

4) Any fishery on the North Sea stock in 1986/1987 is likely to drive the stock even lower.

The optimum range of spawning stock biomass, the minimum fishable biomass, the optimum fishing pattern, and long-term potential of the two mackerel stocks are also discussed by Anon. (1986) and the general conclusions still apply.

With a fish such as mackerel, the yield-per-recruit curve tends to be flat-topped. As a result, the position of $F_{max}$ is poorly defined. In this situation, $F_{0.1}$ is usually used as the more appropriate biological reference point. This level of fishing mortality, however, is not necessarily the same as the safe biological limit of F. As an alternative, ACFM recommends that safe biological limits be identified within which the stock is likely to continue to produce adequate levels of recruitment.

The stock-recruitment scatter plot for Western mackerel based on the VPA given in this report is shown in Figure 3.1. It is clear that there is as yet no identified relationship between parent stock and recruitment. Calculations of spawning stock biomass per recruit, however, enable one to superimpose lines on this plot corresponding to different levels of F. From this, additional biological reference points can be defined, as explained in Anon. (1983). At high values of F, there will be no evidence that the stock has ever produced sufficient recruits to maintain itself under that level of exploitation. The upper limit of F might, therefore, be defined by the line that envelopes almost all historic values of stock and recruitment ($F_{high}$). A further value that divides the stock-recruitment points in half is the value at which there is reasonable evidence that the stock can sustain itself ($F_{median}$). Using the method outlined in Anon. (1983), these values are as follows:

| | |
|---|---|
| $F_{high}$ | 0.33 |
| $F_{median}$ | 0.14 |

The stability of the values of these reference points is based on the implicit assumption that recruitment will on average be lower than the average values so far recorded if the spawning stock size falls. There is no basis for this assumption, but in the absence of any other relevant evidence, the present values can be used to define reasonably prudent levels of exploitation in the management of this stock.

In the absence of reliable stock and recruitment data for North Sea mackerel, a similar analysis has not been made for this stock. It should also be borne in mind that values of SSB per recruit change if the exploitation pattern or maturity ogive changes. The one given here is based on the most recent exploitation pattern and on the historical maturity ogive (i.e., 60% of 2-group mature).

## 4 STOCK DISTRIBUTION AND MIXING

### 4.1 Distribution of Mackerel Fisheries and Stocks in 1986

The main source of information about the seasonal distribution of the adult components of the mackerel stocks outside the spawning season comes from the distribution of catches in the commercial fisheries. Since the relative magnitude of catches in each area and season depends on the distribution of fishing effort as well as on the distribution of mackerel, it is recognized that the distribution of catches may not in all cases be a reliable guide to distribution. The distribution of fishing effort is affected by management controls (e.g., closed areas, allocation of TACs, and national quotas among areas) and by economic considerations (e.g., proximity of ports of landing). However, it is also clear that intensive fisheries can only develop in areas where mackerel are abundant. In 1986, the officially reported distribution of catches could not be taken as a reliable guide to where the fish were actually caught in all areas and seasons. A better idea of the distribution of catches was obtained from unofficial reports, but it was not possible to express the information on the precise distribution of catches quantitatively. With these reservations in mind, the quarterly distribution of the fishery in 1986 is shown qualitatively in Figures 4.1a-d.

In the first quarter, most of the catch was taken in the area of the pre-spawning migration along the edge of the continental shelf west of Scotland and Ireland. This contrasted markedly with the fishery in December 1985 which was predominantly to the north of Scotland. The fishery to the west of Scotland ended in early March, while most of the catches to the west of Ireland were taken in February and March.

The southward progression of the fishery towards the main spawning grounds southwest of Ireland is also seen in the distribution of catches in the second quarter of 1986 (Figure 4.1b). The only other fishery in this quarter was in the Skagerrak and its approaches.

By the third quarter of 1986, the major fisheries took place in the eastern half of Divisions IIa and IVa and in the Skagerrak, with smaller concentrations of catch in the western half of Division IVa and Division VIa (Figure 4.1c). The main month of catching in the eastern part of Divisions IIa and IVa was August, while in the more westerly parts of Division IVa the fishery did not open until mid-September. The distribution in August was similar to that at the same time in 1985.

In the fourth quarter of 1986, there was a marked westward shift in the fishery to the northwestern North Sea and easternmost parts of Divisions VIa and Vb, with smaller quantities taken west and northwest of Ireland and in the eastern half of the North Sea. Unofficial reports for this period indicate that the fishery was furtherest to the west (over the boundary between Divisions IVa and VIa) in October and that it moved back into Division IVa north and east of the Shetlands in November and then to the west of Shetlands in Division IVa in December. Provisional reports for January 1987 indicate a very rapid shift in the fishery to the area west of Scotland and northwest of Ireland as in January 1986. The traditional overwintering area around North Rona (the northern part of Division VIa) thus appears not to have been used by mackerel in the fourth quarter of 1986. Instead, the fish were distributed further to the northeast (Figure 4.1d).

## 4.2 Review of Information of Stocks

At the last two meetings of the Working Group, a major effort was made to review all the available data on stock separation and distribution (Anon., 1985, 1986).

It was concluded that there are still two main separate spawning areas showing the same pattern as in earlier years (Anon., 1986). However, there is evidence of a change in distribution outside the spawning season.

Walsh and Martin (1986) postulated a recent shift in distribution of the Western mackerel stock based on changes in the main areas of the fishery. They suggested the changes may have been due to major variations in the strength of the North Atlantic drift at the shelf edge. When the current is strong, the Western mackerel stock will have a northerly distribution during its feeding migration. On the other hand, when the current is weak, the fish will migrate into the North Sea.

Eltink et al. (1986) have presented evidence of a link between mackerel in the southern North Sea, in the Celtic Sea, and western Channel areas. The evidence suggests that the Western stock gives an "overspill" of recruits to the North Sea spawning stock. At present, there are no data for a quantitative examination of this possibility.

Bakken and Westgård (1986) have carried out a major new analysis of the Norwegian tagging material. The main conclusions that can be drawn from these data are that tagged fish from the two series of releases were well separated in the period 1970-1980.

In the period 1980-1985, the recapture of tags shows that the tagged fish have been almost randomly mixed between areas and seasons. This suggests that the major changes in distribution and abundance of the two mackerel stocks have led to a situation that makes the recent tagging data less reliable as a method of stock separation than it was in the past.

Hopkins (1986) and Dawson (1986a) have done statistical analyses on otolith morphometric measurements from different areas and seasons in order to discriminate between stocks. Neither of the authors are, however, yet prepared to draw any firm conclusions as to whether this method gives valid results.

In spite of the extensive mixing of the two mackerel stocks and the corresponding difficulty in allocating the catches to stock, the Working Group continued to treat the two stocks as separate for assessment purposes and no combined assessment was carried out.

Since the North Sea stock is currently at a very low level, any misallocation of catches is unlikely to have a significant effect on the assessment of the Western stock.

Table 4.1 shows the releases and recaptures of tags in the Norwegian tagging experiments for the later years.

### 4.3 Recent Changes in Distribution

#### 4.3.1 Juvenile distribution

In 1985, the Mackerel Working Group discussed the apparent changes in the distribution of juvenile Western mackerel that had taken place since about 1981. These changes were illustrated by comparing the annual ratios of the catches of Western stock juveniles (1- and 2-year-olds) from Division VIa to total catches of Western stock juveniles in all areas with the ratios of total catches of all ages of the Western stock in Division VIa to the total catch of the Western stock in all areas. After 1981, there was a tendency for the catches of both juveniles and adults to increase proportionately in Division VIa (Table 4.2 and Figure 4.2).

In 1986, the proportion of catch of both juveniles and adults of the Western stock in Division VIa declined (Table 4.2 and Figure 4.2). This was largely because a high proportion of the Western stock catches was made in Division IVa. Combining these catches in Division IVa with those in Division VIa, the proportion of the catches taken in these northern areas is similar to that in 1985. The 1986 distribution, however, shows that the majority of juveniles had an even more northerly and easterly distribution than in 1985. However, had the closed area off southwest England not been introduced in 1983, the relative proportion of Western stock juveniles taken in northern areas in the first and fourth quarters is likely to have been less, since the available evidence indicates that there is still a significant juvenile component of the Western stock present in the Celtic Sea and English Channel during the winter months.

To investigate the distribution of each year class in more detail,the distribution of catches made by research vessels has been plotted in Figures 4.3-4.7. The abundance indices were derived from research vessel trawl surveys by England (first and fourth quarters, 1984-1987), Ireland (fourth quarter, 1985 and 1986), Netherlands (first and fourth quarters, 1984-1987), Scotland (first and fourth quarters, 1985-1987), Federal Republic of Germany (first quarter, 1985-1987), Norway (first quarter, 1985-1987) and Denmark (first quarter, 1985-1987).

The occurrence of the 1984, 1985, and 1986 year classes expressed as a percentage (number) of catches taken in the commercial mackerel fishery in each ICES division in 1985 and 1986 is shown in Figures 4.8-4.12.

### 4.3.2 <u>The 1986 year class</u>

Over the 1986/1987 winter, the highest concentration of the 1986 year class was found in the Western area southeast of Ireland (Figure 4.4). In the North Sea, the highest concentration occurred between the Shetland Islands and Norway. This year class occurred during the fourth quarter of 1986 only in the small catches off Ireland and the southwest of England and did not appear in the North Sea catches (Figure 4.10).

### 4.3.3 <u>The 1985 year class</u>

Research vessel trawl surveys indicated high concentrations of the 1985 year class in the area south of Ireland between October 1985 and April 1986 (Figure 4.4), while one year later only one high concentration was found southwest of England (Figure 4.5). Owing to severe weather conditions, however, the coverage in the November/December 1986 survey was not as extensive as in 1985.

The 1985 year class did not appear as 0-group in the catches in 1985 (Figure 4.8), but appeared as 1-group in 1986 in all areas except Divisions IIa, IVb, and Vb (Figure 4.11).

In the Danish acoustic survey of the eastern North Sea and Skagerrak in August 1986, this year class was as abundant as the 1984 year class in 1985 (Kirkegaard, 1986). During English and Dutch bottom trawl surveys during the third quarter of 1986, this year class was abundant along the Dutch coast and in some hauls in the central North Sea. These bottom trawl surveys, however, are probably not ideal for sampling mackerel when there is a thermocline, because the mackerel are probably in the upper water layers under these conditions.

### 4.3.4 <u>The 1984 year class</u>

Research vessel trawl surveys in the period October 1984 - March 1985 indicated concentrations of the 1984 year class to the west of Scotland and in the Celtic Sea area (Figure 4.6).

The 1984 year class was abundant in the catches in 1985 to the west of the British Isles and in the southern North Sea and Skagerrak (Figure 4.9). As 2-group, this year class was also very abundant in catches in all areas (Figure 4.12).

In the Danish acoustic surveys in August 1985 and 1986, this year class was very abundant in the eastern North Sea and Skagerrak (Kirkegaard, 1986; Kirkegaard et al.,1986). In a Norwegian survey of Division IVa and the Skagerrak in October 1985, the 1984 year class was also very abundant (Iversen and Westgård, 1986).

## 4.4 Allocation of Catches to Stocks

Until 1984, stock mixing ratios were calculated from the Norwegian tagging data. Due to major uncertainties associated with this method, the Working Group last year decided not to use the stock catch data estimated using the tagging data (Anon., 1986). Since no other data on mixing ratios were available at last year's meeting, it was decided not to proceed with a separate North Sea stock assessment. However, to have an updated data base, the estimated catch data were put in the files.

Using the catch-in-numbers data for the North Sea stock estimated in the last 4-5 years in prior reports gives an age structure in the VPA for the North Sea stock which is very different from what was seen on the North Sea spawning ground during the 1984 and 1986 spawning seasons.

To get a more reliable age composition in the North Sea VPA, it was decided to estimate the North Sea stock catch in numbers by age in 1986, 1985, and 1984 for the 1983 year class and older fish using data from the 1984 and 1986 North Sea egg surveys and information on the relative distribution of the two stocks by quarter.

### Catches in 1984 and 1985 by age group

The total catch of 3-year and older fish from spawning time in 1984 to 1986 was estimated by back-calculating the estimated spawning stock size in number by age in 1986 to fit the 1984 stock estimate, using the exploitation pattern given in the 1984 report (Anon., 1984). The calculated catch at age was allocated to year class assuming a constant fishing mortality coefficient. The proportion of F and M before spawning was set equal to 0.1 and 0.4, respectively, which are the same values as used in the North Sea VPA in previous reports.

### Catches in 1986

The catch in numbers by age in 1986 allocated to the North Sea stock was calculated using three sources of information:

1) the Working Group's best estimate of the relative proportion of the two stocks present in the North Sea (Sub-area IV and Division IIIa) by quarter and age group, based on the available information from research vessel surveys and catch data (Table 8.3);

2) the Working Group's best estimate of the number of 1-year-old fish in 1984 and 1985 in the North Sea and Western mackerel stocks as shown in the text table below:

| Year | North Sea stock | Western stock |
|---|---|---|
| 1984 | 500 | 4,000 |
| 1985 | 250 | 3,500 |

Numbers in millions.

3) age distribution of the North Sea spawning stock in 1986 in Norwegian and Danish research vessel samples:

| Age | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 4.6 | 11.1 | 18.4 | 7.2 | 5.8 | 3.6 | 4.3 | 6.8 | 5.4 | 8.9 | 6.0 | 5.1 | 12.8 |

The catch in Divisions IVb and IVc was taken to be pure North Sea stock. The relative proportion in percent of the catches in 1986 allocated to age groups in each area is summarized in Table 4.2.

Catch of 1- and 2-group

The catch in number of 1-group mackerel in Divisions IVa and IIIa allocated to the North Sea stock by quarter in 1986 was calculated using the number in the 1985 year class in the Western and North Sea stocks (paragraph 2 above) and the proportion of the 1-group present in the North Sea area as given in Table 8.3.

The catch of 1-group in Divisions IIa and VIa was all assumed to be from the Western stock.

The catch in number of the 2-group in Divisions IVa and IIIa was also calculated using the number in the stock's proportions in Table 8.3. In Divisions IIa and VIa, the complementary values were used. It was assumed that the 1984 year class from both stocks experienced the same F from 1984-1986.

Catch of ages 3-15+ in Divisions IIa, IIIa, IVa, and VIa

The catch in tonnes (C) for age groups 3-15+ was calculated by subtracting the SOP of the 1- and 2-group from the total catch. The proportion of this catch allocated to the North Sea stock in the North Sea area ($P_{ns}$) is given by:

$$P_{ns} = \frac{B_{ns} \times p_{ns}}{B_w \times p_w + B_{ns} \times p_{ns}}$$

where:

$B_{ns}$ = spawning stock biomass of the North Sea stock from the 1986 egg survey,

$B_w$ = spawning stock biomass of the Western stock from the 1986 egg survey,

$p_{ns}$ = proportion of the North Sea spawning stock present in the area as given in Table 8.3,

$p_w$ = proportion of the Western spawning stock present in the area as given in Table 8.3.

The mean weight in the catch of the North Sea stock ($w_{ns}$) was calculated using the age distribution in the text table above and the observed weight at age in the catches. The total number of North Sea fish ($N_{ns}$) caught is then:

$$N_{ns} = \frac{C \times P_{ns}}{w_{ns}}$$

The number caught in each age group 3-15+ was then arrived at using $N_{ns}$ and the age distribution above.

This procedure was used in Divisions IVa and IIIa. In Divisions VIa and IIa, the same method was used except that $p_{ns}$ and $p_w$ were replaced by $(1-p_{ns})$ and $(1-p_w)$ since this is outside the North Sea area.

## 5 NORTH SEA AND NORWEGIAN SEA AREAS

### 5.1 The Fishery in 1986

Total landings for 1977-1986 by country are shown in Table 5.1 for the North Sea, Skagerrak, and Kattegat (Sub-area IV and Division IIIa) and in Table 5.2 for the Norwegian Sea (Divisions IIa and Vb). The catches in 1984 and 1985 were revised according to updated reports, and the recorded catches were increased by the following tonnages:

| Year | Area | Tonnes | % increase |
|---|---|---|---|
| 1984 | IV+IIIa | 177 | 0.4 |
| 1985 | IV+IIIa | 1,108 | 2.3 |
| 1984 | IIa | 4,287 | 4.6 |
| 1985 | IIa | 174 | 0.2 |

The total reported landings from the North Sea, Skagerrak, and Kattegat in 1986 were 89,347 t which is an increase from 1985 of about 80%.

In addition to the reported catches in this area, it seems that substantial catches in the third and fourth quarters were reported as catches in Division VIa, but were really taken in Division IVa (Table 5.3).

The catch in Divisions IIa and Vb was 102,234 t which is an increase of about 30% since 1985. Most of the catches (87%) were taken by Norway in July and August mainly south of 64°N and east of 2°E.

The quarterly distribution of catches by sub-areas and divisions is given in Table 5.3.

## 5.2 Assessment of the North Sea Stock

### 5.2.1 Catch in numbers in 1986

The catch in number at age in Divisions IIa, IIIa, IVa, IVb, IVc, and Vb is shown in Table 5.4

Division IIa

The USSR and German Democratic Republic catches were allocated to the main fishing season in Division IIa and divided into age groups using the Norwegian data.

Division IIIa

The Swedish catch was allocated into age groups by quarter using the combined Norwegian and Danish data.

Division IVa

Sampling data were available for the Danish, Norwegian, Scottish, and Dutch catches. Catches made by the Federal Republic of Germany were allocated to age groups using the Dutch data.

As described below in Section 6.3.1, a proportion of misreported catches from Division VIa was transferred to Division IVa for the purpose of calculating numbers at age in the two divisions. These have been included in the numbers given in Table 5.4.

Division IVb

Sampling data were available for the Dutch catches and the Danish catches taken just south of Division IVa (75% of the total Danish catches in Division IVb). The remaining Danish catch and the French, English, and Scottish catches were allocated to age groups using the Dutch data.

Division IVc

Catch in numbers at age was available only from the Netherlands. The Danish, French, and English catches were divided into age groups using the Dutch data.

Division Vb

Sampling data were available for the Danish and Scottish landings from Division Vb. Catches made by the USSR were raised using combined fourth quarter data of the other countries. Samples in the fourth quarter contained a mean of 25% of the 1984 year class which is rather less than in samples from Division VIa.

### 5.2.2 Revision of the 1984 and 1985 data

In Division IIa in 1984, the Soviet catches were increased by 4,287 t, as reported by ICES. The numbers by age were increased according to this amount in last year's Working Group report (Anon., 1986), but the catch table was not corrected. Table 5.2 is now updated with the correction in catches as reported by ICES for 1984 and 1985.

The other corrections in the catches as given in Section 5.1 are minor and no corrections in numbers at age were made in the computer files.

### 5.2.3 Weight at age and maturity

Mean weights at age in the catches by quarter in 1986 were provided by Norway (Divisions IIa, IIIa, and IVa), Denmark (Divisions IIIa and IVa), Netherlands (Divisions IVa,b,c) and Scotland (Division IVa). Weighted (by number) mean catch weight-at-age estimates were made by division by quarter and by division by year for catches from the North Sea area and the North Sea stock.

A comparison between the calculated sum of products (SOP) for the divisions and the reported catches in 1986 shows a close agreement.

Mean weights at age in the stock on 1 January and at time of spawning were unchanged from those used in the 1985 assessment (Anon., 1985).

