

International Council for the  
Exploration of the Sea

C.M.1990/H:5  
Pelagic Fish Committee

**SECOND REPORT OF THE EEC - NORWEGIAN JOINT SCIENTIFIC GROUP  
ON MIGRATION AND AREA DISTRIBUTION OF MACKEREL  
(WESTERN STOCK)**

Brussels, 12-13 December 1989

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This Scientific Study Group Report was set up jointly by the Commission of the European Communities and the Norwegian Ministry of Fisheries. The report is published through ICES for the purpose of information.



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## 1. INTRODUCTION

In the agreed record of conclusions of the fisheries consultations between the European Economic Community and Norway, Brussels 26-28 November 1986, the following statement concerning the Western mackerel stock was made:

"Noting the differing views of Norway and the Community with respect to the stock, the Parties agreed jointly to study and elaborate more closely the migratory pattern and area distribution of the fishery, for this stock".

A first meeting of a Norwegian-EEC joint scientific group on migration and distribution of mackerel (Western stock) was convened in Bergen from 11 to 13 November 1987 (Anon. 1988b).

In the Agreed Record of the EEC-Norway fisheries consultations, 30 November - 1 December 1988, "... The parties agreed that scientists from Norway and the Community together should continue their work on all relevant aspects relating to the biology and migratory pattern of the Western mackerel stock".

### 1.1. Terms of reference

A second meeting of an EEC-Norwegian joint scientific group on migration and distribution of mackerel (Western stock) was convened from 12 to 13 December 1989 in Brussels with the following agreed terms of reference:

"The study group should collect and update the most relevant information on stock and catch distribution, in particular for the most recent years, specified on seasons and year-classes. Relevant data for the North Sea stock should also be considered."

In order to facilitate the use of the information, the group decided to revise the previous report (Anon., 1988b) and to produce an updated, complete report.

### 1.2. Participants

E. Bakken	Institute of Marine Research, Bergen
E. Barnwall	Fisheries Research Centre, Dublin
W.A. Dawson	Fisheries Laboratory, Lowestoft
H. Dornheim	Sea Fisheries Institute, Hamburg
A. Eltink (Chairman)	Netherlands Institute for Fishery Investigations, IJmuiden
J.C. Guéguen	IFREMER, Nantes
S.A. Iversen	Institute of Marine Research, Bergen
E. Kirkegaard	Danish Institute for Fisheries and Marine Research, Charlottenlund
D.W. Skagen	Institute of Marine Research, Bergen
M. Walsh	Marine Laboratory, Aberdeen

### 1.3. Previous reports

The overall distribution of mackerel and the fishing areas during the 1960s and early 1970s are described in ICES Cooperative Research Report N° 37 (1974). The distribution (Fig. 6 of that report) is, however, not given separately for the two stocks.

Distribution and migration for both the North Sea stock and the Western stock are given in ICES Cooperative Research Report N° 74 (1978). Illustrations (Figs. 7, 8, 12 and 13) of main distribution areas, total distribution range, overwintering areas and spawning areas are presented.

The "Report of the Norwegian - EEC Joint Scientific Sub-group on Distribution of Shared Fish Stocks in the North Sea" (Anon., 1979) includes mackerel, but covers the North Sea only.

The distribution and migration of the Western mackerel stock are described in various reports of the ICES Mackerel Working Group, notably in the 1981, 1986 and 1988 reports (Anon. 1981, 1986, 1988a). The Working Group reports and the report of the first meeting of the Norwegian-EEC joint scientific group on migration and distribution of Western mackerel (Anon., 1988b) constitute the main source of published data utilized by the present Norway-EEC Working Group.

A map of the ICES statistical area, with Sub-areas and Divisions, referred to in the text is given in Fig. 1.1.

#### 1.4. Stock definition

The ICES Mackerel Working Group in its 1986 report (Anon., 1986) discussed the basis for mackerel stock definition in detail. Two stocks of mackerel are identified on the basis of their spawning grounds: a Western stock and a North Sea stock. While there is evidence that mackerel of Western origin recruit to the North Sea spawning stock through the Channel and possibly also via the north of Scotland (Eltink *et al.* 1986), the Working Group was unable to quantify the extent to which this occurs, and retained the view that there are two principal stocks within the total area of distribution (ICES Divisions IIa, IIIa, IVa-c, Va,b, VIa,b, VIIa-k, VIIIa,b,d,e).

At the present meeting, the joint EEC-Norway study group still accepts that there are two stocks; one spawning in the North Sea and one in the Western area.

## 2. SPAWNING AREAS

### 2.1. North Sea spawning area

Investigations in the mackerel spawning area in the North Sea have been carried out every summer since 1986 except in 1985 and 1987. During the early years only the northern part of the spawning area was investigated. From 1980 to 1988 the total spawning area was covered several times each year during the spawning period in order to estimate total egg production and size of spawning stock. In 1989 the survey was limited and covered the main spawning area only once.

The spawning period in the North Sea falls between mid May and the end of July, with the main spawning during the second half of June. The spawning area during the periods 1977-1984 and 1986-1988 is shown in Fig. 2.1. The figure is based on data given in Iversen (1981, 1982), Iversen and Eltink (1983), Iversen and Westgård (1984), and Iversen *et al.* (1985, 1987, 1989). Spawning takes place within the delineated area every year, with the main spawning ( $>100$  eggs/m<sup>2</sup> in at least 2 years) within the shaded area. The spawning area is well defined, and the size and location appear to be rather constant. The total spawning area seems, however, somewhat reduced since the early 1970s, when the spawning stock was much larger.

## 2.2. Western spawning area

Mackerel egg surveys for the Western stock have been conducted triennially since 1977 for stock assessment purposes. The Western spawning area for the 1977, 1980, 1983 and 1986 surveys combined is shown in figure 2.1. This stock has been observed spawning in the same area every year with only minor changes in the distribution within the Western area spawning ground (Lockwood, Nichols and Dawson 1981; Lockwood *et al.* 1981; Thompson *et al.* 1984; Anon 1987a and Coombs *et al.* 1989.)

Western mackerel commence spawning in March and continue through to July with a peak in May-June. In 1986 and 1987 the area to the north of 54°N was also investigated, (Fig 2.1). Although some spawning takes place in this area it only constitutes between 5 and 10 percent of the total Western stock egg production, (Molloy and King 1987). This area was once again investigated in 1989, together with the rest of the Western mackerel spawning ground. Although these data are still provisional, initial indication suggest the proportion of the Western stock spawning to the north of 54°N are no different to the proportions previously observed. The provisional egg data are not included in fig. 2.1, however, there is no evidence to suggest a shift in distribution in 1989. The timing of peak spawning in 1989 was the same as in previous years.

## 3. DISTRIBUTION OF LARVAE AND JUVENILES LESS THAN ONE YEAR OLD

### 3.1. Larvae

Information was available about trends in the distribution, abundance and seasonal occurrence of larvae around the British Isles (Coombs and Mitchell 1981). In general, the main concentrations were found to be closely associated with the main spawning areas to the southwest of Ireland (See Fig. 2.1.). Smaller numbers of larvae were also located to the west of Ireland and Scotland.