Due to differences between weights at age observed during the spawning survey in 1986 and those usually used by the Working Group, the weight in stock at spawning time was changed in the WEST file for 1986. The average weights for the different age groups obtained during the egg survey were plotted together with average weights obtained from the Danish fishery in the second quarter. A line was fitted by eye through these data points giving the smoothed weight (grams) at age at spawning time shown below.

| Age | Danish samples (QII) | Norwegian survey data | Smoothed |
|---|---|---|---|
| 1 | - | - | 200 |
| 2 | 227 | 325 | 300 |
| 3 | 334 | 400 | 340 |
| 4 | 367 | 408 | 380 |
| 5 | 393 | 425 | 415 |
| 6 | 442 | 455 | 460 |
| 7 | 534 | 479 | 500 |
| 8 | 598 | 559 | 540 |
| 9 | 573 | 543 | 580 |
| 10 | 675 | 579 | 620 |
| 11 | 635 | 638 | 665 |
| 12 | 775 | 620 | 700 |
| 13 | 812 | 664 | 745 |
| 14 | 712 | 700 | 780 |
| 15+ | 780 | 882 | 825 |

About 180 1984 year-class fish were caught during the egg survey in 1986, and 15% of these fish had spawned or were going to spawn. These figures may be representative for the maturity ogive for the proportion of the year-class fish present on the spawning ground at spawning time, but not necessarily for the whole year class. In samples taken during the Norwegian part of the egg survey and in the Norwegian tagging experiment in the North Sea in July-August, the proportion of 2-year-old spawners was very low, about 3%. As no data on the relative distribution of the 1984 year class in the North Sea during the spawning season were available to the Working Group, it was not possible to estimate the maturity ogive. However, the Working Group agreed that the value was considerably lower for the 2-year-old fish in 1986 than the 37% used in previous years, and the minimum estimated value of 3% was used.

The data obtained during the egg survey indicate nearly 100% maturity of 3-year and older mackerel in 1986 and, as in previous reports, 100% was used for these age groups.

5.2.4 Spawning stock biomass estimate from the egg survey in 1986

By applying the egg production estimate for the North Sea ($30 \times 10^{12}$) and the fecundity length relation given by Iversen and Arloff (1983), the spawning stock was estimated at 45,000 t, applying a sex ratio of 1:1. The average weight of the spawning fish collected during the surveys was 553 g, which means a spawning stock of $81.4 \times 10^6$ fish. This is the lowest spawning stock size recorded in the North Sea in the period 1969 to the present. An age composition of the spawning stock was constructed based on Danish and Norwegian samples in the spawning area during the egg survey.

5.2.5 The state of the North Sea stock

Owing to major uncertainties associated with allocating catches to stocks and estimates of recruitment, the Working Group last year decided not to proceed with a North Sea stock assessment (Anon., 1986).

This situation has not changed since last year. There are still problems in allocating the catches to stocks, and no new data to quantify the relative strength of the 1984 year class recruiting to the North Sea and the Western spawning stocks were available. This year class was observed in large quantities in the North Sea in the third and fourth quarters both in 1985 and 1986 (Kirkegaard, 1986; Kirkegaard et al.,1986; Iversen and Westgård, 1986). However, not many 2-year-old fish recruited to the spawning stock in the North Sea in 1986 since the spawning stock estimated from the egg survey in 1986 was the lowest recorded and since spawning fish of the 1984 year class were poorly represented in samples from the spawning area.

The Danish acoustic survey in August 1986 (Kirkegaard et al., 1986) indicated that the 1985 year class was even more abundant in 1986 in the eastern part of the North Sea and Skagerrak than was the 1984 year class in 1985. The area investigated is shown in Figure 5.1. However, the distribution of the 1985 year class appeared to be more restricted than the 1984 year class in 1985 since the 1985 year class did not appear in the Norwegian coastal fishery in 1986. Rich year classes usually are easily spotted in this fishery.

With the small spawning stock in 1986, a prediction of the status of the spawning stock in 1987 and 1988 is totally dependent on the strength of the 1984 and 1985 year classes. Usually 100% of the 3-year-old North Sea mackerel spawn. Therefore, the Working Group considers it very important to sample the North Sea stock during the spawning period in the spawning area in 1987 to obtain information about the strength of the 1984 and 1985 year classes.

5.3 Management Considerations

In 1986, about 32,000 t of mackerel were estimated to have been caught from the North Sea stock, of which about 25,000 t were from the spawning component (Section 4.4). If these figures are correct, the spawning stock will have been reduced by more than 50% during 1986. The expected catch of North Sea mackerel in 1987 cannot at present be estimated. However, it is likely that there will be a fishery in the North Sea predominantly for Western mackerel which will also take North Sea mackerel. If the distribution of this fishery is the same as in 1986, the fishing mortality rate on the North Sea stock in 1987 is likely to be similar to that in 1986. Owing to a lack of data to quantify the strength of the 1984 and 1985 year classes in the North Sea stock, it is at present impossible to make a realistic prediction of the spawning stock size in either 1987 or 1988. It is, therefore, of considerable importance to obtain further information to enable ACFM to give advice on the North Sea stock at its meeting in November 1987. Relevant information may be obtained from:

1) a Norwegian acoustic survey of the North Sea in July during the second half of the spawning season;

2) a Norwegian and Danish acoustic and trawling survey of the eastern North Sea and Skagerrak in August aimed particularly at 1- and 2-year-old mackerel;

3) a Scottish acoustic survey in April-May covering Division IVa and the main mackerel spawning areas in Division IVb.

There will, however, be no egg survey in 1987.

Since North Sea mackerel disperse widely throughout the North Sea and adjacent areas outside the spawning season, total protection of the North Sea stock can only be achieved by widespread closures of mackerel fisheries in Sub-area IV and Divisions IIa and VIa. As pointed out in Section 4.2, however, there are major fisheries on Western stock mackerel in these areas. While in no way being able to solve this fundamental dilemma of how to protect the North Sea stock without at the same time closing major fisheries on the Western stock, the Working Group is, nevertheless, able to make a number of positive suggestions:

a) In the first place, there are thought to be few Western stock mackerel in the North Sea in the first seven months of the year and a total closure of Sub-area IV from January-July inclusive would thus provide some protection of the North Sea stock.

b) Even in the latter half of the year, there is no evidence that Western stock fish penetrate into Divisions IVb and IVc, and these two divisions could remain closed for the entire year.

c) The main nursery grounds of North Sea mackerel are in the eastern part of the North Sea and in Division IIIa. Since any recovery of the North Sea spawning stock is dependent on the survival of immature mackerel that are destined to recruit to it (whether originating from the North Sea or Western spawning stocks), measures should be taken to prevent any exploitation of immature mackerel in the North Sea. For this reason, the 30-cm minimum landing size at present in force in the North Sea and Division IVa should be maintained in all mackerel fisheries in these areas and by-catches of mackerel in other fisheries should be kept to an absolute minimum.

## 6 WESTERN AREA

### 6.1 The Fishery in 1986

The landings by country for the Western area (Sub-areas VI and VII and Divisions VIIIa,b) from the 10-year period 1977-1986 are shown in Table 6.1. The figures for 1986 are preliminary. Some slight changes have been made to the 1984 and 1985 catches because of the addition of some very small Spanish and USSR catches. Some changes have also been made in the distribution of the unallocated catches in those years, which do not, however, alter the total quantities landed. The total catch for 1986 amounted to about 378,000 t which was considerably lower (-19%)

than the 1985 figure and is in fact the lowest figure recorded since 1978. The highest recorded catch figure was that of 1979 when nearly 647,000 t were taken. The Working Group also considered that considerable quantities of mackerel, estimated at about 148,000 t and included in Table 6.1, were reported as having been taken from the Western area in Division VIa, but were in fact taken east of $4^0$ in Division IVa. This misreporting of catches had also been commented upon in the 1986 Working Group report, but the amounts misreported in 1985 were small by comparison. As in recent years, the total catch which could not be attributed to any country was substantial and represented 17% of the total catch recorded. The amounts of fish which were caught but later discarded has decreased in recent years, and although some discarding still takes place, the amounts for 1986 were considered negligible.

The total landings were 378,000 t while the agreed TAC was 362,000 t. The TAC recommended by ACFM for this stock was 290,000 t.

The main catches from the fishery were again taken by the UK (Scotland), Ireland, the Netherlands, and Norway. However, it should again be pointed out that these figures cannot be taken as a true indication of catches for all countries because of the amounts of fish in the "unallocated" category. Nevertheless, considerable decreases were reported by a number of countries, particularly Scotland and Ireland. The decrease in the total catch was partly due to improved management controls, partly due to abnormally severe weather conditions particularly in the fourth quarter of the year, and partly due to reduced quotas. The late migration of shoals from Division IVa to Division VIa may also be responsible for the decrease in the catches in Division VIa.

The reported catches taken by sub-area are shown in Table 6.2. Prior to 1986, there was an increasing trend in the catches taken in Division VIa and a decreasing trend in those from Sub-area VII. This trend has been taken to reflect the changing distribution of the shoals. The pattern in 1986, however, showed a reversal in this trend with a decline in the catches in Division VIa and an increase in those in Sub-area VII. However, it should be pointed out that the catches in 1986 were very much affected by management controls which prevented fishing by the Dutch fleet in the third and fourth quarters and also by severe weather conditions in the latter part of the year. This reversal of catch trends cannot, therefore, be taken as evidence of a change in stock distribution.

The distribution of the catches per quarter corrected for misallocated catches is shown in Table 5.3.

### 6.2 Discarded Catches

As previously indicated, the amounts of mackerel caught but later discarded have decreased very much in recent years. The amounts during 1986 were considered to be negligible. This decrease may be the result of the shift in the fishery away from the Cornwall area. The Working Group is aware, however, that some discarding must still take place, and the problem could become apparent again particularly if a number of good year classes entered the fishery.

## 6.3 Assessment of the Western Stock

### 6.3.1 Catch in numbers in 1986

Division VIa

Since it was known that considerable quantities of mackerel caught in Division IVa in the third and fourth quarters of the year had been misreported as having been caught in Division VIa, a rough estimate of the quantities misreported was subtracted from the nominal numbers at age calculated for Division VIa.

Sample data for Division VIa were provided by Ireland, the Netherlands, Norway, and UK (Scotland). Landings by the Faroese were converted to numbers at age using data from Norway, Ireland, and UK (Scotland), while those by the Federal Republic of Germany and UK (England) were raised using Dutch data.

Catches in numbers at age in Division VIa, after subtraction of appropriate quantities of misreported catches, are given in Table 6.3. The age compositions show a strong representation of the 1984 year class in the first (41%), third (47%), and fourth (57%) quarters, but a much weaker one (16%) in the small landings in the second quarter. In contrast to 1985, the percentage of 1-group (1985 year class) in the catches was very small (3% in the fourth quarter).

Divisions VIIa-c

Numbers-at-age data in Division VIIb were supplied by Ireland and the Netherlands. The age distributions of the Irish and Dutch first and second quarter catch in Division VIIb were applied to the English catches in the first and second quarters. The age compositions show a fairly low representation of the 1984 year class in the first two quarters (first, 11%; second, 32%); however, it was much higher for the fourth quarter (89%). Numbers-at-age-data in Division VIIc were supplied by the Netherlands for the first quarter.

The combined Irish and Dutch age distributions were applied to the small catches in Division VIIa for each quarter, because there were no age compositions for this area. The number-at-age data are presented in Table 6.3.

Divisions VIId-k

Numbers-at-age data were supplied by England and the Netherlands for Divisions VIIe,f, the Netherlands for Division VIIg, and Ireland and the Netherlands for Division VIIj. The 1984 year class was most strongly represented in the third quarter (72%) with only 24% in the first quarter, 14% in the second, and 4% in the fourth. Although only 720 t were taken from Divisions VIIe,f in the fourth quarter, 86% was from the 1986 year class.

The combined English, Dutch, and Irish age distribution for Divisions VIId-k was applied to the French catches in Divisions VIId-k for each quarter.

All the age distributions were calculated from commercial samples with the exception of the English fourth quarter age distribution for Divisions VIIe,f which was calculated from research vessel samples. The number-at-age data are presented in Table 6.3.

Divisions VIIIa,b

No numbers-at-age data were supplied for Divisions VIIIa,b. The annual age distribution for Divisions VIId-k was applied to the total catch in Divisions VIIIa,b. Catches in Divisions VIIIa,b accounted for only 0.1% of the total catch in Sub-area VII and Divisions VIIIa,b.

### 6.3.2 Revision of the 1984 and 1985 catch-in-numbers data

Although some slight changes have been made in the 1984 and 1985 catch data, the quantities amounted to less than 0.5% of the total landings. Some changes have, however, been made to the catches in numbers at age for these years because of the method used in allocating catches to stocks. Therefore, there are some slight differences between the catch-in-number data in Table 6.8 and the data used in the previous Working Group report. The total numbers are, however, the same.

### 6.3.3 Mean weight at age

Mean weights at age in the catches by quarter in 1986 were provided by Scotland (Divisions VIa and IVa), England (Divisions VIIe,f), Ireland (Divisions VIa, VIIb, and VIIj), and the Netherlands (Divisions IVa, VIa, VIIb, VIIc, VIIj, VIIg, and VIIe). Weighted (by number) mean catch weight-at-age estimates were made by division by quarter and by division by year for catches from the Western area and the Western stock.

Mean weights at age (kg) in the spawning stock at spawning time were estimated for 1986 by using samples from Dutch commercial freezer trawlers in Division VIIj in March, April, and May and are shown in the text table below (1-year-olds are rarely taken in samples; therefore, a constant weight of 0.070 is taken):

| Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\overline{w}$(kg) | 0.070 | 0.164 | 0.261 | 0.290 | 0.345 | 0.337 | 0.395 | 0.467 | 0.441 | 0.451 | 0.562 |

### 6.3.4 Maturity at age

According to the historic maturity ogive (Anon., 1986), 60% of the 1984 year class (2-year-olds) was expected to spawn. This is equivalent to 30% of the spawning stock in number in 1986 estimated by VPA by the 1986 Mackerel Working Group (Anon., 1986). Compared to an observed value of 17%, this implies either that the maturity ogive appropriate to the 1986 data differs from the historic one, or that the samples taken on the spawning ground underestimate the abundance of the 1984 year class (Anon., 1987), i.e., not all of the 2-groups were present on the main spawning ground.

The Working Group decided to change the percentage of mature 2-year-olds in 1986 on the following basis:

1) The 2-year-olds on the spawning ground in 1986 were about 3 cm smaller than the 2-year-olds in 1985.

2) Expected number of mature 1984 year class as a percentage of the total number of spawning fish is 30%, and the observed number of spawning females in the 1984 year class as a percentage of the total number of spawning fish is 11%.

Therefore, the expected percentage of the mature 2-year-olds in 1986 was reduced by approximately 2/3 to 20%.

### 6.3.5 Spawning stock biomass estimate from the 1986 egg survey

From the results of the egg surveys carried out in the Western area in 1986, the Mackerel Egg Production Workshop (Anon., 1987) estimated a total egg production of $1.165 \times 10^{15}$. This was composed of $1.12 \times 10^{15}$ eggs in the area covered on previous surveys and a further $4.56 \times 10^{13}$ eggs produced in Division VIa. This is equivalent to a total number of spawning fish of $4{,}578 \times 10^{6}$ and a spawning stock biomass of 1.5 million t.

This and the associated estimates of egg production and spawning stock biomass from previous egg surveys are listed in Table 6.4.

The estimated total number of spawning fish was apportioned to age using the estimated age composition of stage 6 fish sampled on research vessel surveys and in Dutch commercial samples obtained during the egg survey period (Anon., 1987). The resulting number of spawning fish at each age is given in Table 6.5.

### 6.3.6 Exploitation pattern

Separable VPA (SVPA) was used to derive the most appropriate exploitation pattern to determine levels of fishing mortality at age in the most recent year and for the oldest true age groups in earlier years. This was carried out using a data set on ages 0-10 for the years 1978-1986 and in order to take into account the possibility of a change in exploitation pattern in recent years (see Section 7), the catch-in-numbers data were subjectively weighted according to the method of Stevens (1984). Maximum weighting (1.0) was assumed for the years 1982-1986 and minimum weighting (0.001) for the period 1978-1981. A terminal F reference age of 4 years and a terminal S of 1.0 at age 10 give an exploitation pattern with a more or less constant exploitation on age groups 4-10. Since there is no concrete evidence to suggest how the older age groups are exploited relative to the reference age, a flat exploitation pattern was chosen as being the most reasonable, setting the relative F on 4-10 year olds in the terminal year to 1.0. The relative F on 2- and 3-year-olds was then determined by SVPA (Table 6.7). However, terminal values for 0- and 1-group were adjusted to generate the estimated numbers given in Section 6.3.8 for the 1985 and 1986 year classes.

### 6.3.7 Fishing mortality and stock size

To tune the VPA, SVPA was carried out using several values of input F to obtain the input values for the oldest age group in each year and for each age group in the last year. Outputs were given in terms of spawning stock biomass referred to 1 January. Spawning stock biomass estimates from the egg surveys given in Table 6.5 were converted to estimates for 1 January by adding the catch in tonnes taken in the first half of the year from the Western sub-areas (VI, VII, and VIII) obtained from earlier Working Group reports and 5/12 of the weight dying through natural mortality using Pope's cohort analysis formula:

$$\text{Biomass at 1 Jan} = \left[\left(\begin{array}{l}\text{Biomass at}\\ \text{spawning}\end{array} \div e^{M/2}\right) + \begin{array}{l}\text{Catch in}\\ \text{first two}\\ \text{quarters}\end{array}\right] \div e^{M/2}$$

The comparison of spawning stock biomasses from VPA and the egg surveys is given in Table 6.6. Values of the correlation coefficient were high using a wide range of values of input F. As in 1984, the value chosen was that which gave a minimum deviation between the two series of estimates (i.e., F on 4-group and older of 0.22).

Results of the VPA are given in Tables 6.9-6.10. The spawning stock size in 1986 at spawning time is estimated to be 1.64 million t compared to an estimate of 2.1 million t in 1985, an approximate reduction of 20%. It is important to note, however, that a large part of this reduction is due to the reduced number of 2-group (1984 year class) fish estimated to have spawned in 1986 (20%) as opposed to that used in previous years (60%). The total biomass of age 2 and older fish was reduced by only 3-4% between 1985 and 1986. The total number of fish in the stock on 1 January 1986 was 17% less than in 1985.

Results from this VPA using the exploitation pattern generated by SVPA show some marked changes from that produced by last year's Working Group (Annex to Anon., 1986). The 1986 version estimated a spawning stock biomass of 1.3 million t at 1 June 1986 compared to 1.6 million t presented here. A large part of this discrepancy may be explained by the new exploitation pattern adopted for 1986, but also by the method used in tuning the VPA to the egg survey estimates. This year, the Working Group tuned the VPA to the whole series of egg survey estimates rather than to the most recent survey alone. The text table below compares the estimates of spawning stock biomass at spawning time as estimated by the egg survey data with those derived from VPA in 1986 and 1987.

Spawning stock biomass at spawning time, 1 June ($t \times 10^{-6}$)

| Year | VPA 1986 WG | VPA 1987 WG | Egg survey estimate |
|---|---|---|---|
| 1977 | 3.2 | 3.0 | 3.0 |
| 1980 | 2.3 | 2.3 | 2.9 |
| 1983 | 2.0 | 2.4 | 2.4 |
| 1986 | - | 1.6 | 1.5 |

The results derived from this year's VPA show the closest agreement with those from the egg surveys.

Mean F at age for the period 1978-1982 is plotted together with the F-at-age values input for 1986 (Figure 6.1). A comparison of the two sets of values indicates that the mean for the period 1978-1982 ("old" exploitation pattern) only differs significantly from the 1986 ("new") exploitation pattern for ages less than 4. The values input for 0- and 1-year-olds in 1986 were determined by the estimated recruitment (see Section 6.3.8), but the F on 2- and 3-year-olds is appreciably less and clearly indicates that the age of selection has increased from age 3 to age 4. These changes may reflect natural changes in the distribution and abundance of juveniles, but it is also possible that they reflect the management measures imposed in Divisions VIIe,f, i.e., the introduction of the closed area off southwest England in 1983.

### 6.3.8 Recruitment

Prior to 1986, the number of 1-group mackerel in the Western stock at 1 January had been calculated by using catch data for the previous year's fishery and the mean exploitation pattern as determined from the SVPA. In 1986, however, this method gave a very low estimate of the strength of the 1984 year class when compared with rather high abundance from the trawl surveys (Figure 4.7). An examination of the abundance indices of 1-group fish from the recruit surveys in Sub-area VII and the abundance of 1-group in the stock from VPA showed that there was a reasonable level of agreement between the two series. At the present Working Group meeting, however, the SVPA indicated that the exploitation pattern was rather different from that obtained by the previous assessment, and the VPA given in Table 6.10 indicates that the abundance of the 1984 year class was more consistent with the recruitment survey indices and was close to the mean abundance of the five good year classes over the period 1975-1983.

The surveys carried out in 1986 confirmed the strength of this year class. The information about the 1985 year class obtained from the 1986 surveys indicates that it was well represented in the surveys conducted in Sub-area VII and may be of similar size to the 1984 year class, and it was set at a size of 3,500 million fish at age 1.

Because of the poor coverage of the 1986 survey, there is very little information available about the size of the 1986 year class. However, in those areas covered, it was poorly represented.

## 6.4 Forecast for the Western Stock

To carry out catch and stock predictions into 1988, the following parameters and assumptions were used:

a) The stock size in number at ages 2-11+ at 1 January 1987 was taken from the VPA (Table 6.10).

b) The number of 1-group in 1987 was taken to be 750 million, i.e., close to the abundance of the second lowest year class in recent years (the 1982 year class). The justification for a low value is based on the low abundance of the 1986 year class in surveys during the fourth quarter of 1986.

c) The number of 0-group was set at the geometric mean of estimates for the years 1972-1984.

d) The exploitation pattern for age groups 2-11+ in 1987 and 1988 was assumed to be the same as that used in the VPA for 1986. The F on 1-group was, however, put at a value of 0.06 (corresponding to $F_{4-11}$ = 0.225) because the F on 1-group in 1986 had been reduced to create a year-class strength of 3,500 million in 1986. F on the 0-group in 1987 was set at 0.001 but this has a negligible effect on the output.

e) Recruitment of 0-group in 1988 was set at the same level as 1987.

f) Since the 1984 year class appears to have been unusual in its distribution and age of first maturity, the proportion of mature 2-group fish was assumed to be at the earlier level of 60%.

g) The catch in 1987 was assumed to be 550,000 t based on the agreed TAC and additional quantities likely to be caught.

The input parameters for the prediction are listed in Table 6.11. The options for 1988 are given in Table 6.12 and Figure 6.2.

A catch of 550,000 t in 1987 is expected to generate an F of 0.25. With almost full recruitment of the 1984 year class, the spawning stock biomass is expected to increase by about 15%, but to decrease again in 1988 under all options of F.

## 7 CONSERVATION MEASURES TO PROTECT JUVENILE FISH

### 7.1 Existing Measures

In the North Sea, the only measure employed to protect juvenile mackerel is a minimum landing size of 30 cm. In the Western area, the measure actually employed since 1983 has been the closed area off southwest England (the mackerel "box"), within which large concentrations of small fish have occurred. Information provided by this year's VPA suggests that there have been changes in the exploitation pattern from that during the period 1978-1981 and during the period 1982-1986. As pointed out in Section 6.3.7, this may have resulted at least in part from the introduction of the closed area.

### 7.2 Evidence of Change in Distribution of Juveniles

There has been a northward shift in the relative distribution of juveniles to Divisions IVa and VIa (Section 4.3). There is also evidence to suggest a change in distribution of the juveniles within the Channel. Figure 7.1 illustrates where the main concentrations of mackerel have been found in relation to the "box" for the last three winter seasons. These maps are based on both commercial catches and English and Dutch research vessel data. The percentage of fish less than 30 cm (i.e., juveniles) within each rectangle is also shown. Figure 7.1 indicates a more easterly distribution of juveniles in the most recent winter season 1986/1987. This has enabled a commercial fishery to take place outside the mackerel "box" where catches of 10,000 t have been taken over the period 1 January 1987 to 13 February 1987, 80% of which have been juveniles (i.e., fish that have not yet spawned). Figure 7.1 indicates that the proportion of juveniles has been much higher during the last two seasons, 1986/1987 and 1985/1986 than in the season 1984/1985. This is almost certainly due to the poor year classes of 1982 and 1983 showing up in small proportions during the 1984/1985 season and the strong 1984 year class and average 1985 year class appearing in the 1986/1987 season. If this more easterly distribution continues, it may be necessary to review the area of the mackerel "box" to enable it to continue to be effective.

### 7.3 Exploitation of Juvenile Fish - Possible Conservation Measures

The Working Group evaluated the following conservation measures:

1) Maintain the existing "box"

2) Marginal extension of the existing "box"

Both of these options have been discussed in Sections 7.1 and 7.2 above.

3) Closure of other areas

If additional areas could be identified, this would undoubtedly be a very effective measure. However, the change in distribution of juveniles makes it very difficult to define such an area at present.

4) Minimum size regulations

This has been applied in the North Sea without apparent problems until 1985 and, to some extent, 1986. This is most probably because the large 1969 year class and small year classes in recent years have resulted in bigger fish dominating the catches until the recent widespread distribution of the 1984 year class which appeared in North Sea catches. However, the success of this measure depends on avoidance of areas where small and large fish are mixed. In areas where large quantities of juvenile fish are present, a high level of discarding is liable to occur.

5) Mesh regulations

Extensive experiments using conventional diamond-meshed trawls show that mesh selection is not an effective way of selecting adult mackerel. However, recent experiments with square-meshed midwater trawls indicate that there may be some protection of juveniles by this means (Casey, pers. comm.). The viability of mackerel escaping such meshes has not yet been investigated.

6) Ad hoc closures

*Ad hoc* closures in areas and at times when small fish are present in high concentrations offer the potential advantage of a quick response to changes in the distribution of juvenile fish and avoid the problem of discarding. However, it would require intensive research in such areas to monitor changes.

### 7.4 Research Recommendations

The Working Group recommends that both the area inside and outside the "box" should be monitored while the fishery is restricted so that the distribution of juveniles can be assessed.

Further work should be carried out with square-mesh nets.

## 8 DATA REQUESTED BY THE AD HOC MULTISPECIES WORKING GROUP

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

The catch in number of the North Sea mackerel stock in 1986 is given in Table 8.1 by age and quarter. The total catch (in tonnes) in 1986 in each quarter is also included. The method used to allocate catches in tonnes into number at age and stock is explained in Section 4.4.

## 8.2 Mean Weight at Age by Quarter

This year, new data were available for weight at age in the spawning stock at the time of spawning (second quarter). For the rest of the year, the weight at age of the stock must be approximated by the observed weight at age in the catch. The weight-at-age data are given in Table 8.2.

## 8.3 Stock Distribution by Quarter

As explained in Section 4.1, much of the information on adult mackerel distribution is obtained from the distribution of catches. For the immature age groups, survey data are also available (Section 4.3). On the basis of the material available, an indication of the percentage of each stock that was in the North Sea (Sub-area IV) during each quarter of 1986 is given in Table 8.3.

### 1-group

While recruitment to the North Sea stock is poor, there are no obvious nursery areas that can be identified as containing predominantly North Sea mackerel. It has been assumed from stronger year classes in the past, however, that all North Sea 1-group mackerel are present in the North Sea throughout the year.

From the large quantities of 1-group mackerel that were found along the coasts of the eastern North Sea and in the Skagerrak, mainly in the latter half of 1985 and 1986, it must be concluded that there is an immigration from the Western stock. The approximate percentage of this age group that migrates into the North Sea can be estimated from the abundance during the August acoustic survey and the estimated total size of the year class.

### 2-group

Only small quantities of 2-group mackerel are found in the North Sea in the first two quarters of the year, and it must be supposed that these consist of the North Sea stock and a small proportion of the Western stock. Earlier tagging experiments indicate that some North Sea mackerel in this age group leave the North Sea to winter in Division VIa. From their proportion in catches in the North Sea, Western stock 2-year-olds clearly joined the adult migration into the North Sea in 1986 and by the fourth quarter, almost 70% of the total catch of this age group was taken in the North Sea. This has been used as an indication of the percentage of the Western stock in the North Sea at this time. In the third quarter, almost half of the catch of 2-group was made in Division IIa which indicates that a smaller proportion was in the North Sea.

### 3-group and older

It can be assumed that all the adults of the North Sea stock are in the North Sea in the second quarter. Outside this period, however, they mix extensively with the Western stock, dispersing into Divisions IIa and VIa. In the last two quarters, it has, therefore, been assumed that the proportion remaining in the North Sea is the same as in the Western stock. When the Western stock adults migrate to the spawning grounds in the first quarter, it must be assumed that North Sea adults gradually move back into the North Sea.

From the proportion of the catches of mackerel taken in the North Sea in each quarter, it appears that about half of the Western stock was in the North Sea in the third quarter (with most of the remainder in Division IIa) and about 70% in the fourth quarter.

It should be noted that some of the percentages for the Western stock given in Table 8.3 are very much higher than those given in Figures 9.1 - 9.4 of the 1986 report (Anon., 1986). This represents a real change in the migration pattern of the Western stock which remained in the North Sea until much later in 1986 than in previous years. The beginning of this change was noted in 1985, however, when the main fourth quarter fishery was across the border of Divisions IVa and VIa.

### 8.4 Review of the Multispecies Working Group Report

The Working Group found little need to comment on the report of the Multispecies Assessment Working Group meeting held in November 1986 because the value of M used in both assessments is the same and there is no additional predation mortality caused by the predators included in the MSVPA. The cause of mackerel natural mortality is not known, but it is thought that predation by other fish predators (e.g., elasmobranchs) and by cetaceans might be significant.

The Working Group also recognizes the difficulty caused by the migration of the Western mackerel stock into and out of the North Sea each year and would point to the fact that the time spent in the North Sea increased in 1986 to most of the third and fourth quarters of the year. This means that as much as 0.8-1.1 million of Western mackerel may have been in the North Sea for around six months (see Tables 8.3 and 6.10).

## 9 DEFICIENCIES IN DATA

The Working Group again considered the deficiencies in the data used to make assessments. These deficiencies were comprehensively reviewed by the 1986 Working Group and in general the situation has remained unchanged. The Working Group would, however, like to highlight the following points:

### 9.1 Catch Statistics

All Working Group members appear to be reasonably satisfied with the accuracy of the catches which they presented to the meeting. There are, however, considerable discrepancies between the reported "official" catches and the catches reported by Working Group members for a number of countries. This presents problems in interpreting the national catch statistics.

There is a real lack of information about the location from which catches are taken. Inaccuracies in the origin of catches create considerable difficulties in interpreting the catch data.

## 9.2 Biological Data

Information about egg mortality, fecundity, and maturation is required in relation to the egg production estimates. These points have been discussed in detail in Sections 2 and 6.3.5. Further information is also needed about the mean weights at age and length distributions by age and maturity stage during the spawning season for both the North Sea and Western stocks. An agreed maturity scale is essential for this purpose.

## 9.3 Hydroacoustic Surveys

There are no fishery-independent estimates of stock size apart from the egg surveys. In addition, the next series of egg surveys will not be carried out until 1988 for the North Sea and 1989 for the Western area. In the meantime, consideration should be given to carrying out acoustic surveys on the overwintering concentrations west of Scotland and Ireland.

In Division IIIa and in the eastern part of Division IVb, Denmark has rather successfully carried out an acoustic and trawl survey aimed at young mackerel (1- and 2-group) and herring (Kirkegaard, 1986; Kirkegaard *et al*., 1986). In 1987, Denmark will carry out a similar survey in August. In addition, Norway will cover the Norwegian part of Division IVa and parts of Division IIIa at the same time for the same purpose. In addition to the acoustic equipment, a Fotö herring trawl, which has proved very efficient for catching pelagic species, will be used by both Denmark and Norway.

## 9.4 Recruit Surveys

There is still a serious lack of information about recruitment. Recruitment surveys for juvenile mackerel have been carried out by the UK (England) in Sub-areas VII and VIII since 1979. In recent years, Scotland, the Netherlands, and Ireland have also started similar surveys, and the area has been extended to cover Divisions VIIb and VIa. The results of these surveys have been used by the Working Group to obtain an indication of the abundance of 0-, 1-, and 2-group mackerel in different areas.

## 9.5 Ageing

The results of the otolith exchange in 1985 indicated an unacceptable level of agreement of ages for fish older than 10 years (Anon., 1986; Dawson, 1986b). An Otolith Reading Workshop has been planned for May 1987 in an attempt for otolith readers to resolve their age differences on the older age groups. The Working Group agreed to continue using numbers at age for age groups 0 to 11+ for Western stock assessments until this problem has been resolved.

## 9.6 A Data Base for Mackerel Data

The Working Group members discussed a working document by T. Westgård (1987) on the exchange format of a future mackerel data base. As in 1986, the Working Group still thinks that a data base should be developed along these lines. It was agreed that each country involved will produce a tape with the relevant data and that the Institute of Marine Research in Bergen will be given the responsibility to set up a first version of a working data base. Such a data base could only be used by members of the Mackerel Working Group and data would only be published as a part of the Working Group report. When a data base has been set up, a workshop should be held in Bergen to work on a detailed analysis of the mackerel data. Later on, the data base should be transferred to the ICES computer facilities.

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Table 4.1 Results of Norwegian tagging experiments. Tag returns are from Norwegian landings to selected factories 1981-1986.

| | Releases | | Recaptures | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Norwegian Sea | | | | | | North Sea | | | |
| | Year | No. | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1982 | 1984 | 1985 | 1986 |
| O | 1970 | 4,540 | - | - | - | 1 | - | - | - | - | - | - |
| F | 1971 | 5,000 | - | - | - | - | - | - | - | - | - | - |
| F | 1972 | 5,086 | - | 1 | - | 1 | 1 | - | - | - | - | - |
| | 1973 | 8,205 | - | 1 | - | - | - | - | - | - | - | - |
| S | 1974 | 10,028 | - | 4 | - | 1 | 2 | - | - | - | - | - |
| O | 1975 | 10,003 | - | - | - | - | 4 | - | - | - | - | - |
| U | 1976 | 9,474 | - | 3 | - | 1 | 1 | - | - | - | - | 1 |
| T | 1977 | 14,032 | 2 | 4 | 1 | 2 | 3 | - | - | - | - | - |
| H | 1978 | 18,169 | 3 | 5 | 2 | 8 | 5 | 1 | 1 | 1 | - | 1 |
| | 1979 | 20,183 | 3 | 7 | 1 | 5 | 14 | 5 | - | - | 3 | 1 |
| I | 1980 | 9,992 | 2 | 4 | - | 4 | 7 | 1 | - | - | - | - |
| R | 1981 | 9,872 | - | 5 | 3 | 5 | 5 | 4 | - | 1 | - | - |
| E | 1982 | 10,065 | - | 5 | 5 | 5 | 5 | 4 | 1 | 1 | 3 | - |
| L | 1983 | 13,400 | - | - | 16 | 25 | 24 | 12 | - | 3 | 5 | 2 |
| A | 1984 | 14,512 | - | - | - | 8 | 37 | 20 | - | 1 | 2 | 5 |
| N | 1985 | 25,069 | - | - | - | - | 32 | 72 | - | - | 7 | 14 |
| D | 1986 | 18,015 | - | - | - | - | - | 51 | - | - | - | 13 |
| | Sum | 205,750 | 10 | 39 | 38 | 66 | 140 | 170 | 2 | 7 | 20 | 37 |
| | 1970 | 3,505 | - | - | - | - | - | 1 | - | - | - | - |
| I | 1971 | 9,305 | - | - | - | - | - | - | - | - | - | - |
| N | 1972 | 11,818 | - | - | - | 1 | - | - | - | - | - | 1 |
| | 1973 | 7,277 | - | - | - | 2 | - | 1 | - | - | - | 1 |
| T | 1974 | 4,493 | - | - | - | 1 | 1 | - | - | - | - | - |
| H | 1975 | 9,995 | - | - | - | 1 | - | 2 | 1 | - | - | - |
| E | 1976 | 1,763 | - | 1 | - | - | - | - | - | - | - | - |
| | 1977 | 7,094 | - | - | - | - | 1 | 3 | - | - | - | - |
| N | 1978 | 12,173 | - | 2 | - | 5 | 3 | 1 | - | 2 | 1 | - |
| O | 1979 | 11,991 | 2 | 2 | 2 | 8 | 5 | 4 | 1 | - | - | - |
| R | 1980 | 5,676 | - | 1 | 3 | 5 | 5 | 3 | 1 | - | 1 | 1 |
| T | 1981 | 4,199 | - | - | 2 | 3 | 8 | 2 | 1 | - | - | 2 |
| H | 1982 | 13,164 | - | - | 7 | 16 | 25 | 18 | 2 | 1 | 2 | 2 |
| | 1983 | 9,216 | - | - | - | 26 | 21 | 19 | - | 2 | 2 | 4 |
| S | 1984 | 13,587 | - | - | - | - | 36 | 33 | - | - | 2 | 6 |
| E | 1985 | 20,273 | - | - | - | - | - | 43 | - | - | 3 | 19 |
| A | 1986 | 15,001 | - | - | - | - | - | 4 | - | - | - | 4 |
| | Sum | 160,530 | 2 | 6 | 14 | 68 | 105 | 134 | 6 | 5 | 11 | 40 |

Table 4.2 The relative proportion in percent of the total catches by division and quarter in 1986 allocated to the North Sea stock.

| | Quarter | | | |
|---|---|---|---|---|
| Division | 1 | 2 | 3 | 4 |
| | | 3 years and older | | |
| IIa | 1 | - | 3 | 3 |
| IIIa | 25 | 100 | 3 | 3 |
| IVa | 25 | 100 | 3 | 3 |
| IVb | 100 | 100 | 100 | 100 |
| IVc | 100 | 100 | 100 | 100 |
| VIa | 1 | - | 3 | 3 |
| | | 1984 year class | | |
| IIa | 3 | - | - | 3 |
| IIIa | 50 | 55 | 20 | 10 |
| IVa | 50 | 55 | 20 | 10 |
| IVb | 100 | 100 | 100 | 100 |
| IVc | 100 | 100 | 100 | 100 |
| VIa | 3 | - | - | 3 |
| | | 1985 year class | | |
| IIa | - | - | - | - |
| IIIa | 100 | 25 | 20 | 20 |
| IVa | 100 | 25 | 20 | 20 |
| IVb | 100 | 100 | 100 | 100 |
| IVc | 100 | 100 | 100 | 100 |
| IVa | - | - | - | - |

Table 5.1 Nominal catch (t) of MACKEREL in the North Sea, Skagerrak, and Kattegat (Sub-area IV and Division IIIa) 1977-1986. (Data were submitted by Working Group members.)

| Country | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | 49 | 10 | 10 | 5 | 55 | 102 | 93 | 68 | - | 48 |
| Denmark | 21,833 | 18,068 | 19,171 | 13,234 | 9,982 | 2,034 | 11,285 | 10,088 | 12,424 | 24,497 |
| Faroe Islands | 42,836 | 33,911 | 28,118 | 1,770 | - | 720 | - | - | 1,356 | - |
| France | 2,529 | 3,452 | 3,620 | 2,238 | 3,755 | 3,041 | 2,248 | - | 322 | 1,200 |
| German Dem. Rep. | 41 | 233 | - | - | - | - | - | - | - | - |
| Germany, Fed. Rep. | - | 284 | 211 | 56 | 59 | 28 | 10 | 112 | 217 | 1,856 |
| Iceland | - | - | - | - | - | - | - | - | - | - |
| Ireland | - | - | - | 738 | 733 | - | - | - | - | - |
| Netherlands | 2,673 | 1,065 | 1,009 | 853 | 1,706 | 390 | 866 | 340 | 2,340 | 9,380 |
| Norway | 180,800 | 82,959 | 90,720 | 44,781 | 28,341 | 27,966 | 24,464 | 27,311 | 30,835 | 50,600 |
| Poland | 298 | - | - | - | - | - | - | - | - | - |
| Sweden | 4,012 | 4,501 | 3,935 | 1,666 | 2,446 | 692 | 1,903 | 1,440 | 760 | 1,258 |
| UK (Engl.& Wales) | 105 | 142 | 95 | 76 | 6,520 | 16 | 16 | 2 | 143 | 18 |
| UK (Scotland) | 1,590 | 3,704 | 5,272 | 9,514 | 10,575 | 44 | 4 | 13 | 7 | 490 |
| USSR | 2,765 | 488 | 162 | - | - | - | - | - | - | - |
| Unallocated + discards | - | - | 500 | - | 3,216 | 450 | 96 | 202 | 2,042 | - |
| Total | 259,531 | 148,817 | 152,823 | 87,931 | 67,388 | 35,483 | 40,985 | 39,576 | 50,124 | 89,347 |

[1] Preliminary.