In the North Sea there were some indications of a southerly shift in the distribution of larvae during the period 1948-1977. This shift in larvae distribution was also evident for larvae of other fish species and may have been caused by changing environmental conditions. It might also have been caused by decreases in the spawning stock in the northern part of the North Sea.

The larvae taken during the egg surveys conducted in recent years in both the North Sea and in the Western area are all closely associated with the main spawning areas (Fig. 2.1.). The dispersion and subsequent drift of the larvae away from the spawning grounds has not yet been investigated.

### 3.2. Juveniles less than one year old

Mackerel spawn over a fairly long period from March to July. Growth during the first months is very rapid and a length of 22cm may be attained by the end of the year in which they were spawned. At this size they can be exploited in commercial fisheries in their first winter. Considerable numbers were taken during the winters of 1976/77 - 1981/82, mainly in the fisheries conducted in Division VIIe, f (Anon., 1987b). Subsequent to this period, catches of this age group in this area decreased considerably but it is not possible to decide whether this was due to 1) the introduction of the protective box around Cornwall, 2) the very poor year-classes of 1982 and 1983, 1985 and 1986 or, 3) a change in distribution of the juvenile fish or, 4) a combination of some of these. In recent years a small proportion of first-year mackerel of the 1987 year-class was caught to the west of the UK during the winter 1987/88. This age group is not taken in catches from the North Sea.

The distribution of first-year mackerel during the winters of 1987/88, 1988/89 and 1989 (Oct-Dec), as indicated by research vessel surveys is shown in Figs. 3.1., 3.2. and 3.3. Fig. 3.1. is taken from the 1989 ICES Mackerel Working Group (Anon., 1989a) supplemented by results from the 1988 IYF Survey (Anon., 1989b). Figs. 3.2. and 3.3. were compiled from similar data not then available to the 1989 Working Group.

In the winter of 1987/88 juveniles of the 1987 year-class were widely distributed along the continental shelf edge west of Ireland and the Celtic Sea and the western Channel (Fig. 3.1). Elsewhere they were scarce or absent from the catches. The distribution and abundance were similar to those of the strong 1984 year-class which showed a more northerly distribution than those of the previous four year-classes.

In the winter of 1988/89 juveniles of the 1988 year-class were abundant to the west and south of Ireland and in the Bay of Biscay but absent from catches north of 59° (Fig. 3.2). They were scarce or absent over most of the North Sea as in most recent years.

Preliminary data for the winter of 1989/90 indicate the 1989 year-class to have been present in catches west and south of Britain from the north to the south of the area sampled and with patches of highest abundance near the shelf edge west and south of Ireland and west and southwest of Brittany (Fig. 3.3).

Fig. 3.4. shows the mean distribution of first winter juveniles from winter research vessel surveys for all available years combined. Data for the North Sea cover the years 1960-61 and 1967-1987 and were obtained from the ICES International Young Fish Surveys (Walsh, 1974, 1977, 1979 and subsequent annual ICES reports of the IYFS). Data for western areas were obtained by combining results of Dutch, Scottish, English and Irish research vessel surveys for the winters 1981/82 to 1986/87 inclusive.

The data are intended to provide a generalized winter distribution pattern with which individual years may be compared. They indicate two main distribution centres in the North Sea, one in the east central North Sea, the other close to the Norwegian trench in the northern North Sea. These are considered to be the main nursery areas of the North Sea stock. To the west of Britain the main concentrations of juveniles were found over a wide area from North Rona down into the Bay of Biscay but in greatest abundance near to the shelf edge south of Ireland and in the Western Channel and its approaches. These are considered to be juveniles of the western stock.



Very little is known about the distribution of this age group outside the winter period.

#### 4. DISTRIBUTION OF JUVENILES

##### 4.1. Commercial catch data

Information on the distribution of juvenile mackerel, defined here as 1- and 2-group, is poor. This is largely because these age groups are incompletely recruited to the directed mackerel fisheries. In addition, there are regulations in some areas designed to protect juvenile mackerel, including a 30cm minimum landing size in the North Sea, and since 1983, a closed area in parts of Sub-area VII. This means that the distribution of catches in the mackerel fisheries is an incomplete representation of the true distribution of these age groups.

With these reservations in mind, some positive indications of the distribution of concentrations of juvenile mackerel can be obtained from the estimated catches in numbers at age in each ICES Division. These are given in Tables 4.1. and 4.2. for the years 1980-1988. Up to and including 1985, it was assumed for assessment purposes that all 1- and 2-group mackerel caught in the North Sea area (Sub-area IV, Divisions IIA and IIIA) belonged to the North Sea stock, and that all those caught in other areas belonged to the Western stock. Since 1986, it has been recognized that a proportion of the juveniles caught in the North Sea area may have originated from the Western stock (Anon., 1987b, 1988a).

Table 4.1. indicates that substantial quantities of 1-group Western stock are caught in the Western areas (Sub-areas VII and VIII up to 1983; and Division VIa from 1982-1985). High percentages of 1-group mackerel in Division IIIa were observed in all years from 1985 onwards. In the North Sea (Sub-area IV), increasing catches of 1-group fish were observed in 1987 and 1988, whereas in the western areas (Sub-area VI, VII and VIII) fish of the youngest age group represented only a small part of the total catch.

Table 4.2. indicates that in the early 1980s, prior to the implementation of the closed area off Cornwall, the largest quantities of 2-group mackerel were caught in the Western areas and particularly VIIId-k. In most recent years significant landings of 2-group mackerel caught in northern areas have been recorded (e.g. VIa in 1986-87; IVa in 1986, 1987, 1988).

The closed area introduced in 1933 around the south-west of England is one area where juvenile mackerel have been consistently found since the change in adult distribution in the early eighties. A small fishery has taken place around this box. The catches taken have comprised predominantly juvenile fish, i.e. the 1- to 2-group mackerel from the winter fishery. The proportions of juveniles in the catches reflect the year-class strengths of the 1- to 2-group fish in the stock.

##### 4.2. Survey data, 1-group

###### Winter (4th and 1st quarters)

Information on second-winter mackerel (1-group 4th quarter, 2-group 1st quarter) are available from English, Scottish, Irish, French and Dutch bottom trawl surveys in the Western area (Divisions VIa, Sub-areas VII and VIII) in the 4th quarter and from English and Scottish data in the 1st quarter. These data are summarized in Dawson *et al* (1988) for the winters 1981/82 - 1987/88. Data from the North Sea for these winters are given in reports of the International Young Fish Surveys carried out in February each year and for earlier winters in Walsh (1974, 1977 and 1979).

The main concentrations of second-winter mackerel during the four winters prior to 1985/86 were found in the Celtic Sea (Divisions VIIg, h, j) and the western Channel (Division VIIe) with low concentrations west of Scotland and hardly any presence in the North Sea. In earlier years (Walsh, 1974) when the North Sea stock was stronger, second-winter mackerel were found mainly in the east-central North Sea but with a slightly wider distribution than that of first winter mackerel given in Fig. 3.4.

In the winters of both 1985/86 and 1986/87 second-winter mackerel, year-classes 1984 and 1985 respectively, were found in the Celtic Sea and western Channel as before, but were more abundant west of Scotland than in previous years. The 1984 year-class was abundant in the Skagerrak and the eastern part of Division IVa during October 1985. Distribution data for the winters of 1987/88 and 1988/89 are given in Figs. 4.1. and 4.2. respectively. The 1986 year-class in 1987/88 was mainly concentrated in the Celtic Sea and western Channel, while the 1987 year-class had a much wider distribution to the west of Britain with concentrations west of Scotland as well as further south.