Note: In contrast to the corresponding tables in Working Group reports for years prior to 1982, the catches do not include catches taken in Division IIa.

Table 5.2 Nominal catches (t) of MACKEREL in the Norwegian Sea (Division IIa), 1977-1986 (catches from Division Vb included).

| Country | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986[6] |
|---|---|---|---|---|---|---|---|---|---|---|
| Denmark[2] | - | - | - | - | 801 | 1,008 | 10,427[3] | 11,787[4] | 7,610[5] | 3,283[7] |
| Faroe Islands[1] | - | 283 | 6 | 270 | - | 180 | - | 138 | - | - |
| France[2] | - | 2 | - | - | 6 | 8 | - | - | 16 | - |
| Germany, Fed. Rep.[2] | - | - | - | - | 51 | - | 5 | - | - | - |
| German Dem. Rep.[2] | - | 53 | 174 | 2 | - | - | - | - | - | 16 |
| Norway[1] | 1,400 | 3,867 | 6,887 | 6,618 | 12,941 | 34,540 | 38,453 | 82,005 | 61,065 | 85,400 |
| Poland[2] | - | - | - | - | - | 231 | - | - | - | - |
| UK (Engl. & Wales)[1] | + | 1 | - | - | 255 | - | - | - | - | - |
| UK (Scotland)[2] | - | - | - | 296[2] | 968[2] | - | - | - | - | 2,131[7] |
| USSR[2] | - | - | 5 | 1,450 | 3,640 | 1,641 | 65 | 4,292 | 9,405 | 11,404[8] |
| Total | 1,400 | 4,206 | 7,072 | 8,340 | 18,662 | 37,608 | 48,950 | 98,222 | 78,096 | 102,234 |

[1]Data provided by Working Group members.

[2]Data reported to ICES.

[3]Includes 1,497 tonnes caught in Division Vb.

[4]Includes 920 tonnes caught in Division Vb.

[5]Includes 4,920 tonnes caught in Division Vb.

[6]Preliminary.

[7]From Division Vb.

[8]Includes 2,253 t caught in Division Vb.

Table 5.3 Quarterly catches of MACKEREL by division in 1986.

| Division | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| IIa | - | - | 92,967 | 1,600 | 94,567 |
| IIIa | - | 1,605 | 4,196 | 752 | 6,553 |
| IVa-c | 1 | 926 | 70,389[1] | 159,780[2] | 231,096 |
| Vb | - | - | 157 | 7,510 | 7,667 |
| VIa | 57,092 | 1,845 | 1,454 | 41,063 | 101,454 |
| VII | 77,274 | 44,125 | 4,028 | 2,777 | 128,204 |
| VIIIa,b | ... | ... | ... | ... | 74 |

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

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

Table 5.4 MACKEREL catch in numbers ('000) by age group for the North Sea area (Divisions IVa-c), the Norwegian Sea (Divisions IIa and Vb), and the Skagerrak (Division IIIa) in 1986.

| Year class | Age | Division | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | IIa + Vb | IIIa | IVa | IVb | IVc | |
| 1986 | 0 | - | - | - | - | - | - |
| 1985 | 1 | 68 | 5,527 | 7,294 | 14 | 800 | 13,703 |
| 1984 | 2 | 29,481 | 11,349 | 177,185 | 989 | 1,754 | 220,758 |
| 1983 | 3 | 3,882 | 720 | 12,241 | 456 | 205 | 17,504 |
| 1982 | 4 | 8,780 | 683 | 26,451 | 1,187 | 540 | 37,641 |
| 1981 | 5 | 80,849 | 1,401 | 121,555 | 1,910 | 509 | 206,224 |
| 1980 | 6 | 26,079 | 563 | 60,577 | 967 | 959 | 89,145 |
| 1979 | 7 | 20,036 | 344 | 32,778 | 575 | 271 | 54,004 |
| 1978 | 8 | 6,595 | 154 | 11,625 | 345 | 70 | 18,789 |
| 1977 | 9 | 1,278 | 73 | 5,556 | 169 | 2 | 7,078 |
| 1976 | 10 | 3,741 | 92 | 7,776 | 503 | 285 | 12,397 |
| 1975 | 11 | 2,053 | 191 | 8,428 | 251 | 92 | 11,015 |
| 1974 | 12 | 4,283 | 70 | 7,237 | 184 | 143 | 11,917 |
| 1973 | 13 | 1,315 | 62 | 5,060 | 219 | 104 | 6,760 |
| 1972 | 14 | 1,173 | 94 | 2,687 | 70 | - | 4,024 |
| ≤1971 | 15+ | 1,907 | 292 | 10,394 | 540 | 84 | 13,217 |
| Total | | 191,520 | 21,615 | 496,844 | 8,379 | 5,818 | 724,176 |
| Tonnes | | 102,234 | 6,553 | 225,384 | 4,005 | 1,707 | 339,883 |

Table 6.1 Nominal catch (tonnes) of MACKEREL in the Western area (Sub-areas VI and VII and Divisions VIIIa,b). (Data for 1977 as officially reported to ICES; data for 1978-1986 estimated by Working Group.)

| Country | 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|
| Belgium | 1 | 1 | 3 | 3 | - |
| Denmark | 698 | 8,677 | 8,535 | 14,932 | 13,464 |
| Faroe Islands | 3,978 | 15,076 | 10,609 | 15,234 | 9,070 |
| France | 35,702 | 34,860 | 31,510 | 23,907 | 14,829 |
| German Dem. Rep. | 431 | - | - | - | - |
| Germany, Fed.Rep. | 446 | 28,873 | 21,493 | 21,088 | 29,221 |
| Ireland | 23,022 | 27,508 | 24,217 | 40,791 | 92,271 |
| Netherlands | 35,766 | 50,815 | 62,396 | 91,081 | 88,117 |
| Norway | 362 | 1,900 | 25,414 | 25,500 | 21,610 |
| Poland | 2,240 | - | 92 | - | 1 |
| Spain | 2,001 | 599 | 543 | 3,684 | 1,365 |
| UK (England + Wales) | 132,320 | 213,344 | 244,293 | 150,598 | 75,722 |
| UK (N. Ireland) | 97 | 46 | 25 | - | 4,153 |
| UK (Scotland) | 52,662 | 103,671 | 103,160 | 108,372 | 109,153 |
| USSR | 16,396 | - | - | - | - |
| Unallocated | - | - | 54,000 | 98,258 | 140,322 |
| Total, ICES members | 306,122 | 485,370 | 586,290 | 593,448 | 599,298 |
| Bulgaria | - | - | - | - | - |
| Rumania | - | - | - | - | - |
| Discard | - | 50,700 | 60,600 | 21,600 | 42,300 |
| Grand total | 306,122 | 536,070 | 646,890 | 615,048 | 641,598 |

(cont'd)

Table 6.1 (cont'd)

| Country | 1982 | 1983 | 1984 | 1985 | 1986[3] [4] |
|---|---|---|---|---|---|
| Belgium | - | + | - | - | + |
| Denmark | 15,100[2] | 15,000[2] | 200 | 400 | 300 |
| Faroe Islands | 11,100 | 14,900 | 9,200 | 9,900 | 1,400 |
| France | 12,300 | 11,000 | 12,500 | 7,400 | 11,200 |
| German Dem. Rep. | - | - | - | - | - |
| Germany, Fed.Rep. | 11,200 | 23,000 | 11,200 | 11,800 | 7,500 |
| Ireland | 109,700 | 110,000 | 84,100 | 91,400 | 70,000 |
| Netherlands | 67,200 | 73,600 | 99,000 | 37,000 | 49,800 |
| Norway | 19,000 | 19,900 | 34,700 | 24,300 | 21,000 |
| Poland | - | - | - | - | - |
| Spain | - | - | 100 | + | - |
| UK (England + Wales) | 82,900 | 62,000 | 30,000 | 9,600 | 8,900 |
| UK (N. Ireland) | 9,600 | 800 | 1,100 | - | + |
| UK (Scotland) | 147,400 | 120,100 | 167,200 | 196,300 | 143,300 |
| USSR | - | + | 200 | + | - |
| Unallocated | 97,300 | 105,500 | 18,000 | 75,100 | 64,600 |
| Total, ICES members | 582,800 | 555,800 | 467,500 | 463,200 | 378,000 |
| Bulgaria | - | - | - | - | - |
| Rumania | - | - | - | - | - |
| Discard | 24,900 | 11,300 | 12,100 | 4,500 | - |
| Grand total | 607,700 | 567,100 | 479,600 | 467,700 | 378,000 |

[1] Sub-area VIII does not include Division VIIIc. Spanish catches have been adjusted accordingly since 1977.

[2] Faroese catches have been revised for 1982 and 1983.

[3] Preliminary.

[4] Includes catches misreported from Division IVa.

Table 6.2 Catches of MACKEREL (tonnes) by Sub-areas in the Western area. Discards not estimated prior to 1978.

| | VI | | | VII and VIII | | |
|---|---|---|---|---|---|---|
| Year | Landings | Discards | Catch | Landings | Discards | Catch |
| 1969 | 4,800 | - | 4,800 | 66,300 | - | 66,300 |
| 1970 | 3,900 | - | 3,900 | 100,300 | - | 100,300 |
| 1971 | 10,200 | - | 10,200 | 122,600 | - | 122,600 |
| 1972 | 10,000 | - | 10,000 | 157,800 | - | 157,800 |
| 1973 | 52,200 | - | 52,200 | 167,300 | - | 167,300 |
| 1974 | 64,100 | - | 64,100 | 234,100 | - | 234,100 |
| 1975 | 64,800 | - | 64,800 | 416,500 | - | 416,500 |
| 1976 | 67,800 | - | 67,800 | 439,400 | - | 439,400 |
| 1977 | 74,800 | - | 74,800 | 259,100 | - | 259,100 |
| 1978 | 151,700 | 15,200 | 166,900 | 355,500 | 35,500 | 391,000 |
| 1979 | 203,300 | 20,300 | 223,600 | 398,000 | 39,800 | 437,800 |
| 1980 | 218,700 | 6,000 | 324,700 | 386,100 | 15,600 | 401,700 |
| 1981 | 335,100 | 2,500 | 337,600 | 274,300 | 39,800 | 314,100 |
| 1982 | 340,400 | 4,100 | 344,500 | 257,800 | 20,800 | 278,600 |
| 1983 | 315,100 | 22,300 | 317,400 | 245,400 | 9,000 | 254,400 |
| 1984 | 306,100 | 1,600 | 307,700 | 176,100 | 10,500 | 186,600 |
| 1985 | 388,140 | 2,735 | 390,875 | 75,043 | 1,800 | 76,843 |
| 1986[1] | 249,700 | - | 249,700 | 128,300 | - | 128,300 |

[1] Preliminary.

Table 6.3 MACKEREL catch in numbers ('000) by age group for Western area (Sub-areas VI and VII and Divisions VIIIa,b) in 1986.

| Year class | Age | VIa | VIIa-c | VIId-k | VIIIa,b | Total |
|---|---|---|---|---|---|---|
| | | Division | | | | |
| 1986 | 0 | - | 25 | 18,100 | 19 | 18,144 |
| 1985 | 1 | 6,409 | 724 | 8,260 | 9 | 15,402 |
| 1984 | 2 | 138,094 | 25,440 | 42,001 | 44 | 205,579 |
| 1983 | 3 | 4,886 | 4,020 | 5,951 | 6 | 14,863 |
| 1982 | 4 | 14,369 | 6,302 | 10,561 | 11 | 31,243 |
| 1981 | 5 | 51,989 | 41,125 | 40,865 | 43 | 134,022 |
| 1980 | 6 | 33,799 | 29,994 | 46,228 | 48 | 110,069 |
| 1979 | 7 | 19,950 | 20,443 | 27,669 | 29 | 68,091 |
| 1978 | 8 | 6,111 | 6,809 | 8,095 | 8 | 21,023 |
| 1977 | 9 | 2,262 | 1,967 | 1,181 | 1 | 5,411 |
| 1976 | 10 | 6,082 | 6,033 | 6,776 | 7 | 18,898 |
| 1975 | 11 | 4,243 | 2,893 | 3,926 | 4 | 11,066 |
| 1974 | 12 | 2,596 | 3,093 | 2,075 | 2 | 7,766 |
| 1973 | 13 | 2,111 | 3,057 | 1,230 | 1 | 6,399 |
| 1972 | 14 | 1,182 | 986 | 309 | - | 2,477 |
| ≤1971 | 15+ | 4,692 | 3,975 | 9,287 | 10 | 17,964 |
| Total | | 298,775 | 156,886 | 232,514 | 242 | 688,417 |
| Tonnes | | 101,454 | 58,959 | 69,245 | 74 | 229,732 |

Table 6.4 Estimates of egg production, number of spawning fish, and spawning stock biomass derived from egg surveys of the Western mackerel stock.

| Year | Egg production ($10^{15}$) | Number of spawning fish ($10^6$) | Spawning stock biomass ($10^6$ t) |
|---|---|---|---|
| 1977[1] | 1.98 | 8,995 | 3.0 |
| 1980[2] | 1.84 | 7,310 | 2.9 |
| 1983[2] | 1.50 | 6,985 | 2.4 |
| 1986[3] | 1.166 | 4,578 | 1.5 |

[1] Lockwood *et al*. (1981).
[2] Anon. (1984).
[3] Anon. (1987).

Table 6.5 Estimated numbers of spawning fish at age in the Western spawning stock in 1986.

| Age | Number x $10^{-6}$ |
|---|---|
| 2 | 494 |
| 3 | 142 |
| 4 | 188 |
| 5 | 998 |
| 6 | 865 |
| 7 | 687 |
| 8 | 114 |
| 9 | 156 |
| 10 | 151 |
| 11 | 215 |
| 12 | 206 |
| 13 | 64 |
| 14 | 32 |
| 15+ | 266 |
| Total | 4,578 |

Table 6.6 Spawning stock biomass estimates in tonnes x $10^6$ (referred to 1 January) from egg surveys and VPA at different values of input F at age 4+.

| Year | Egg survey estimate (x) | Biomass estimate from VPA (y) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.15 | 0.20 | 0.22 | 0.25 | 0.30 | 0.35 |
| 1977 | 3.30 | 3.54 | 3.37 | 3.32 | 3.27 | 3.21 | 3.16 |
| 1980 | 3.36 | 2.98 | 2.75 | 2.69 | 2.61 | 2.53 | 2.46 |
| 1983 | 2.77 | 3.38 | 2.91 | 2.78 | 2.62 | 2.43 | 2.29 |
| 1986 | 1.78 | 2.66 | 2.04 | 1.88 | 1.67 | 1.43 | 1.25 |
| $E\left[\left(\frac{x-y}{x}\right) \times 100\right]^2$ | | 3,110 | 573 | 430 | 567 | 1,155 | 1,922 |
| " (excluding 1980) | | 2,982 | 243 | 32 | 68 | 545 | 1,205 |

Table 6.7

Title : MACKEREL, WESTERN STOCK
At 10.59.14 02 MARCH 1987
from 78 to 86 on ages 0 to 10
with Terminal F of .225 on age 4 and Terminal S of 1.000

Initial sum of squared residuals was 179.896 and
final sum of squared residuals is 45.900 after 150 iterations

Matrix of Residuals

| Years | 78/79 | 79/80 | 80/81 | 81/82 | 82/83 | 83/84 | 84/85 | 85/86 | | WTS |
|---|---|---|---|---|---|---|---|---|---|---|
| Ages | | | | | | | | | | |
| 0/ 1 | 2.020 | 3.456 | 2.418 | 3.633 | 2.222 | -.483 | -.925 | -.825 | .000 | .025 |
| 1/ 2 | .191 | .285 | .307 | .134 | -.627 | -.058 | .487 | .197 | .000 | .141 |
| 2/ 3 | .210 | -.230 | .487 | .087 | .021 | .029 | .433 | -.483 | .000 | .147 |
| 3/ 4 | .256 | .248 | .444 | .075 | .083 | -.042 | .240 | -.282 | .000 | .214 |
| 4/ 5 | -.012 | -.189 | .120 | -.110 | -.017 | .049 | -.013 | -.019 | .000 | .508 |
| 5/ 6 | .056 | .036 | .000 | -.031 | -.078 | -.016 | .044 | .051 | .000 | 1.000 |
| 6/ 7 | -.289 | -.037 | -.253 | .048 | .070 | -.156 | .029 | .057 | .000 | .325 |
| 7/ 8 | -.115 | .080 | -.325 | -.166 | .095 | .156 | -.457 | .207 | .000 | .198 |
| 8/ 9 | -.408 | -.417 | -.330 | -.128 | .161 | .082 | -.304 | .063 | .000 | .201 |
| 9/10 | -.081 | -.033 | -.718 | -.053 | .152 | .118 | -.336 | .067 | .000 | .165 |
| | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | 10.657 | |
| WTS | .001 | .001 | .001 | .001 | 1.000 | 1.000 | 1.000 | 1.000 | | |

Fishing Mortalities (F)

| | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 |
|---|---|---|---|---|---|---|---|---|---|
| F-values | .2105 | .2784 | .2767 | .2165 | .2218 | .2281 | .2147 | .1993 | .2250 |

Selection-at-age (S)

| | 0 |
|---|---|
| S-values | .0011 |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| S-values | .2557 | .5956 | .8206 | 1.0000 | .9831 | 1.0555 | 1.0876 | 1.1311 | 1.0719 | 1.0000 |

Table 6.8 VIRTUAL POPULATION ANALYSIS

MACKEREL, WESTERN STOCK

CATCH IN NUMBERS UNIT: millions

| | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.6 | .0 | 1.3 | 1.0 | 34.2 | 2.0 | 10.3 | 79.5 | 19.5 | 38.3 | 2.0 | .0 |
| 1 | 12.4 | 33.8 | 87.0 | 52.5 | 279.4 | 153.5 | 31.3 | 351.1 | 484.5 | 266.1 | 203.0 | 43.6 |
| 2 | 12.1 | 49.4 | 24.3 | 104.0 | 184.9 | 289.5 | 563.8 | 61.6 | 468.7 | 506.4 | 435.9 | 712.7 |
| 3 | 29.4 | 64.0 | 123.5 | 94.5 | 322.3 | 154.0 | 425.0 | 602.5 | 75.2 | 225.1 | 483.6 | 444.6 |
| 4 | 507.7 | 115.5 | 108.5 | 306.3 | 170.6 | 166.0 | 243.7 | 365.5 | 381.3 | 31.7 | 184.1 | 391.6 |
| 5 | .0 | 582.3 | 191.6 | 192.2 | 288.8 | 51.0 | 258.3 | 217.2 | 282.0 | 174.8 | 24.7 | 130.4 |
| 6 | .0 | .0 | 567.0 | 143.8 | 118.6 | 140.0 | 71.9 | 233.1 | 145.2 | 158.5 | 136.6 | 20.2 |
| 7 | .0 | .0 | .0 | 1246.2 | 279.7 | 64.4 | 151.9 | 86.8 | 158.4 | 97.5 | 108.6 | 91.3 |
| 8 | .0 | .0 | .0 | .0 | 433.8 | 89.4 | 56.7 | 154.2 | 52.4 | 116.6 | 84.5 | 70.9 |
| 9 | .0 | .0 | .0 | .0 | .0 | 158.5 | 83.2 | 70.5 | 139.6 | 35.3 | 87.0 | 47.1 |
| 10 | .0 | .0 | .0 | .0 | .0 | .0 | 210.8 | 74.6 | 43.6 | 138.7 | 24.4 | 48.9 |
| 11+ | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 189.1 | 163.3 | 205.5 | 237.9 | 145.3 |
| TOTAL | 563.2 | 845.0 | 1103.4 | 2140.5 | 2117.3 | 1268.3 | 2106.9 | 2485.7 | 2413.7 | 1996.5 | 2012.3 | 2146.6 |
| SOP ('000 t) | 222 | 319 | 411 | 862 | 682 | 381 | 628 | 767 | 803 | 700 | 700 | 678 |

| | 1984 | 1985 | 1986 |
|---|---|---|---|
| 0 | .5 | .0 | 18.1 |
| 1 | 15.2 | 234.3 | 25.7 |
| 2 | 79.5 | 16.0 | 397.8 |
| 3 | 661.8 | 49.1 | 29.9 |
| 4 | 374.6 | 420.3 | 63.6 |
| 5 | 238.2 | 242.6 | 331.9 |
| 6 | 92.0 | 158.4 | 193.9 |
| 7 | 15.5 | 58.9 | 119.5 |
| 8 | 31.5 | 16.2 | 38.3 |
| 9 | 39.3 | 42.0 | 11.1 |
| 10 | 25.1 | 33.0 | 28.6 |
| 11+ | 65.6 | 100.6 | 80.3 |
| TOTAL | 1658.9 | 1371.4 | 1338.7 |
| SOP ('000 t) | 565 | 556 | 535 |

Table 6.9 VIRTUAL POPULATION ANALYSIS

MACKEREL, WESTERN STOCK

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

| | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .001 | .000 | .000 | .000 | .008 | .003 | .003 | .015 | .004 | .006 | .002 | .000 |
| 1 | .002 | .021 | .023 | .020 | .074 | .040 | .055 | .145 | .112 | .062 | .037 | .065 |
| 2 | .007 | .010 | .018 | .033 | .084 | .097 | .193 | .132 | .276 | .156 | .129 | .167 |
| 3 | .012 | .042 | .031 | .083 | .129 | .089 | .190 | .307 | .224 | .195 | .207 | .179 |
| 4 | .068 | .058 | .088 | .094 | .201 | .086 | .188 | .235 | .306 | .131 | .229 | .243 |
| 5 | .009 | .096 | .121 | .209 | .115 | .081 | .176 | .240 | .271 | .212 | .136 | .238 |
| 6 | .000 | .000 | .124 | .119 | .183 | .071 | .148 | .226 | .237 | .227 | .241 | .148 |
| 7 | .000 | .000 | .000 | .408 | .336 | .135 | .097 | .252 | .223 | .239 | .227 | .238 |
| 8 | .000 | .000 | .000 | .000 | .231 | .161 | .160 | .128 | .225 | .241 | .310 | .215 |
| 9 | .000 | .000 | .000 | .000 | .000 | .116 | .209 | .289 | .155 | .220 | .269 | .269 |
| 10 | .000 | .000 | .000 | .000 | .000 | .000 | .210 | .277 | .275 | .215 | .220 | .225 |
| 11+ | .000 | .000 | .000 | .000 | .000 | .000 | .210 | .277 | .275 | .215 | .220 | .225 |
| ( 3- 8)W | .054 | .081 | .088 | .217 | .177 | .091 | .164 | .238 | .263 | .212 | .221 | .210 |
| ( 4- 8)W | .063 | .088 | .117 | .234 | .195 | .092 | .152 | .211 | .266 | .219 | .235 | .235 |

| | 1984 | 1985 | 1986 | 1978-82 |
|---|---|---|---|---|
| 0 | .000 | .000 | .022 | .006 |
| 1 | .056 | .060 | .008 | .082 |
| 2 | .152 | .073 | .131 | .177 |
| 3 | .218 | .126 | .180 | .225 |
| 4 | .213 | .199 | .225 | .218 |
| 5 | .217 | .196 | .225 | .207 |
| 6 | .249 | .207 | .225 | .216 |
| 7 | .154 | .236 | .225 | .208 |
| 8 | .194 | .226 | .225 | .213 |
| 9 | .168 | .227 | .225 | .228 |
| 10 | .212 | .196 | .225 | .239 |
| 11+ | .212 | .196 | .225 | .239 |
| ( 3- 8)W | .216 | .196 | .225 | |
| ( 4- 8)W | .215 | .202 | .225 | |

Table 6.10 VIRTUAL POPULATION ANALYSIS

MACKEREL, WESTERN STOCK

STOCK SIZE IN NUMBERS UNIT: millions

BIOMASS TOTALS UNIT: thousand tonnes

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

| | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2073 | 4762 | 3384 | 4903 | 4884 | 763 | 3266 | 5786 | 5562 | 7011 | 872 | 348 |
| 1 | 6000 | 1783 | 4099 | 2911 | 4219 | 4172 | 655 | 2801 | 4907 | 4769 | 5999 | 749 |
| 2 | 1965 | 5153 | 1503 | 3447 | 2457 | 3372 | 3449 | 534 | 2086 | 3775 | 3859 | 4975 |
| 3 | 2612 | 1680 | 4389 | 1271 | 2871 | 1944 | 2635 | 2447 | 403 | 1363 | 2781 | 2918 |
| 4 | 8350 | 2221 | 1387 | 3663 | 1007 | 2173 | 1530 | 1875 | 1550 | 277 | 965 | 1946 |
| 5 | 0 | 6717 | 1805 | 1093 | 2870 | 709 | 1716 | 1092 | 1276 | 932 | 209 | 660 |
| 6 | 0 | 0 | 5242 | 1376 | 763 | 2203 | 563 | 1238 | 739 | 838 | 684 | 157 |
| 7 | 0 | 0 | 0 | 3987 | 1051 | 547 | 1766 | 418 | 850 | 502 | 574 | 462 |
| 8 | 0 | 0 | 0 | 0 | 2283 | 647 | 412 | 1379 | 279 | 585 | 340 | 394 |
| 9 | 0 | 0 | 0 | 0 | 0 | 1559 | 474 | 302 | 1045 | 192 | 396 | 215 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 1195 | 331 | 195 | 770 | 133 | 261 |
| 11+ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 839 | 729 | 1141 | 1294 | 774 |
| TOTAL NO | 21001 | 22316 | 21809 | 22652 | 22404 | 18088 | 17660 | 19043 | 19621 | 22205 | 18106 | 13860 |
| SPS NO | 11187 | 12317 | 12270 | 11736 | 10801 | 10734 | 10583 | 8669 | 7323 | 7948 | 8591 | 9095 |
| TOT.BIOM | 4634 | 4526 | 4673 | 4553 | 4145 | 4003 | 3930 | 3582 | 3284 | 3413 | 3211 | 3241 |
| SPS BIOM | 3460 | 3593 | 3652 | 3423 | 3048 | 3009 | 3146 | 2763 | 2301 | 2428 | 2238 | 2421 |

| | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|
| 0 | 4995 | 4035 | 896 | 0 |
| 1 | 309 | 4299 | 3473 | 754 |
| 2 | 604 | 244 | 3483 | 2965 |
| 3 | 3623 | 447 | 195 | 2630 |
| 4 | 2100 | 2507 | 339 | 140 |
| 5 | 1313 | 1461 | 1769 | 233 |
| 6 | 448 | 910 | 1033 | 1216 |
| 7 | 117 | 300 | 637 | 710 |
| 8 | 313 | 86 | 204 | 438 |
| 9 | 274 | 222 | 59 | 140 |
| 10 | 141 | 199 | 152 | 41 |
| 11+ | 369 | 607 | 428 | 399 |
| TOTAL NO | 14598 | 15318 | 12669 | |
| SPS NO | 7456 | 6165 | 4952 | |
| TOT.BIOM | 2769 | 2771 | 2604 | |
| SPS BIOM | 2236 | 2112 | 1636 | |

Table 6.11

List of input variables for the ICES prediction program.

WESTERN MACKEREL CATCH PREDICTION

The reference F is the mean F for the age group range from 4 to 11

The number of recruits per year is as follows:

| Year | Recruitment |
|---|---|
| 1987 | 2810.0 |
| 1988 | 2810.0 |
| 1989 | 2810.0 |

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 | 2810.0 | .00 | .15 | .00 | .067 | .000 |
| 1 | 750.0 | .06 | .15 | .08 | .149 | .070 |
| 2 | 2965.0 | .13 | .15 | .60 | .234 | .156 |
| 3 | 2630.0 | .18 | .15 | .90 | .303 | .244 |
| 4 | 140.0 | .22 | .15 | .97 | .359 | .282 |
| 5 | 233.0 | .22 | .15 | .97 | .393 | .330 |
| 6 | 1216.0 | .22 | .15 | .99 | .440 | .355 |
| 7 | 710.0 | .22 | .15 | 1.00 | .490 | .403 |
| 8 | 438.0 | .22 | .15 | 1.00 | .510 | .430 |
| 9 | 140.0 | .22 | .15 | 1.00 | .556 | .451 |
| 10 | 41.0 | .22 | .15 | 1.00 | .591 | .474 |
| 11+ | 399.0 | .22 | .15 | 1.00 | .630 | .545 |

Table 6.12

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

WESTERN MACKEREL CATCH PREDICTION

| Year 1987 | | | | | Year 1988 | | | | | Year 1989 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| factor | ref. F | stock biomass | sp.stock biomass | catch | Mgmt. opt. | ref. F | stock biomass | sp.stock biomass | catch | stock biomass | sp.stock biomass |
| 1.1 | .25 | 2479 | 1875 | 550 | $F_{med}$ | .14 | 2289 | 1811 | 305 | 2304 | 1773 |
| | | | | | $F_{0.1}$ | .19 | | 1778 | 404 | 2220 | 1671 |
| | | | | | $F_{86}$ | .22 | | 1752 | 481 | 2155 | 1592 |
| | | | | | $F_{high}$ | .33 | | 1685 | 676 | 1991 | 1400 |

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 1989 has been calculated with the same fishing mortality as for 1988.
The reference F is the mean F for the age group range from 4 to 11

Table 8.1 Catch in numbers ('000) and t of the North Sea MACKEREL stock by quarter in 1986.

| Age | Quarter | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 | - | 2 | 1,149 | 2,229 |
| 2 | 2,128 | 594 | 5,905 | 19,868 |
| 3 | 40 | 664 | 639 | 1,178 |
| 4 | 97 | 726 | 1,640 | 2,848 |
| 5 | 161 | 1,129 | 2,937 | 4,033 |
| 6 | 63 | 487 | 1,386 | 2,315 |
| 7 | 51 | 234 | 905 | 1,360 |
| 8 | 31 | 132 | 582 | 730 |
| 9 | 37 | 103 | 451 | 810 |
| 10 | 59 | 201 | 853 | 1,598 |
| 11 | 47 | 163 | 543 | 1,155 |
| 12 | 78 | 151 | 764 | 1,810 |
| 13 | 52 | 69 | 539 | 1,306 |
| 14 | 45 | 107 | 399 | 967 |
| 15+ | 111 | 273 | 1,170 | 2,662 |
| Sum | 3,000 | 5,035 | 19,862 | 44,869 |
| Tonnes | 802 | 2,483 | 9,122 | 19,841 |

Table 8.2 Quarterly mean weight at age (grams) for the North Sea mackerel stock in 1985.

| Age | Quarter | | | | | |
|---|---|---|---|---|---|---|
| | 1[1] | 2[1] | 2[2] | 3[1] | 3[2] | 4[1] |
| 1 | - | 202 | - | 157 | 138 | 218 |
| 2 | 163 | 250 | 227 | 288 | 271 | 288 |
| 3 | 290 | 404 | 334 | 370 | 382 | 370 |
| 4 | 365 | 488 | 367 | 491 | 418 | 465 |
| 5 | 419 | 453 | 393 | 488 | 447 | 516 |
| 6 | 397 | 558 | 442 | 476 | 427 | 463 |
| 7 | 411 | 466 | 534 | 531 | 545 | 525 |
| 8 | 501 | 642 | 598 | 579 | 533 | 652 |
| 9 | 559 | 649 | 573 | 644 | 543 | 674 |
| 10 | 493 | 662 | 675 | 569 | 735 | 640 |
| 11 | 619 | 689 | 635 | 712 | 638 | 732 |
| 12 | 647 | 673 | 775 | 716 | 620 | 729 |
| 13 | 647 | 691 | 812 | 731 | 664 | 705 |
| 14 | 733 | 730 | 712 | 769 | 700 | 779 |
| 15+ | 738 | 708 | 780 | 736 | 882 | 793 |

[1] Weight at age from catches.
[2] Danish and Norwegian research vessel samples from the main spawning area and Skagerrak.

Table 8.3 Estimated percentages of each mackerel stock that was present in the North Sea during each quarter of 1986.

North Sea stock

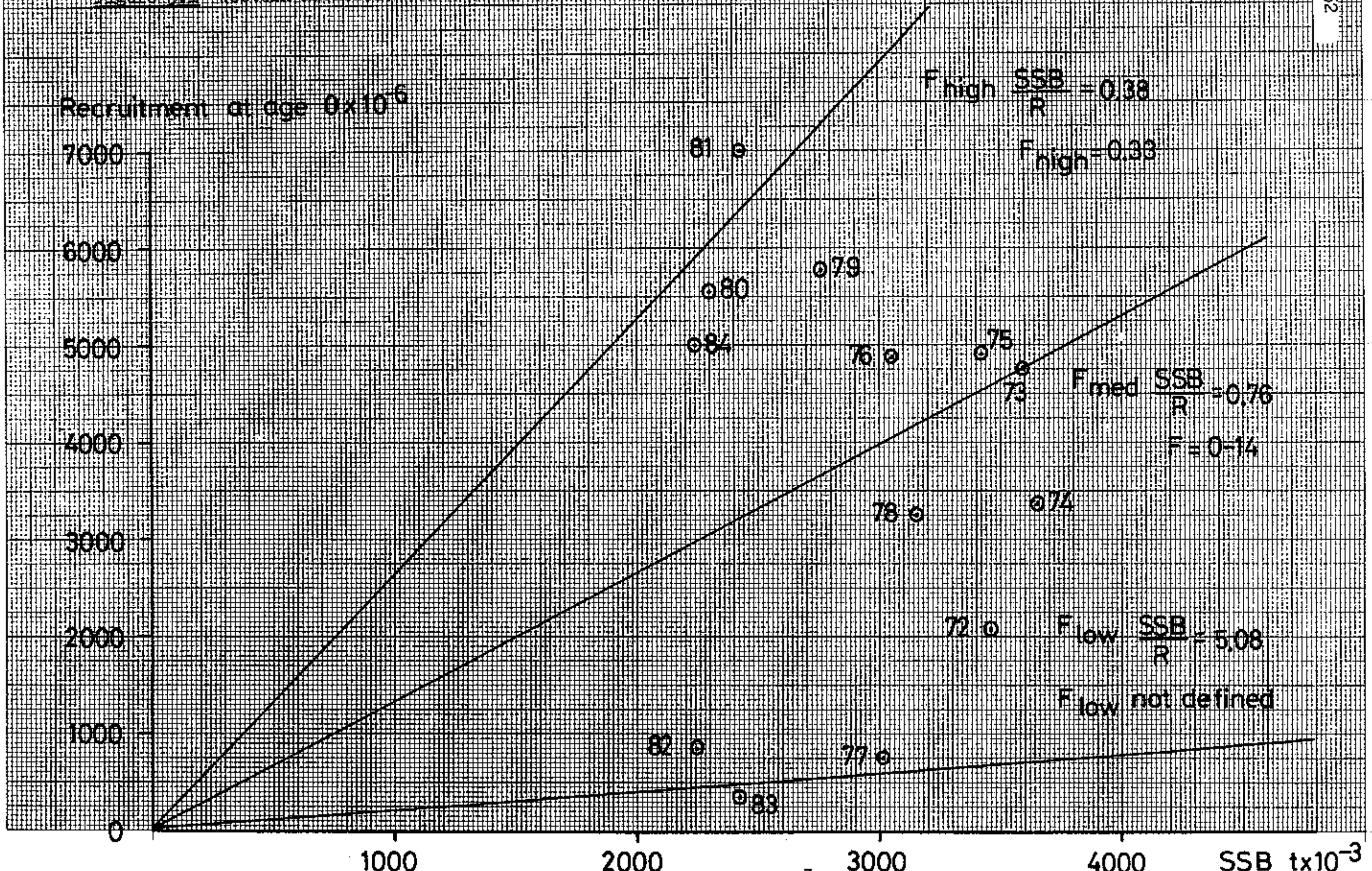
| Age | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 100 | 100 | 100 | 100 |
| 2 | 80 | 100 | 100 | 80 |
| ≥3 | 80 | 100 | 50 | 70 |

Western stock

| Age | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0 | 20 | 30 | 30 |
| 2 | 10 | 10 | 50 | 70 |
| ≥3 | 10 | + | 50 | 70 |

+ = less than 5%.

Figure 3.1 Western mackerel. Stock recruitment.



SSB t x 10^-3

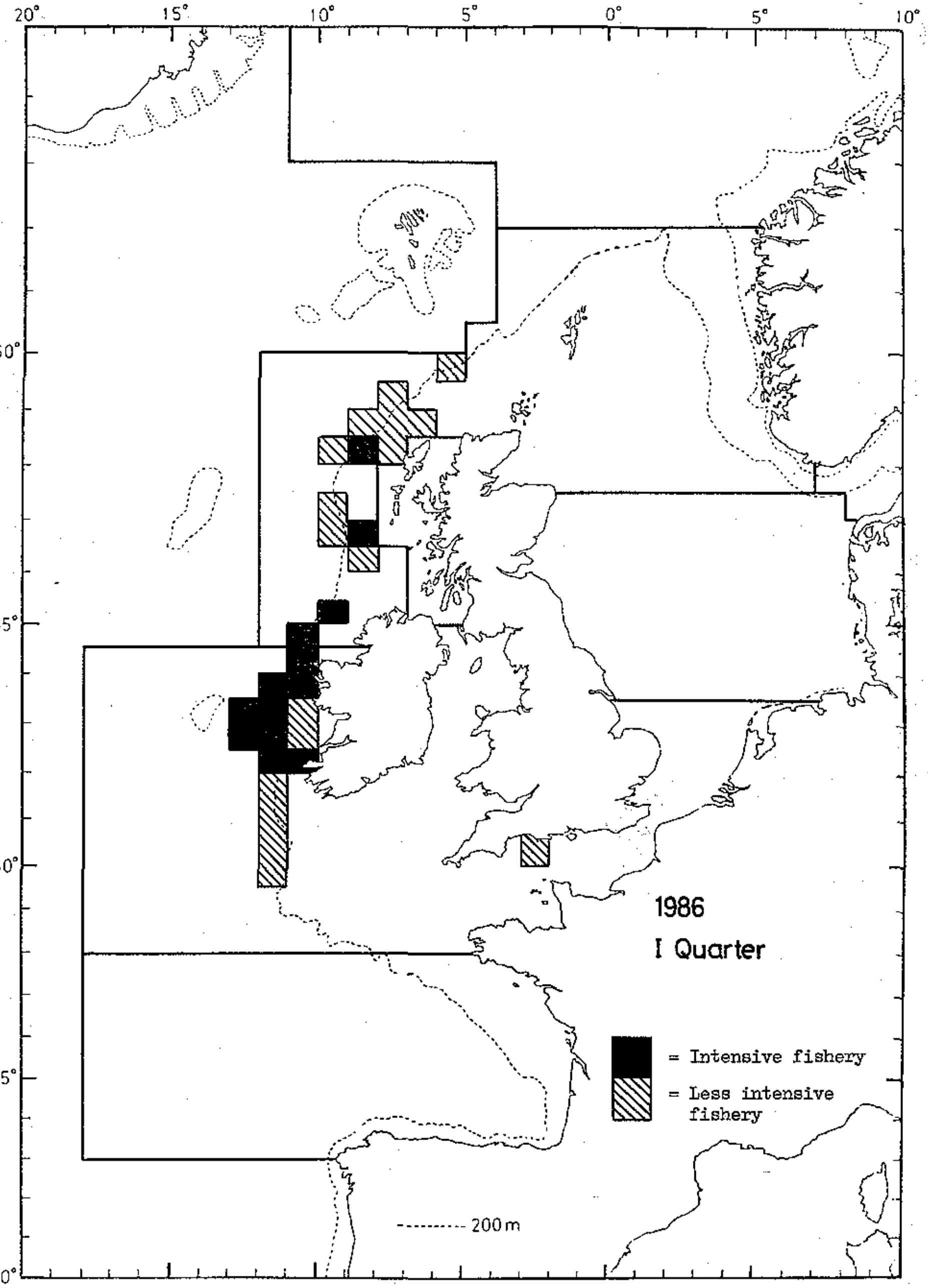



Figure 4.1a  Distribution of mackerel fisheries, first quarter 1986.