#### 2nd quarter

There are no survey data available for this quarter.

#### 3rd quarter

There are no survey data available for the western area during this time period. Information on the abundance of 1-group mackerel is available for the North Sea from both Scottish and English bottom trawl surveys since 1980 and from acoustic surveys in the North Sea and the Skagerrak since 1985 (Kirkegaard 1986, Kirkegaard et al 1987, Kirkegaard et al. 1989, Degnbol et al. 1988).

Data from these sources indicate a relatively high abundance of 1-group mackerel in the east central North Sea and the Skagerrak in some years. In particular, the year-classes 1984 and 1987 were abundant, while that of 1988 was not.

#### 4.3. Survey data, 2-group

Information on the distribution of 2-group mackerel from research vessel surveys indicates that the distribution of the immature part of the age group is almost identical to that of 1-group mackerel.

#### 4.4. Changes in distribution

The proportion of juveniles in the catch data indicates that juvenile Western mackerel have changed their distribution in the 1980s. Table 4.3. indicates that up to and including 1981 juvenile mackerel (0-2 group combined) were mainly found in Sub-areas VII and VIII, where they constituted up to half the catch in numbers in certain years. From 1982 to 1986 juvenile mackerel formed a higher proportion of the total catch in Division VIa, indicating that the distribution was extended to the north in these years. In 1987 and 1988 the proportion of juveniles of the total catch in Division VIa was as before 1982.

The catch data as well as the survey data show that since 1985 large quantities of juvenile mackerel have been present in the eastern part of the North Sea and Skagerrak in summer and early winter. Since the relevant age groups do not appear to be present at other times of the year and they have not recruited to the North Sea spawning stock, it may indicate that since 1985 there has been a migration of juvenile Western mackerel into the eastern North Sea and the Skagerrak.

## 5. DISTRIBUTION OF ADULTS

### 5.1. Fishery data

Catches of mackerel in Sub-areas VI, VII and VIII reflected the catches of the Western mackerel stock until 1977. During the subsequent years till 1981 mackerel taken in the western area (Sub-areas VI, VII and VIII combined) included also mackerel of the North Sea stock. A part of the catch was therefore allocated to the North Sea stock for assessment purposes. A proportion of the mackerel caught in the North Sea area was similarly allocated to the Western stock. These allocations were based on Norwegian tagging data except for the 1986 catches (Anon. 1987b).

Fig. 5.1. indicates that during the period 1981-1988, an increasing proportion of mackerel was taken outside the western areas. This trend might be caused by a northward shift in distribution of the Western mackerel outside the spawning season (see also Section 6).

Shifts in seasonal distribution of Western mackerel have been analysed by the ICES Mackerel Working Group and by various authors by examining changes in the main mackerel fisheries. A thorough examination of the changes is given in the 1985 Mackerel Working Group Report (Anon. 1985, p. 5-9) and in a paper by Walsh and Martin (1986). The results are summarized in Figs. 5.2. and 5.3. of the present report, together with the distribution of the mackerel fisheries in 1987 and 1988 (Anon., 1988a and 1989a).

Throughout the 1960s and 1970s, the main winter fisheries were concentrated in an area around the Cornish Peninsula (Division VIIe, f). During the 1980s the fishery shifted progressively towards the west of the British Isles and further to the northwest and north of Scotland. Some fishing, however, continued in the western Channel.

There is also some evidence from the summer fishery indicating shifts in the distribution of the mackerel as indicated in Fig. 5.3. There has been a progressive northeast shift from around Shetland towards the Norwegian coast, with the exception of the period 1975-1978 (see Section 6.3.). It should, however, be noted that the distribution of catches is influenced by both fisheries regulations and the distribution of the mackerel.

Figs. 5.4. and 5.5. show the distribution of mackerel fisheries by quarter in 1987 and 1988 (Anon., 1988a and 1989a).

The catches reflect where fishing occurred, but do not necessarily reflect the total distribution area of the mackerel. Some misreporting occurred in some quarters in the subdivision of Division VIa which is adjacent to Division IVa, and also in statistical rectangles in Division IIa adjacent to Division IVa. Catches reported in Division IVa may therefore be underestimates.

Catches of mackerel for the period 1978-1988 by quarter and area are listed in Table 5.1. The table shows the shift of the main fishery in the first and last quarter to the north and east. The shift is even more evident when catches are rearranged to take into account the seasonal nature of the fishery as shown in Table 5.2.

In the 1984/1985 and 1985/1986 winter seasons the fishery had shifted from Sub-area VII northwards to Division VIa. The increase in catches in the 4th quarter in Division IVa since 1986 might indicate a further shift of the early winter distribution towards the northern North Sea.

## 5.2 Fishery independent data

Information on the distribution of adult mackerel from research vessel surveys is incomplete and it is therefore not possible to add significantly to what is obtained from commercial catch data. It should be noted, however, that the surveys indicate that the total distribution of mackerel may be more widespread than indicated by the fisheries and that the distribution of commercial catches may not in all instances reflect the precise distribution of the stock.

The following fishery-independent data on distribution of adult mackerel were available at the meeting:

Survey	Time of year	Period	Area	Reference
Dutch groundfish	Oct, Nov	1980-89	IVb east, IVc	A. Eltink (pers.com.)
English groundfish	Aug	1977-89	IV	W. Dawson (pers.com.)
French groundfish	May, Oct	1987-89	VIIh south, VIIa,b	J. Gueguen & J.C. Poulard (1988, 1989)
Scottish groundfish	Aug	1982-86, 1987-89	IVa, IVb	M. Walsh (pers.com.)
Scottish acoustic	Nov	1983, 1985, 1986	VIa north,	Heath (1984), Heath & Copland (1986, 1987)
Danish acoustic	Aug	1985-89	IIIa, IVb	E. Kirkegaard (1986) E. Kirkegaard et.al (1987) E. Kirkegaard et al. (1989)
Norwegian acoustic	Jul/Aug	1987, 1989	IVa, IVb	Degnbol et al. (1988) D.W. Skagen (pers.com.)
IYFS	Feb	1967-89	IV	
North Sea Egg	May-Jul	1987-84, 86, 88	IV	See section 2
Western Area Egg	Mar-Jul	1977, 80, 83, 86, 89	VI, VII, VIII	See section 2
Norwegian Purse Seine	Oct	1985	IVa, IIIa, IVb east	Iversen and Westgård (1986)

### North Sea and Western area egg survey

The egg surveys give a good picture of the distribution of adult mackerel during the spawning season (see Section 2).

### Groundfish surveys

The English and Scottish surveys are carried out in August as bottom trawl surveys. At this time of the year, water masses in the North Sea, except for the most shallow parts, are stratified with a warm surface and a cold bottom layer. Mackerel are normally found in the warm surface layer, and this may influence catchability and make it doubtful to compare data from the different areas in the North Sea. Catches may also include an unknown proportion of North Sea mackerel. However, the data do not show any decrease in abundance as could be expected if the North Sea mackerel constitutes a major part of the catches.