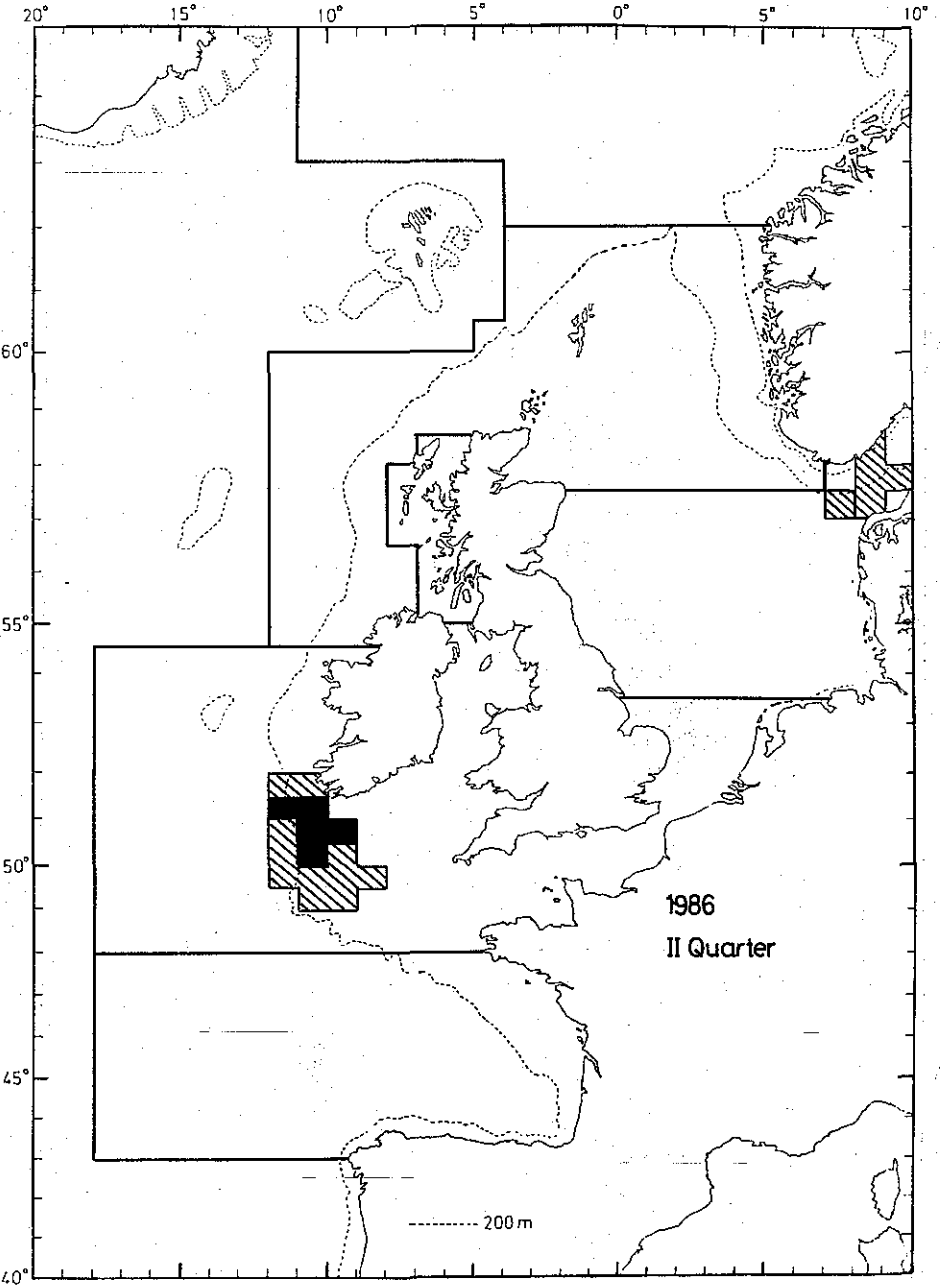



Figure 4.1b Distribution of mackerel fisheries, second quarter 1986.

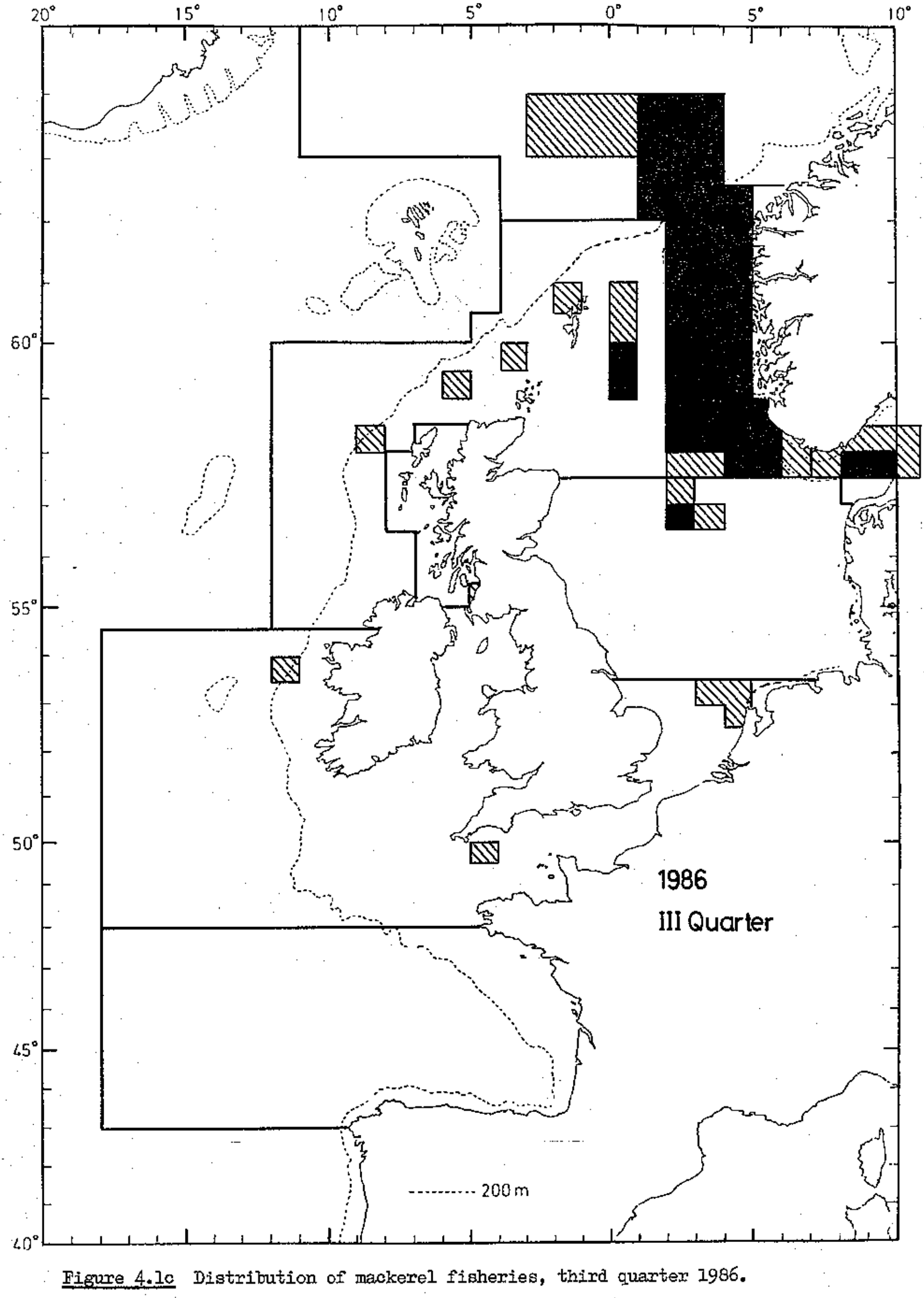



Figure 4.1c Distribution of mackerel fisheries, third quarter 1986.

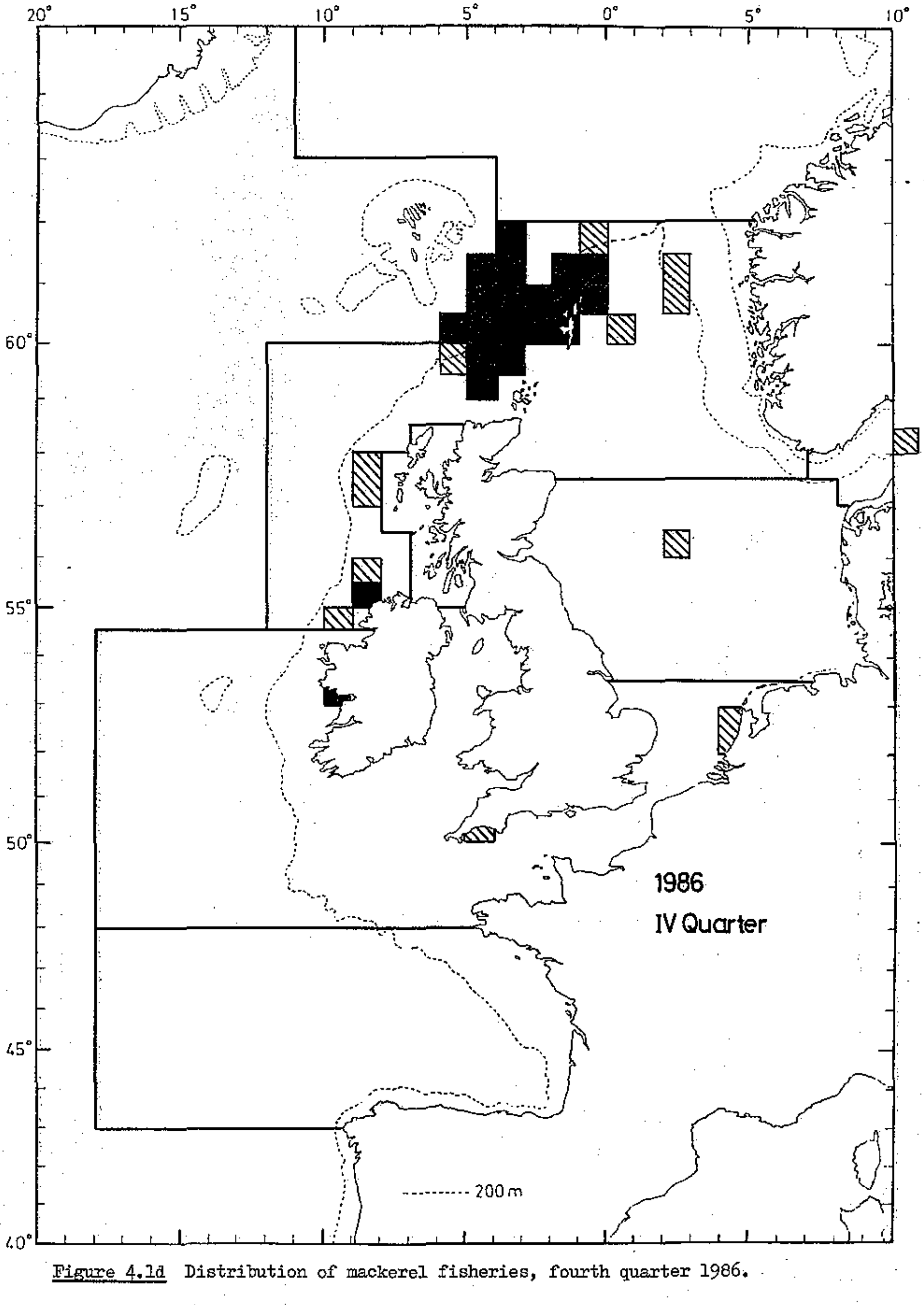
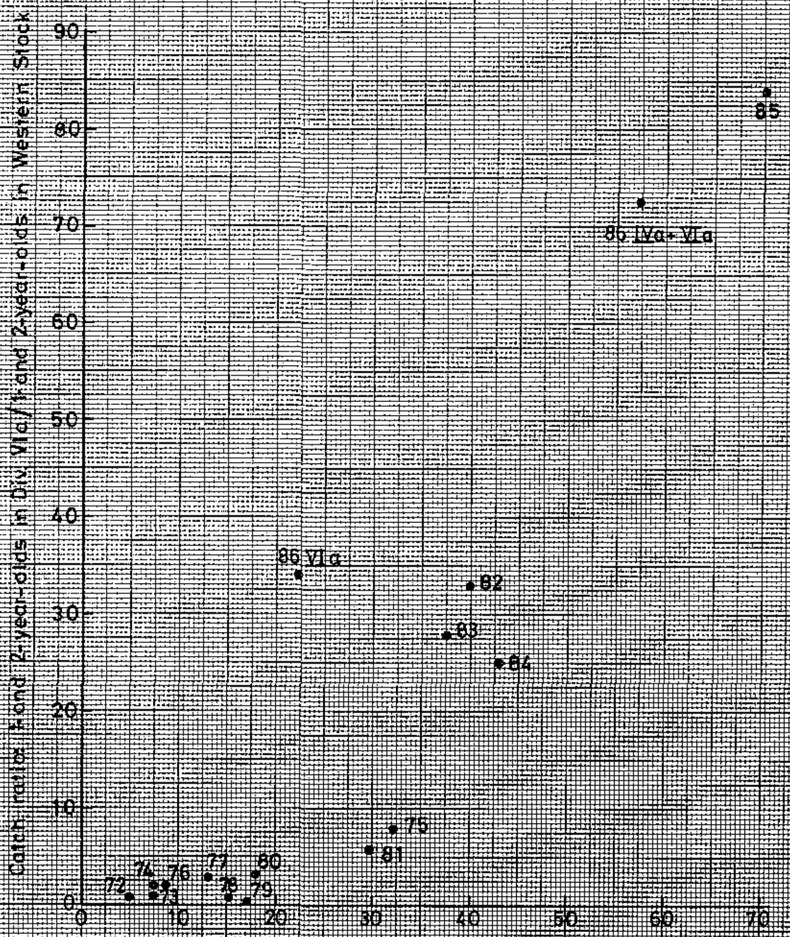



Figure 4.1d Distribution of mackerel fisheries, fourth quarter 1986.

Figure 4.2 The relationship between the juvenile fish (1- and 2-year olds) in Division VIa catches relative to juvenile fish in the Western stock catches and the total Division VIa catch relative to the total Western stock catch.



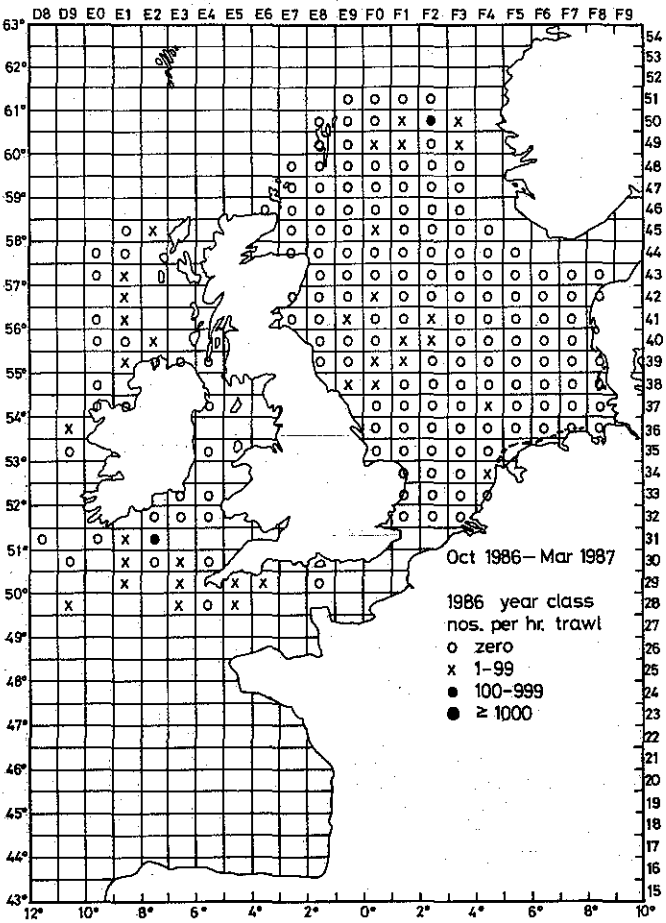



Figure 4.3 Distribution and abundance of the 1986 year class between October 1986 and March 1987 from Danish, Dutch, English, German (FRG), Irish, Norwegian, and Scottish research vessel surveys.

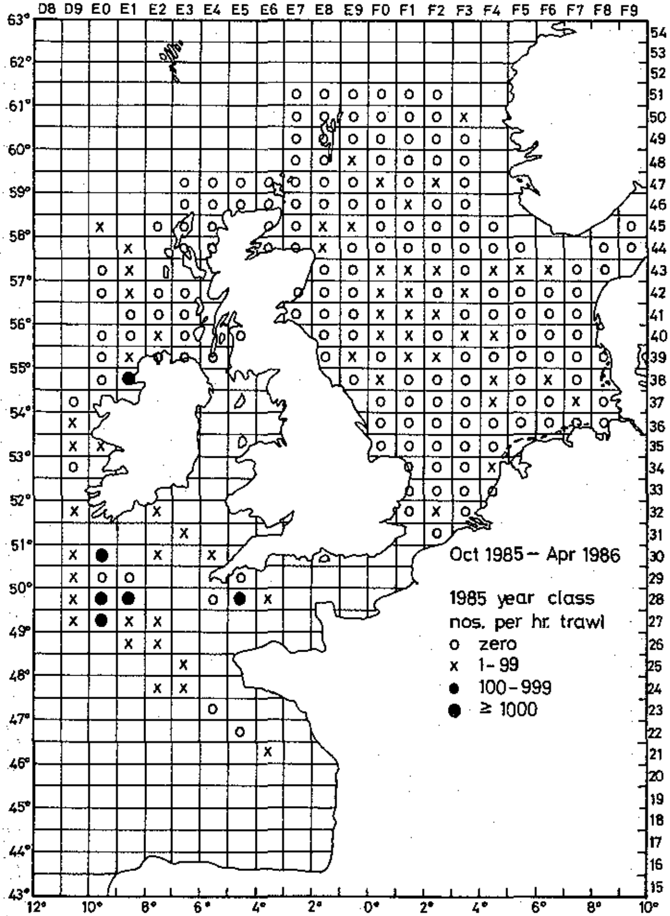



Figure 4.4 Distribution and abundance of the 1985 year class between October 1985 and March 1986 from Danish, Dutch, English, German (FRG), Irish, Norwegian, and Scottish research vessel surveys.