The groundfish surveys show that adult mackerel are present over a large part of the North Sea during August with the main concentration in the northern and east central North Sea.

### Danish acoustic survey

From 1985 to 1988 the survey only covered the most eastern part of Division IVb and the Skagerrak-Kattegat area. The concentration of adult mackerel was found to be very low. In 1989 the survey area was extended further west but very few adult mackerel were caught.

### Norwegian acoustic survey

In 1987 and 1989 Norway conducted acoustic surveys together with Denmark. Norway covered a more northern area. In 1987, the year-classes of 1981, 1982 and, in particular, 1985 were dominant in the area. In 1989, the 1987 year-class was both dominant and widely distributed.

### Scottish acoustic survey

The target species in these surveys are herring and the catches of mackerel are very low. The only catches of adult mackerel were taken during the 1983 surveys in the area northwest of Scotland.

### The International Young Fish Survey (IYFS)

Catches of adult mackerel are very low, and it is not possible to draw any conclusions about the distribution or migration of adult mackerel from the data.

### Norwegian purse seine survey in 1985

The concentration of adult mackerel was found to be very low in the Skagerrak area. In Division IVa adult mackerel were caught throughout the surveyed area, in highest concentration in the northwestern part of the Division.

## 6. MIGRATION

### 6.1. Migration pattern of juveniles

The age of the juveniles discussed in this section is from when they are 6 months old (first winter) to the age of maturity (2 year-olds).

Information available on the juvenile distributions can be found in many earlier reports (Anon., 1984a, 1984b, 1985, 1986, 1987b, 1988a, 1989a, Dawson et al., 1988, E. Kirkegaard 1986, E. Kirkegaard et al. 1987, E. Kirkegaard et al. 1989). Most of this information describes the distribution of juveniles in their first and second winters, both in the North Sea and the Western area (see Section 4). Some information on the distribution of juveniles in the third quarter is available from Danish acoustic surveys conducted in the North Sea. However, very little information is available on the distribution in the second quarter.

Both research vessel data and catch data have been summarized by quarter for the period from the fourth quarter 1986 to the third quarter 1989 and their distribution and migration is illustrated for the first time in Fig. 6.1.

There is a very limited fishery in the Western area during the 3rd quarter, therefore it is difficult to know its main distribution with certainty during this period. While many juveniles are found in the northern and central North Sea and the Skagerrak during the autumn fishery in this area, it is not known what proportion of juveniles remain in the Western area.

The juveniles are distributed throughout the Continental Shelf in the Western area during their first winter. The main concentrations are found along the shelf edge and in the inshore areas to the west of Ireland, southwest of England and around the Brittany peninsula. The juveniles appear to become more widespread as they get older. It is thought that some migrate through the Channel into the central North Sea and others migrate northwards along the 200m contour west of Scotland into the northern North Sea and the Skagerrak during the third quarter. After returning to the Western area for their second winter, they follow a similar migration in their second year when they begin to join the adults on their migration. They can then be found with the adults on their feeding grounds in the northern North Sea and off the Norwegian coast.

There is insufficient data to determine whether or not changes in distribution have taken place over the period described for the adults in Section 6.2.

### 6.2. Migration pattern of adults

The study group reviewed and discussed published information on mackerel migrations, in particular the reports of the ICES Mackerel Working Group, but also assessed the fishery data (Section 5.1.) and the tagging results (Section 6.3.) as means of determining migration patterns. In relation to this the shifts in distribution were given special consideration.

Adult Western stock mackerel migrate between areas of overwintering, spawning and feeding. The spawning area (Section 2), in general terms, remained the same during the last 10 years, while the overwintering area has shifted gradually northwards and the feeding area somewhat eastwards in the latest years.

Figs. 6.2., 6.3. and 6.4. give a schematic outline of the change in migration pattern. The figures are based on similar illustrations presented in the ICES Cooperative Research Reports N°s 37 and 74 (see Section 1.3.), by the ICES Mackerel Working Group (Anon. 1981, 3.1-3.4 and Anon. 1986 Fig. 4.1) and by Bakken and Westgård (1986), as well as charts of catch distribution by month for major fishing fleets available at the meeting.

The shift in overwintering area is reflected in the fishery as demonstrated in Section 5.1. Reported catches in the feeding area in Divisions VIa, IIa and IVa indicate that the extension of the area and the locations of the main concentration area varied during the period 1978-1988. During the late 1970s fishable concentrations of mackerel were mainly found northeast of Shetland in July-August. In the early 1980s fishing extended further north, even as far north as 65°N. In later years fishing indicates that the mackerel occurred further east in the southeastern part of Division IIa and the eastern part of Division IVa (Fig. 6.4.). Western stock mackerel are probably in late summer distributed over a wide area in Division IVa, but the fisheries indicate that a major part of the mackerel follows a migration route across the northern part of Division IVa, most likely north of 59°-60°N. In the most recent years the return migration seems to start somewhat later than in earlier years. It should, however, be noted that the distribution and migration of mackerel in the feeding area seem to vary substantially, although the migration starts from a rather constant area of spawning.

The general migration pattern of adult mackerel in the most recent period, 1985-1988, is illustrated in Fig. 6.4. The migration pattern shown is the same as that indicated for the years 1985-1986 in the previous report of the study group, but the outlined area of feeding and the winter distribution are revised in the light of observations from 1987 and 1988.

It should be noted that Figs. 6.2., 6.3. and 6.4. are presented to illustrate the general migration patterns and the main distribution areas over several years. For this reason, and also due to the lack of observation data, some aspects of the mackerel migration and distribution are not reflected in the figures, e.g. likely migrations through the English Channel and occurrence of mackerel feeding in the Bay of Biscay area.

### 6.3. Norwegian tagging experiments

Mackerel have been tagged by individually numbered steel tags every year since 1970, with two areas of release: one southwest of Ireland in May and one south of Norway in July-August (Hamre 1980, Bakken and Westgård 1986, Iversen and Skagen 1989).

Data on tag returns have been used by the ICES Mackerel Working Group to allocate catches to stocks in Divisions IIa, IVa and VIa for the years up to and including 1984. Details on the method are found in the Mackerel Working Group reports.

The tagging experiments were continued except for the Western area in 1987. A number of mackerel tagged and released southwest of Ireland in May are recaptured during summer and autumn the same year. Figs. 6.5 and 6.6 show the location of such recaptures based on tag recoveries for which detailed information on fishing position are available. A migration of mackerel from the spawning area to the summer/autumn feeding area in the northern North Sea and off the Norwegian coast is indicated by the tagging experiments. It should, however, be noted that the location of recovery is influenced by the fishery and by the catch utilization since reliable data on fishing position are only obtainable when catches are screened by a tag detector. For a large proportion of the catches such detection is impossible. In addition, fishing regulations prohibit or restrict catches in certain areas. For these reasons, the lack of tag returns in other parts of the North Sea and the Skagerrak do not necessarily imply that the feeding migration does not extend into these areas.

Bakken and Westgård (1986) reviewed the Norwegian tag returns for the period 1971 to 1985. They concluded that the mixing of tags from the two series was not uniform between areas, except for the years 1980, 1984 and 1985 when no significant difference between areas could be demonstrated. The proportion of tags from each release area tended to decrease with increasing distance from the release area, at least prior to 1980. A preliminary analysis of the data for the later years indicates that this difference has disappeared.

At the request of the Multispecies Working Group (Anon., 1988c), Iversen and Skagen (1989) estimated the percentage of the western mackerel stock which migrates into the North Sea in the feeding season, using tagging and catch data. It was noted that the main fishery since the early 1980s has shifted gradually from the western Channel, south and west of Ireland towards the North Sea and the Norwegian Sea (Fig. 6.7). Since 1980, it appears that at least 80% of the mackerel caught in Divisions IVa and IIa have been of western stock (Fig. 6.8). The estimated percentage of the western stock which moves into Subarea IV in the 3rd and 4th quarters is shown in Table 6.1. The table is based on the Norwegian tagging experiments southwest of Ireland in May for the period 1973 to 1981 inclusive. For the period 1982-1985 status quo has been assumed since the distribution of catches was similar in this period. For the years 1986 to 1987, the values suggested by the Mackerel Working Group (Anon. 1987, 1988) have been used. In 1988 the main fishery in the 3rd quarter took place in Division IIa, while it moved into Division IVa in the 4th quarter. Therefore, to indicate the more northerly distribution in the 3rd quarter that year, only 40% was suggested and 70% in the 4th quarter.

It should be noted that the tagging experiments are carried out north of the main spawning area just prior to the peak of the spawning and it might be questioned whether the behaviour of the tagged population is representative of that of the total Western stock.

#### 7. DISTRIBUTION OF THE NORTH SEA STOCK

The migration pattern of the North Sea mackerel stock was investigated by tagging experiments and the distribution of the main fisheries between the mid 1960s and mid 1970s (Hamre 1978, 1980). The text table below and Fig. 7.1. (from Hamre 1978) summarizes the knowledge for that period, when the North Sea stock was considerably more abundant than at present.

Event	Time	Area
overwintering	Dec-Mar	Northwestern Norwegian trench Western Shetland shelf
feeding	Apr-May	Northeastern North Sea
spawning	Jun	Central North Sea - Skagerrak
dispersion	Jul-Aug	North and east of Shetland (major component along Norwegian coast, Skagerrak, Kattegat, western Baltic)
dispersion	Sep-Oct	Eastern North Sea
dispersion and overwintering	Nov-Dec	Deeper waters, northern Norwegian trench



It is pointed out that the main purse seine fisheries developed in the late 1960s on very dense concentrations along the Norwegian Trench in the autumn before the mackerel descended to deeper water. Another major fishery occurred in summer around the north and east of the Shetlands and in winter west to North Rona where it exploited a mixture of mackerel of North Sea and Western origin.

Since the mid 1970s the stock of North Sea mackerel declined, and is at present very low. The spawning stock biomass was estimated to be 45,000 tonnes in 1986 and 37,000 tonnes in 1988 (Iversen et al., 1989). Presently, the size of the North Sea stock is very small compared to the Western stock; amounting to about 2% only in 1988. Clearly the catch of mackerel (221,700 tonnes in 1988) taken in the North Sea (i.e. Sub-area IV) is dominated by fish from the Western stock.

Due to the inferior size of the North Sea stock, the distribution of the various age groups cannot be determined with any precision. The only exception is the distribution of the adults at the time of spawning, since this is shown by the egg distribution (Fig. 2.1. and Iversen et al. 1989).

0-group mackerel from the North Sea stock have not been observed in recent years, but some were caught in July 1989 off the northeast coast of England during a research cruise (E. Kirkegaard pers. com.)

1- and 2-group mackerel, presumably originating from the North Sea stock, are recorded in bottom trawl catches in the International Youngfish Survey (see Section 3).

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Table 4.1 Catch in numbers of 1-group mackerel in millions. Figures in parentheses are catch of 1-group as percentage of all age groups. Catches less than 50 000 are given as a plus.

ICES Division	1980	1981	1982	1983	1984	1985	1986	1987	1988
IIa	-	-	-	-	-	1.8	0.1	0.1	+
Vb	-	-	-	-	-	(1.3)	(0.04)	(0.04)	(+)
IIIa	-	1.7	2.2	0.1	-	4.5	5.5	6.9	26.2
	-	(15.2)	(17.4)	(0.4)	-	(42.6)	(25.6)	(21.4)	(82.9)
IVa, N of 59°N	-	0.6	0.4	-	-	0.1	7.3	3.5	22.2
	-	(15.0)	(1.0)	-	-	0.4	(1.5)	(0.8)	(3.4)
IVa, S of 59°N	-	-	-	-	-	(0.8)	+	+	+
IVb	2.7	1.6	(0.3)	-	-	(3.0)	(0.2)	0.8	18.2
	(16.3)	(2.3)	(8.1)	(2.0)	(0.5)	(32.6)	(13.8)	(0.07)	(42.6)
IVc	-	-	0.4	0.1	+	1.1	0.8	-	-
VIa, N of 58°N, in winter	3.0	0.1	21.0	3.0	5.0	129.8	6.4	2.1	9.9
VIa remainder	(0.7)	7.6	47.3	2.7	3.9	59.1	(2.1)	(0.5)	(3.3)
	-	(1.4)	(9.1)	(0.4)	(3.8)	(23.5)	-	-	-
VIIa-c	0.7	0.6	0.2	0.1	2.0	0.6	0.7	-	-
	(0.7)	(0.5)	(0.5)	(0.1)	(3.0)	(0.6)	(0.5)	-	-
VIIId-k	413.2	210.9	129.7	34.9	5.3	34.4	8.3	9.4	24.2
	(24.2)	(18.9)	(12.3)	(3.4)	(0.9)	(25.2)	(3.6)	(2.9)	(9.3)
VIIIa, b	67.6	46.8	4.7	3.0	0.6	2.0	+	2.0	0.5
	(55.5)	(37.2)	(9.7)	(3.4)	(0.9)	(25.3)	(3.7)	(1.0)	(0.00)
Source	Anon. 1981	Anon. 1984 b	Anon. 1984b	Anon. 1984 b	Anon. 1985	Anon. 1986	Anon. 1987b	Anon. 1988a	Anon. 1989 a
Tables	6.1 6.2 6.3	3.6 4.5	3.5 4.4	3.4 4.3	3.4 4.3	5.4 6.3	5.4 6.3	5.4	3.6

VIa,

b.

Table 4.2 Catch in numbers of 2-group mackerel in millions. Figures in parentheses are catch of 2-group as percentage of all age groups. Catches less than 50 000 are given as a plus.