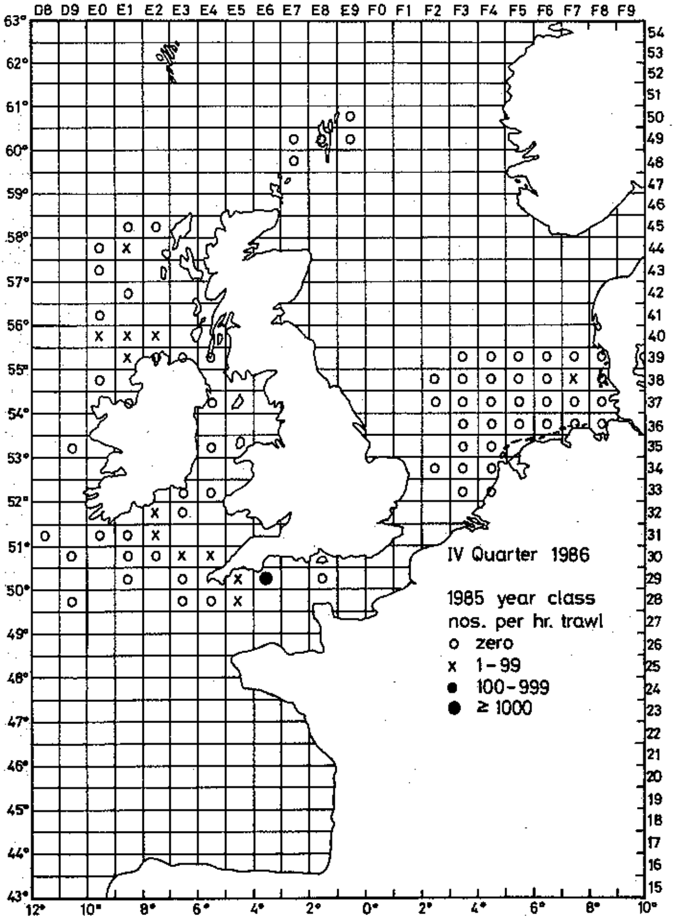



Figure 4.5 Distribution and abundance of the 1985 year class in the fourth quarter of 1986 from Dutch, English, Irish, and Scottish research vessel surveys.

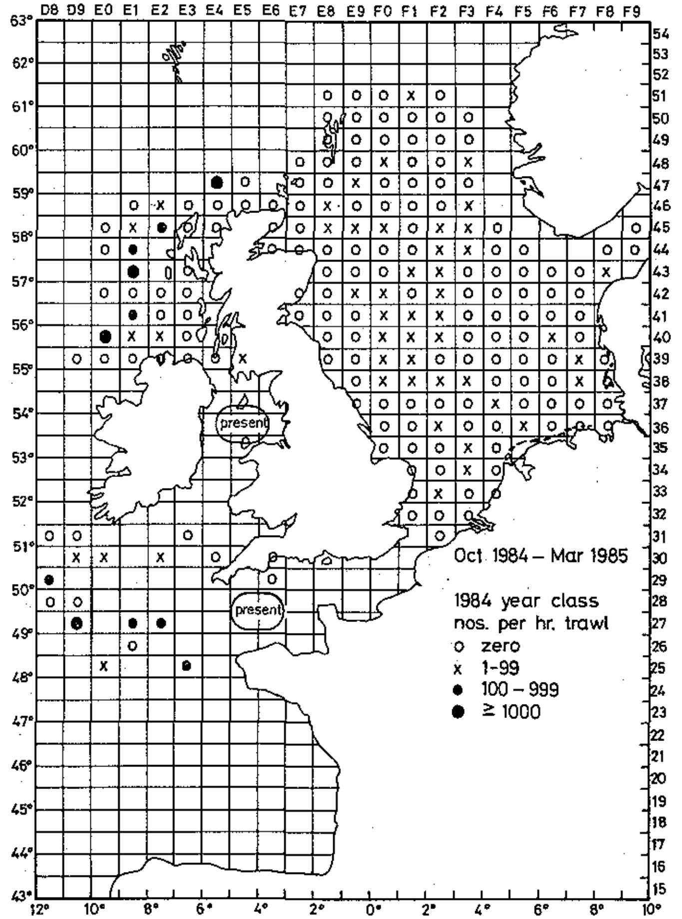



Figure 4.6 Distribution and abundance of the 1984 year class between October 1984 and March 1985 from Danish, Dutch, English, German (FRG), Norwegian, and Scottish research vessel surveys.

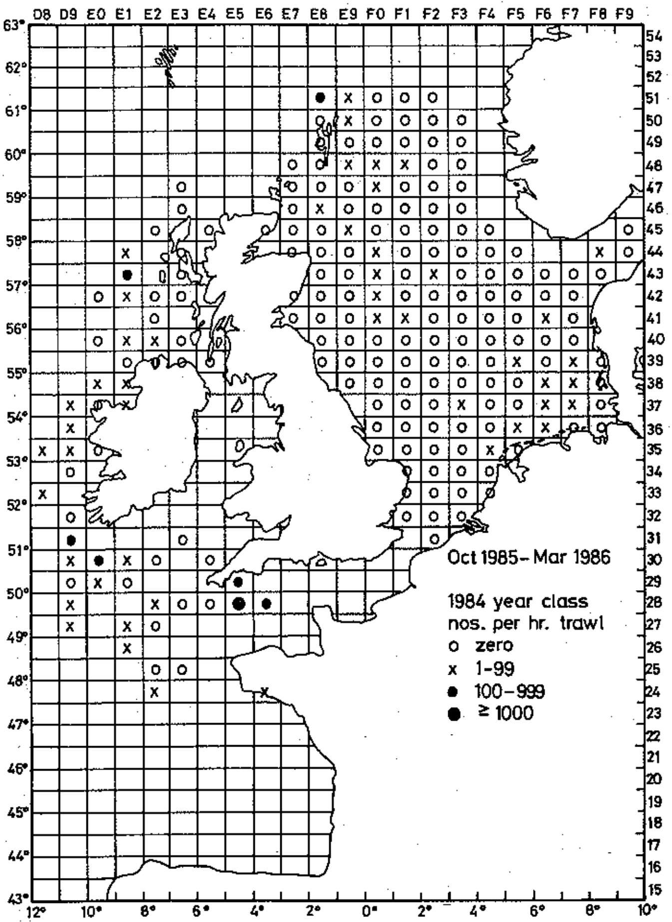



Figure 4.7 Distribution and abundance of the 1984 year class between October 1985 and March 1986 from Danish, Dutch, English, German (FRG), Irish, Norwegian, and Scottish research vessel surveys.

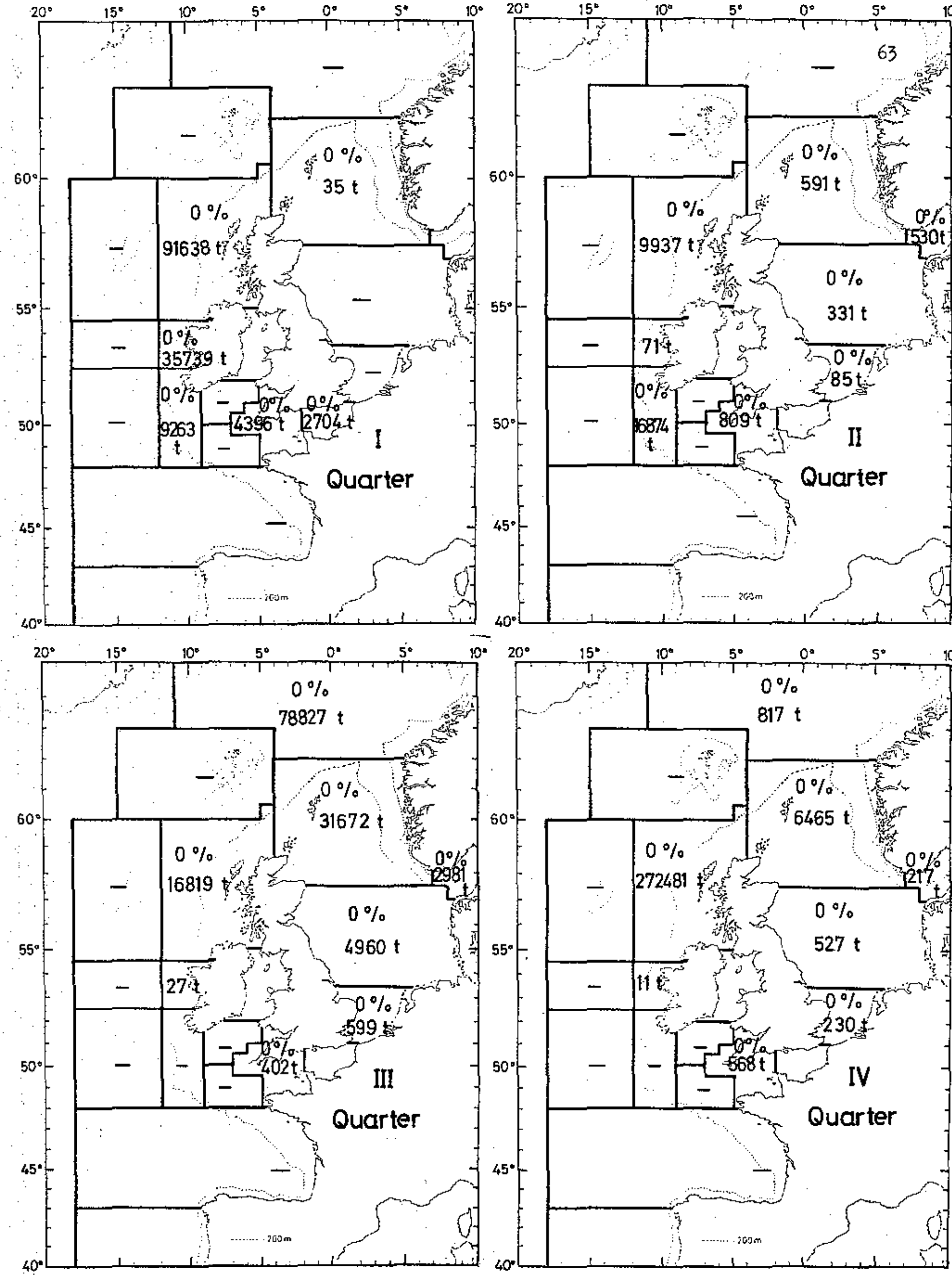



Figure 4.8 The occurrence of the 1985 year class expressed as a percentage (number) of catches taken in the commercial mackerel catches in each ICES division in 1985.

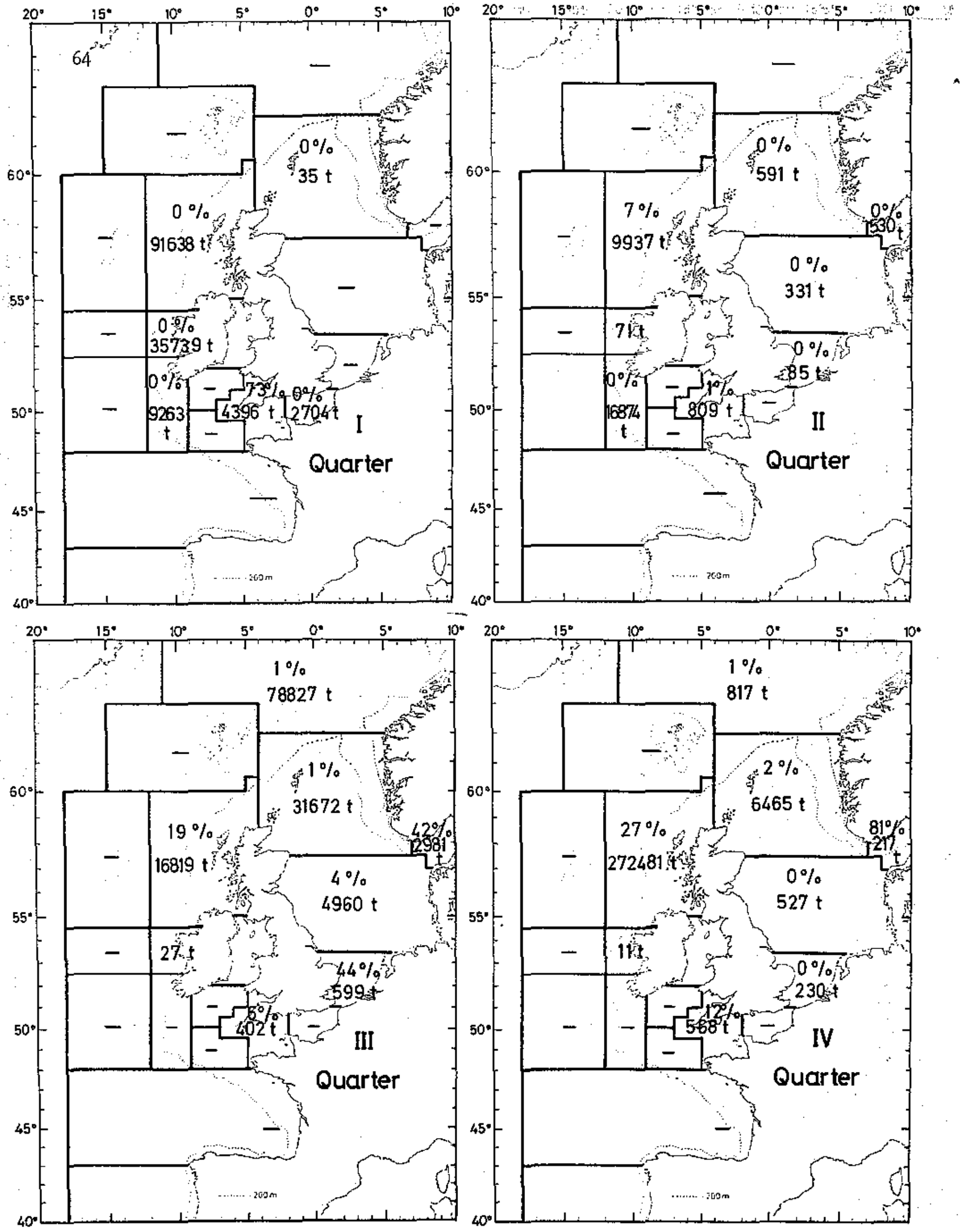



Figure 4.9 The occurrence of the 1984 year class expressed as a percentage (number) of catches taken in the commercial mackerel catches in each ICES division in 1985.

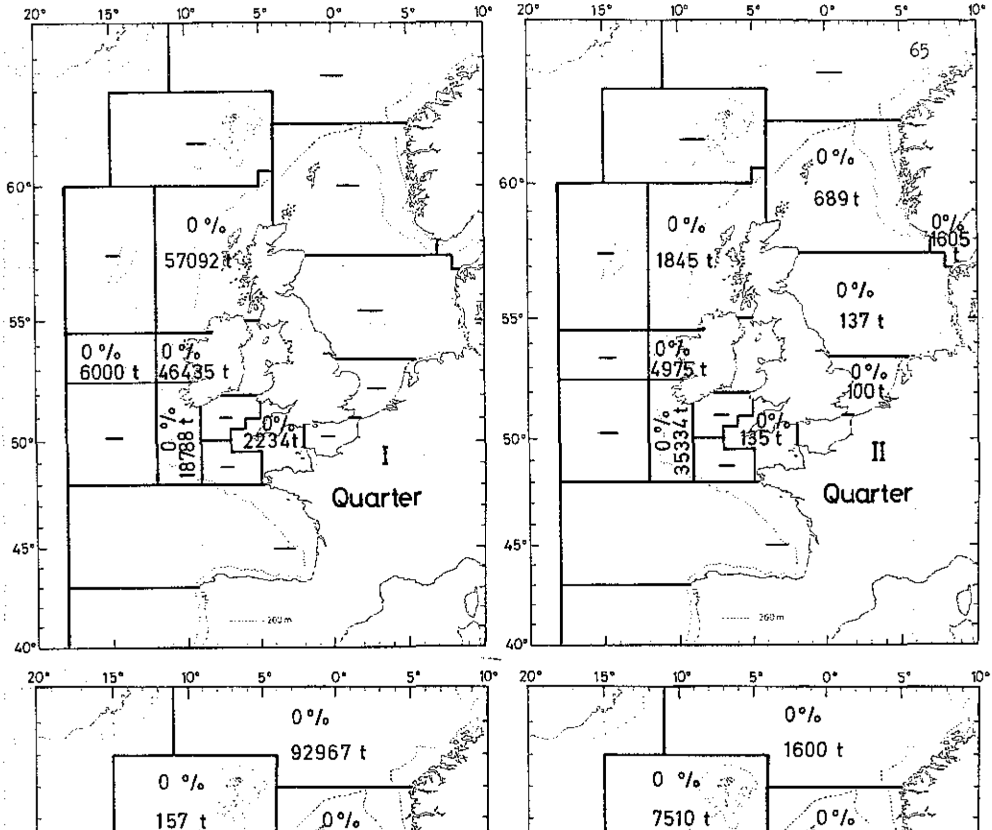



Figure 4.10 The occurrence of the 1986 year class expressed as a percentage (number) of catches taken in the commercial mackerel catches in each ICES division in 1986.

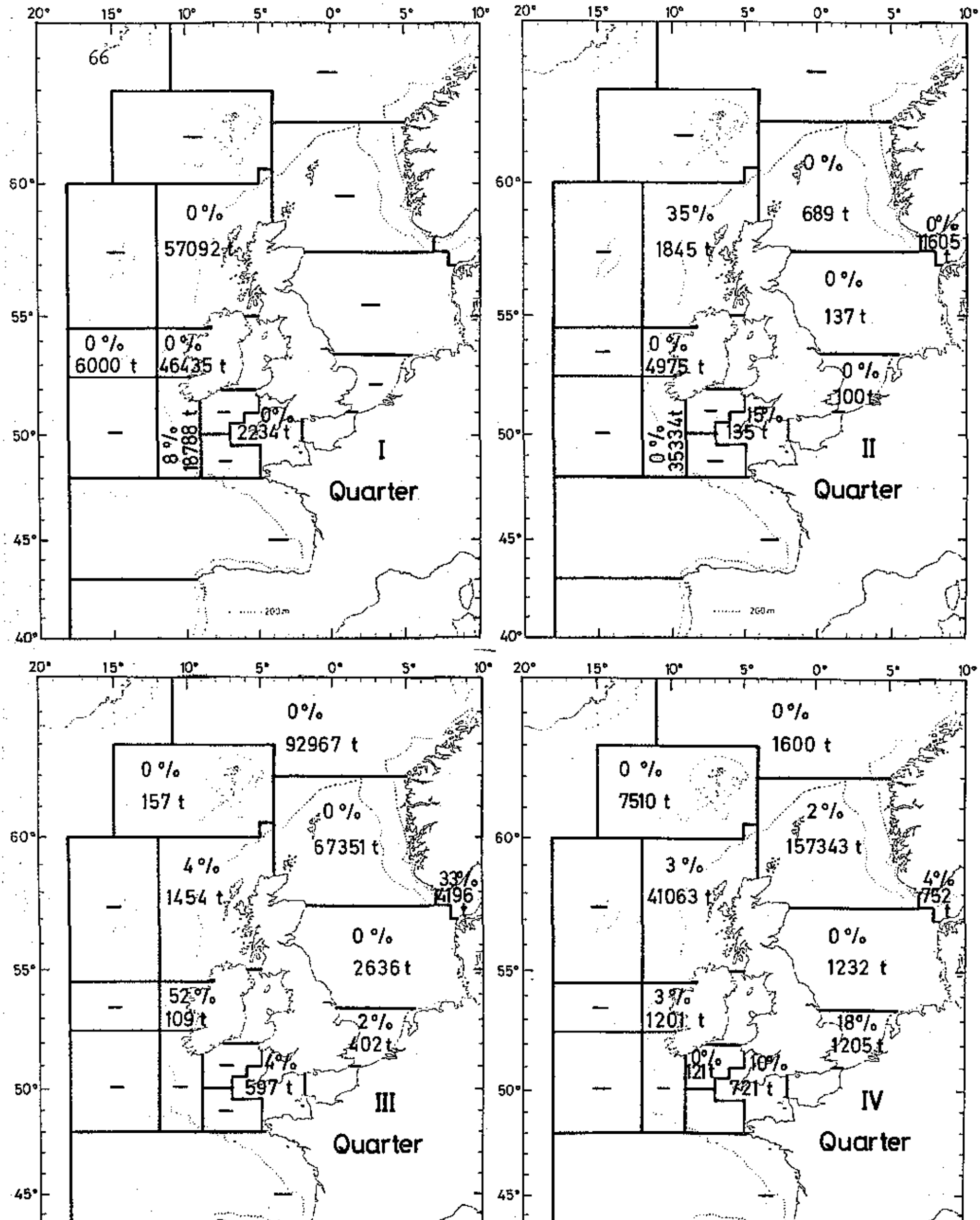



Figure 4.11 The occurrence of the 1985 year class expressed as a percentage (number) of catches taken in the commercial mackerel catches in each ICES division in 1986.