ICES Div	1980	1981	1982	1983	1984	1985	1986	1987	1988
IIa	0.1 (2.1)	-	2.1 (3.5)	2.5 (2.5)	0.4 (0.2)	┆ 0.4	┆ 29.5	┆ 3.4	┆ 17.6
Vb	-	-	-	-	+ (0.2)	(0.3) ┆	(15.4) ┆	(3.4) ┆	(8.2) ┆
IIIa	┆ 0.4	0.4 (3.8)	6.2 (49.9)	6.1 (41.9)	0.6 (5.7)	0.2 (2.2)	11.3 (52.5)	13.3 (41.4)	0.8 (2.6)
IVa, N of 59°N	0.7 0.5	┆ 0.8	┆ 5.5	┆ 6.0	+ (0.2)	0.1 (0.3)	┆ 177.2	┆ 143.0	┆ 58.0
IVa, S of 59°N	┆ 0.5	(19.6) ┆	(13.5) ┆	(14.3) ┆	1.1 (2.0)	0.2 (0.3)	(35.7) ┆	(33.6) ┆	(9.0) ┆
IVb	┆ 1.7	┆ 4.8	0.1 (0.8)	2.2 (14.2)	0.7 (7.4)	0.2 (1.9)	1.0 (11.8)	┆ 1.1	┆ 13.1
IVc	(10.2) ┆	(7.1) ┆	0.5 (9.8)	0.2 (7.8)	0.1 (4.6)	0.1 (4.3)	1.8 (30.1)	(12.7) ┆	(30.7) ┆
VIa, N of 58°N, in winter	┆ 26.0	0.3 (0.4)	84.9 (27.6)	88.5 (51.8)	13.0 (2.0)	12.7 (1.8)	┆ 138.1	┆ 27.6	┆ 8.6
VIa remainder	(5.7) ┆	40.5 (7.4)	59.5 (11.5)	115.2 (16.2)	2.6 (2.6)	1.7 (0.7)	(46.2) ┆	(5.6) ┆	(2.8) ┆
VIIa-c	11.3 (10.6)	20.0 (15.4)	1.7 (3.3)	17.7 (15.3)	0.5 (0.8)	+ (+)	25.4 (16.2)	2.7 (2.2)	┆ 35.0
VIIId-k	412.7 (24.2)	424.6 (38.0)	284.9 (26.9)	459.8 (44.6)	56.5 (9.5)	2.0 (1.5)	42.0 (18.1)	50.3 (26.2)	(13.5) ┆
VIIIa, b	21.8 (17.9)	21.0 (16.7)	5.1 (10.4)	39.6 (44.9)	6.9 (9.5)	0.1 (1.2)	+ (18.2)	+ (0.9)	0.7 (13.4)
Source	Anon. 1981	Anon. 1984	Anon. 1984	Anon. 1984	Anon. 1985	Anon. 1986	Anon. 1987b	Anon. 1988a	Anon. 1989
Tables	6.1 6.2	3.6 4.5	3.5 4.4	3.4 4.3	3.4 4.3	5.4 6.3	5.4 6.3	5.4	3.6

Table 4.3 Percentages of juvenile fish (0-2 groups combined) and total number landed (all age groups) in ICES Division VIa, VII and VIII from 1972 to 1985 inclusive.

Year	Percentage juveniles in catch (by number)		Total catch in nos $\times 10^{-6}$	
	VIa	VII + VIII	VIa	VII + VIII
1972	<0.5	7	30	395
1973	1	26	57	603
1974	2	16	73	712
1975	2	11	679	1301
1976	5	29	159	1670
1977	8	45	166	967
1978	1	37	309	1493
1979	1	26	434	1915
1980	6	49	436	1937
1981	8	56	604	1372
1982	26	37	805	1157
1983	24	45	860	1236
1984	4	9	692	735
1985	21	16	922	239
1986	49	24	299	390
1987	6	20	488	313*
1988	6	28	302+	212*

\* Includes catches from VIIIId,e

+ Includes catches from VIb

Table 5.1 Mackerel catch by year and area in thousands of tonnes

Division	Quarter	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
IIa	1	-	-	-	-	-	-	-	+	-	-	-
	2	-	-	-	-	+	-	+	+	-	-	+
	3	4	-	8	17	37	49	92	71	93	43	113
	4	-	-	-	-	+	+	1	1	2	1	3
IIIa	1	)	)	)	)	-	-	-	-	-	+	-
	2	)	)	)	)	1	+	1	1	2	1	+
	3	)	)	)	)	3	5	5	3	4	9	6
	4	)	)	)	)	+	+	+	+	1	+	1
IVa	1	)	4	+	2	2	)	+	+	+	+	9
	2	)	8	6	5	6	)	4	2	1	1	+
	3	)	130	140	76	46	)	22	27	31	37	67
	4	)	8	8	5	2	)	2	1	2	7	164
IVb-c	1	)	)	)	)	)	)	)	)	)	-	-
	2	)	)	)	)	)	)	)	)	)	+	+
	3	)	)	)	)	)	)	)	)	)	3	2
	4	)	)	)	)	)	)	)	)	)	2	1
VIa	1	2	26	19	24	36	25	39	92	57	105	99
	2	2	12	7	9	7	17	5	10	2	1	6
	3	78	60	57	95	54	55	5	17	1	2	3
	4	69	105	135	213	244	231	259	273	41	80	13
VIIa-k	1	124	185	197	119	150	115	111	51	77	79	48
	2	42	17	38	50	41	51	41	18	44	15	15
	3	14	20	33	25	16	10	4	2	4	4	4
	4	152	157	99	66	32	65	12	2	3	3	10
VIIIa, b, d, e	1	+	+	+	1	1	1	1	+	+	+	1
	2	1	1	1	1	1	1	1	+	+	+	+
	3	1	1	1	1	1	1	1	+	+	+	+
	4	1	1	1	1	1	1	1	2	+	+	+



Table 5.2

Catches in thousands of tonnes rearranged by season (catches in 3rd and 4th quarters added to catch in 1st quarter following year)

Season	Area			
	Division IIa	Division IIIa and IVa-c	Division VIa	Division VIIa-k
1978/79	4	138	173	351
1979/80	0	150	184	374
1980/81	8	83	216	251
1981/82	17	48	344	241
1982/83	37	23	323	163
1983/84	49	28	325	186
1984/85	39	34	356	67
1985/86	72	44	347	81
1986/87	95	241	147	86
1987/88	44	299	180	55
1988*	116	286	15	13

\*Includes only catches in 3rd and 4th quarters 1988 as the catch figure in the 1st quarter 1989 was not available to the group.

Table 6.1. Estimated percentages of Western mackerel by number present in the North Sea (Subarea IV).

Year	3rd quarter	4th quarter	
1973	65	10	)
1974	30	5	)
1975	70	10	) estimated
1976	15	5	)
1977	5	5	) from
1978	10	5	)
1979	25	10	) tag returns
1980	40	25	)
1981	45	35	)
1982	45	35	)
1983	45	35	) estimated
1984	45	35	)
1985	45	35	) from catches
1986	50	70	)
1987	50	70	) See Section 6.3
1988	40	70	)

ICES Fishing Areas

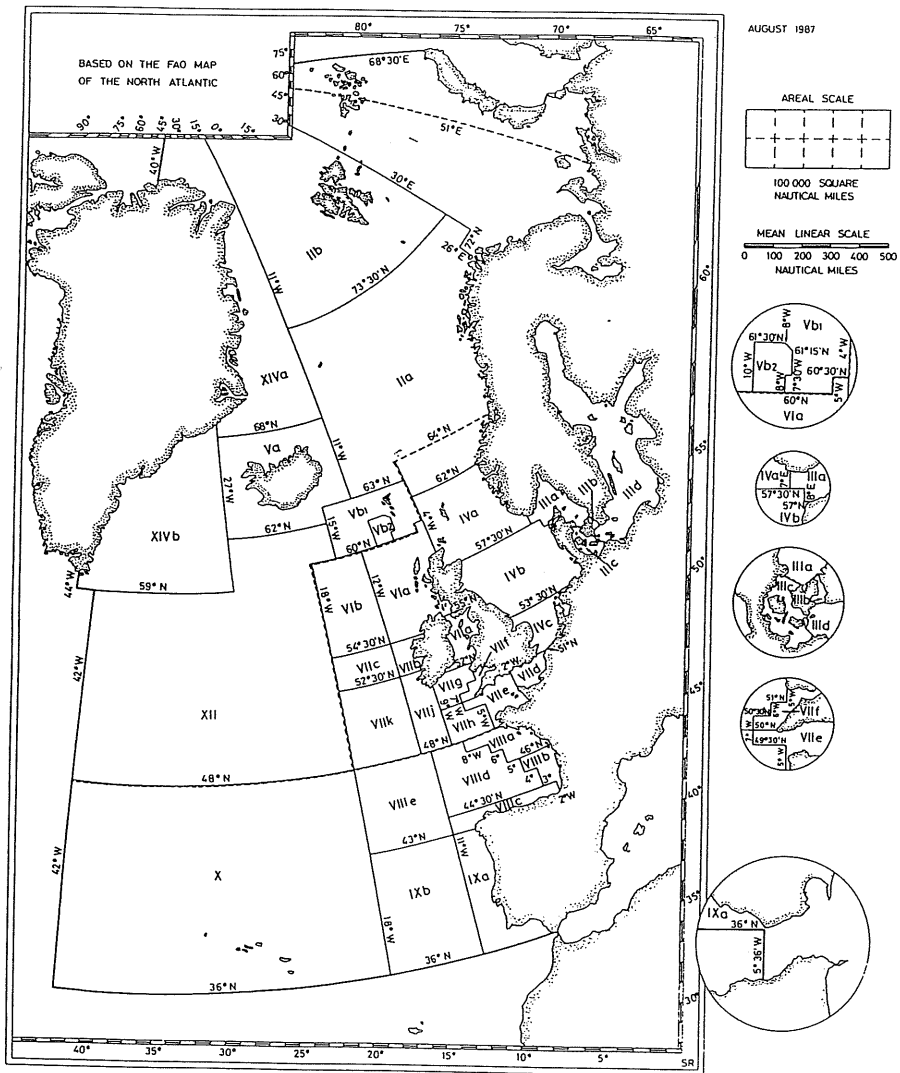
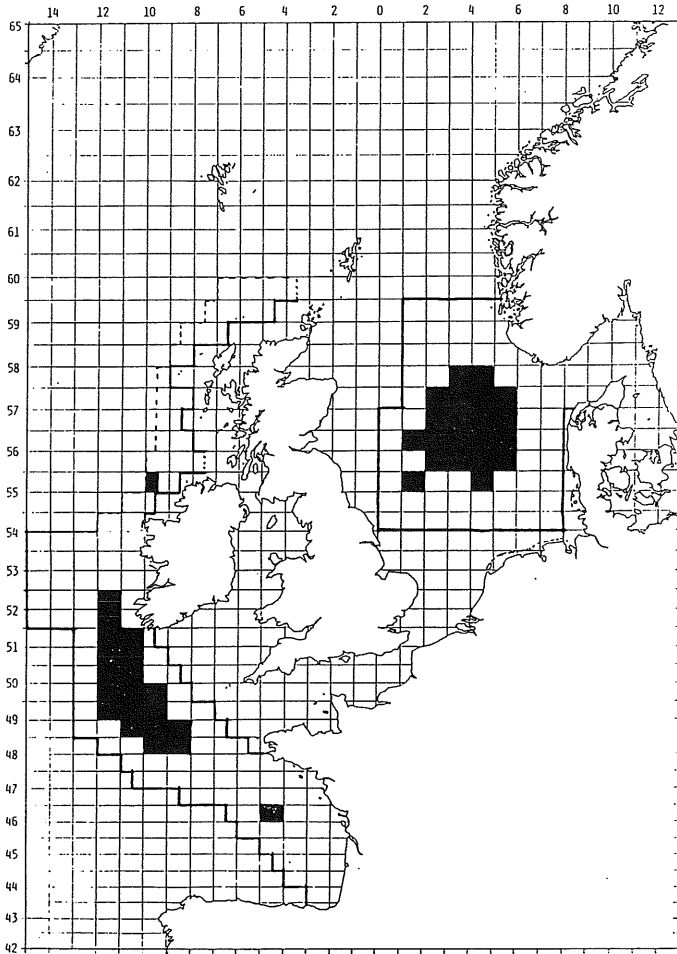


Figure 1.1 ICES statistical areas.



**Figure 2.1** Mackerel spawning areas in the period 1977 - 1988. Shaded areas indicate  $>100$  eggs/m<sup>2</sup> in at least two of the years.

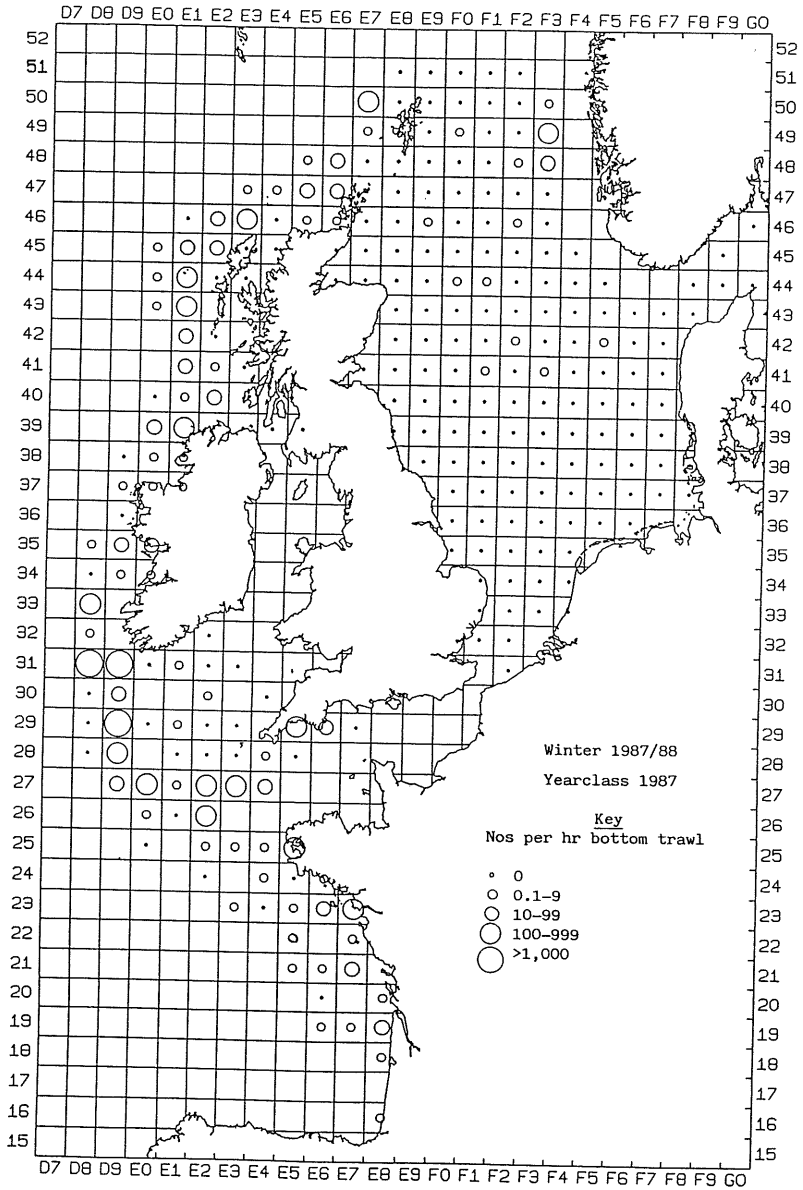


Figure 3.1 Distribution and abundance of first-winter mackerel (1987 year class) between October 1987 and March 1988 from research vessel surveys.