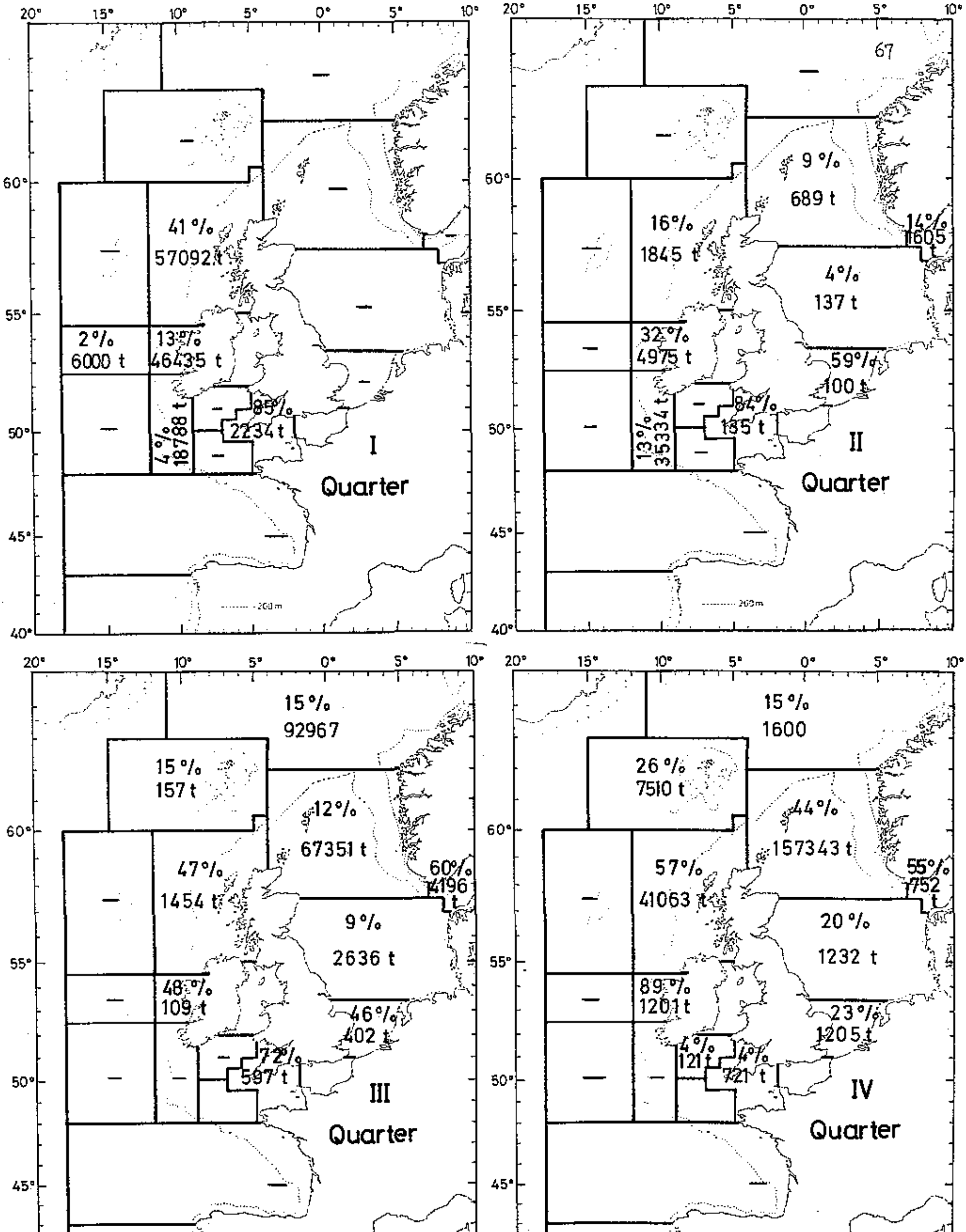



Figure 4.12 The occurrence of the 1984 year class expressed as a percentage (number) of catches taken in the commercial mackerel catches in each ICES division in 1986.

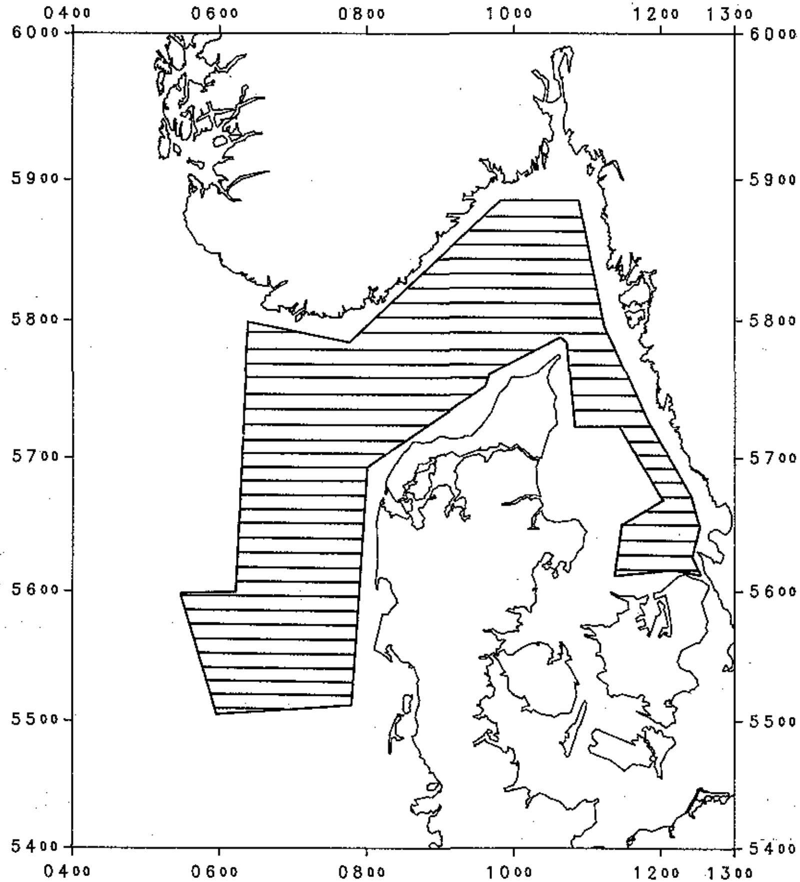



**Figure 5.1** The area covered by R/V "Dana" in July 1985 and August 1986.

Figure 6.1 Fishing mortality at age as input to VPA and mean F for the period 1978-1982.

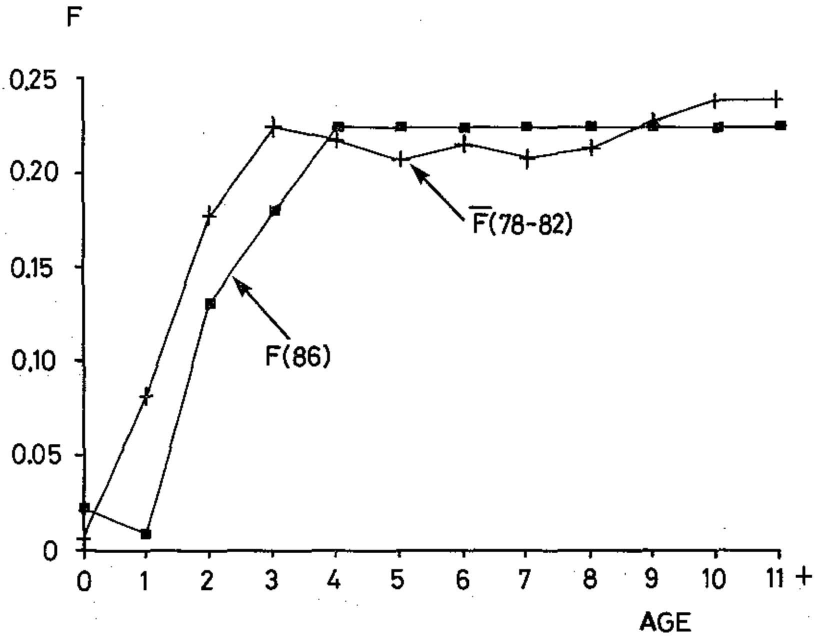
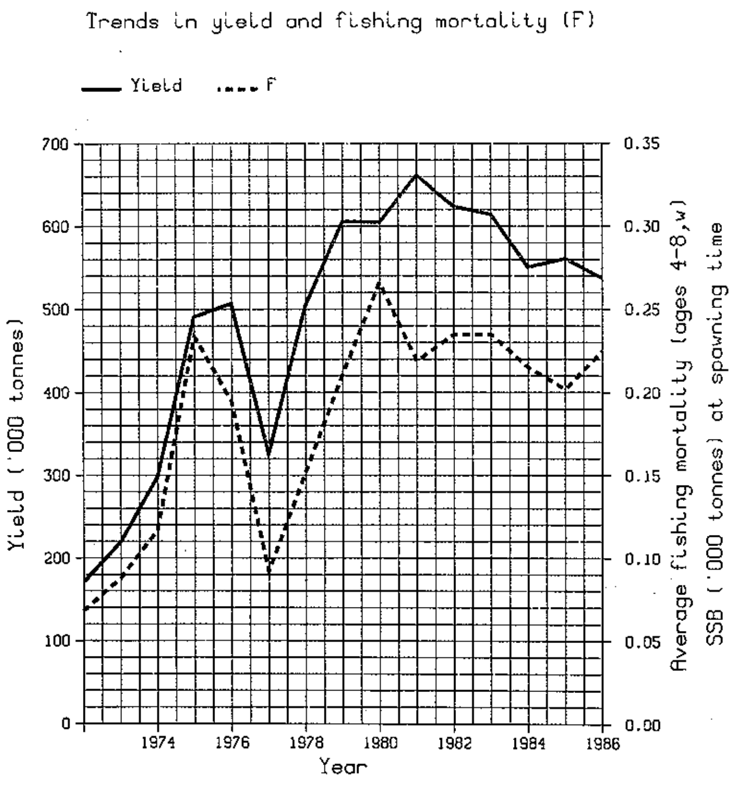
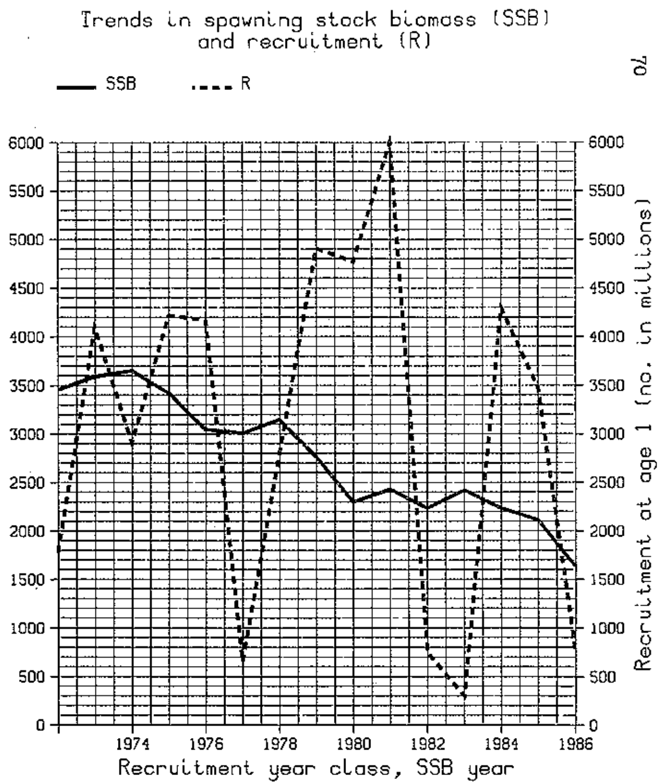


Figure 6.2

# FISH STOCK SUMMARY
## STOCK: Mackerel, Western Stock
## 02-03-1987




A



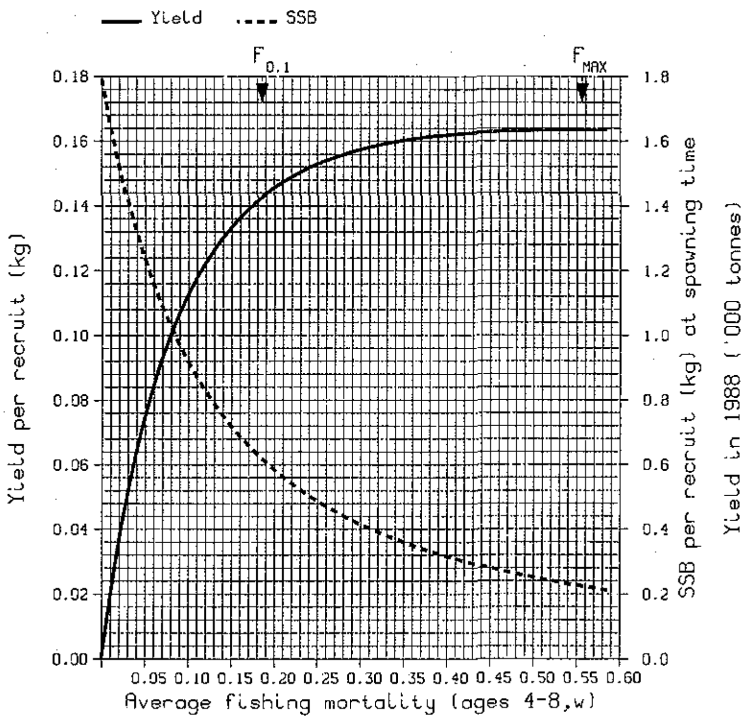

B

contd.

Figure 6.2 cont'd.

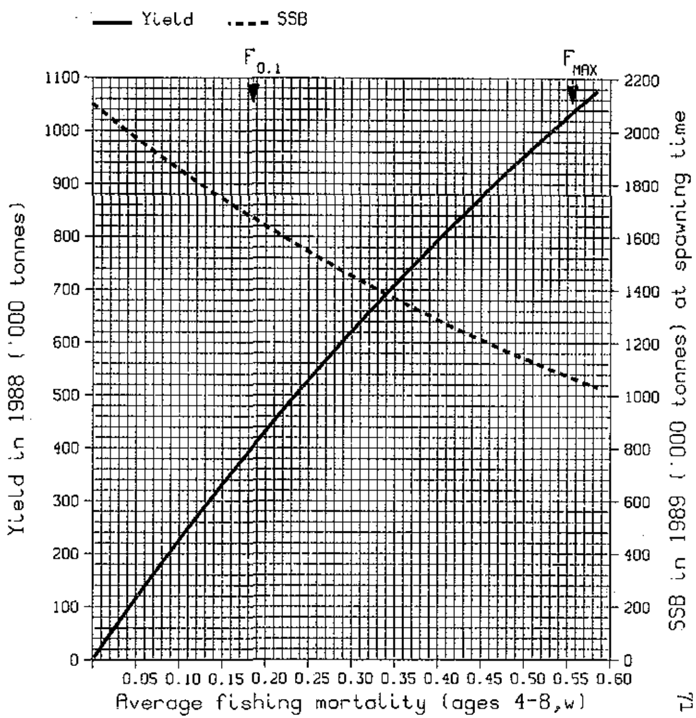
# FISH STOCK SUMMARY
## STOCK: Mackerel, Western Stock
## 02-03-1987

Long-term yield and spawning stock biomass

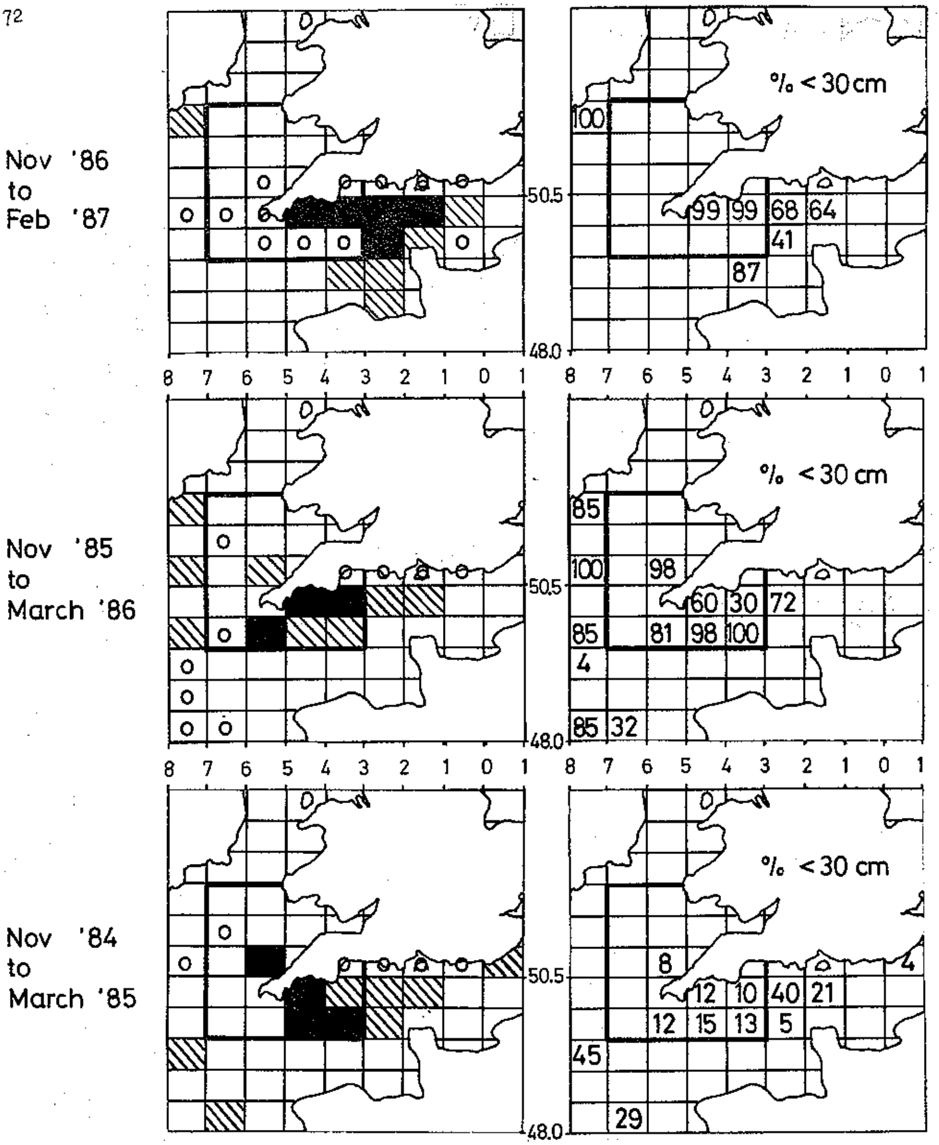



C

Short-term yield and spawning stock biomass




D




Mackerel box boundary

Areas of high concentrations of mackerel

Areas of low concentrations of mackerel

o Areas where no or very few mackerel were found

Figure 7.1 Distribution of mackerel off SW England for the winter seasons 1986/1987, 1985/1986 and 1984/1985. Information is based on both research vessel data and commercial catches.