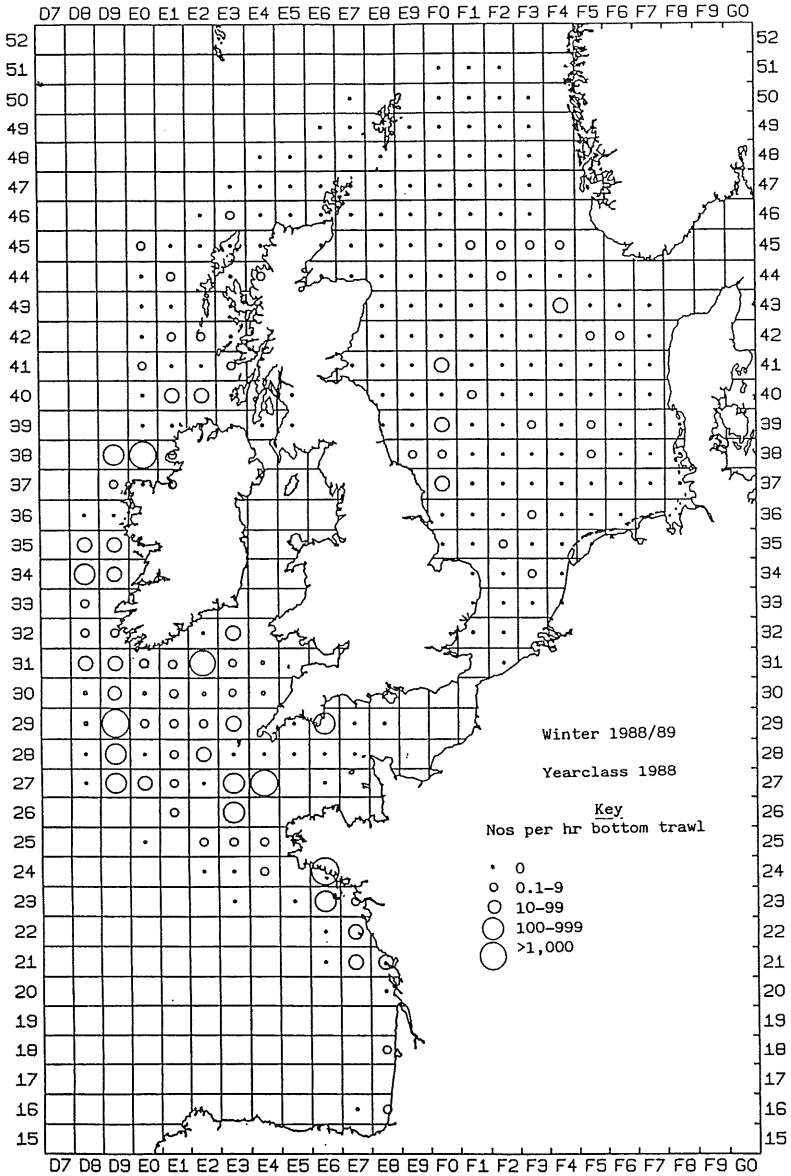


Figure 3.2 Distribution and abundance of first-winter mackerel (1988 year class) between October 1988 and March 1989 from research vessel surveys.

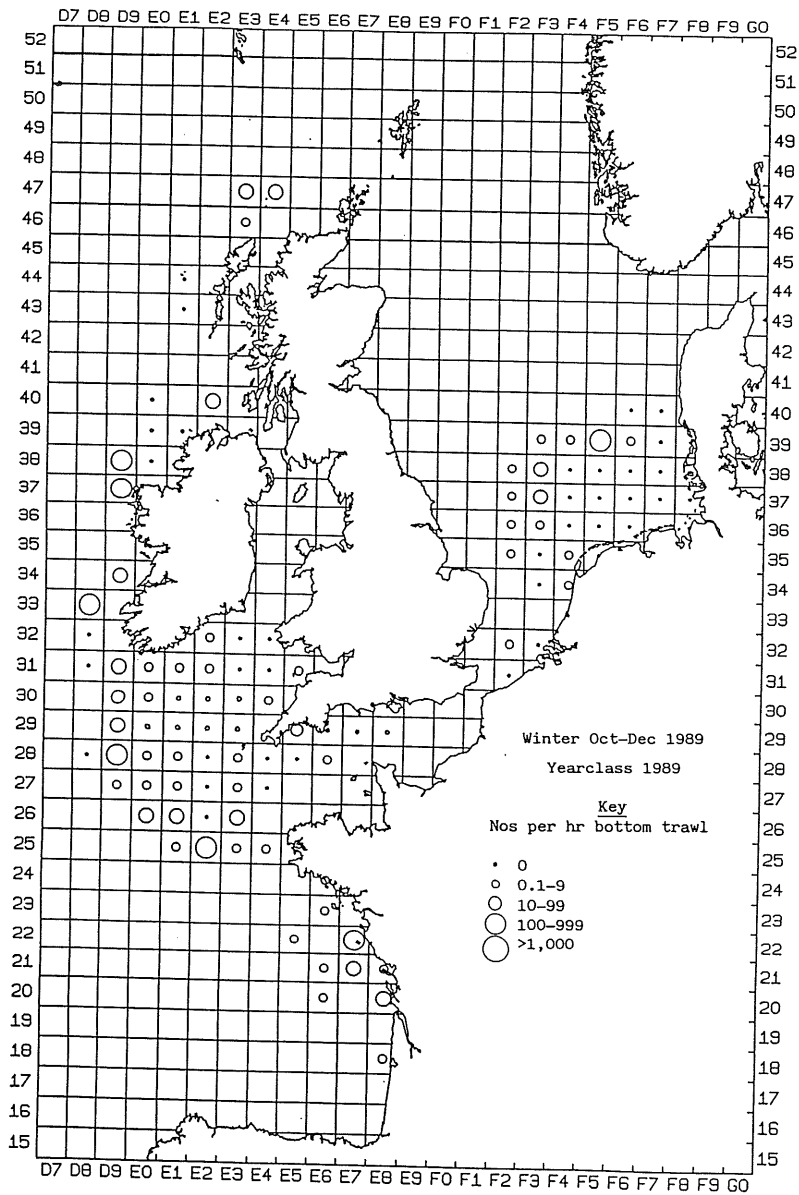
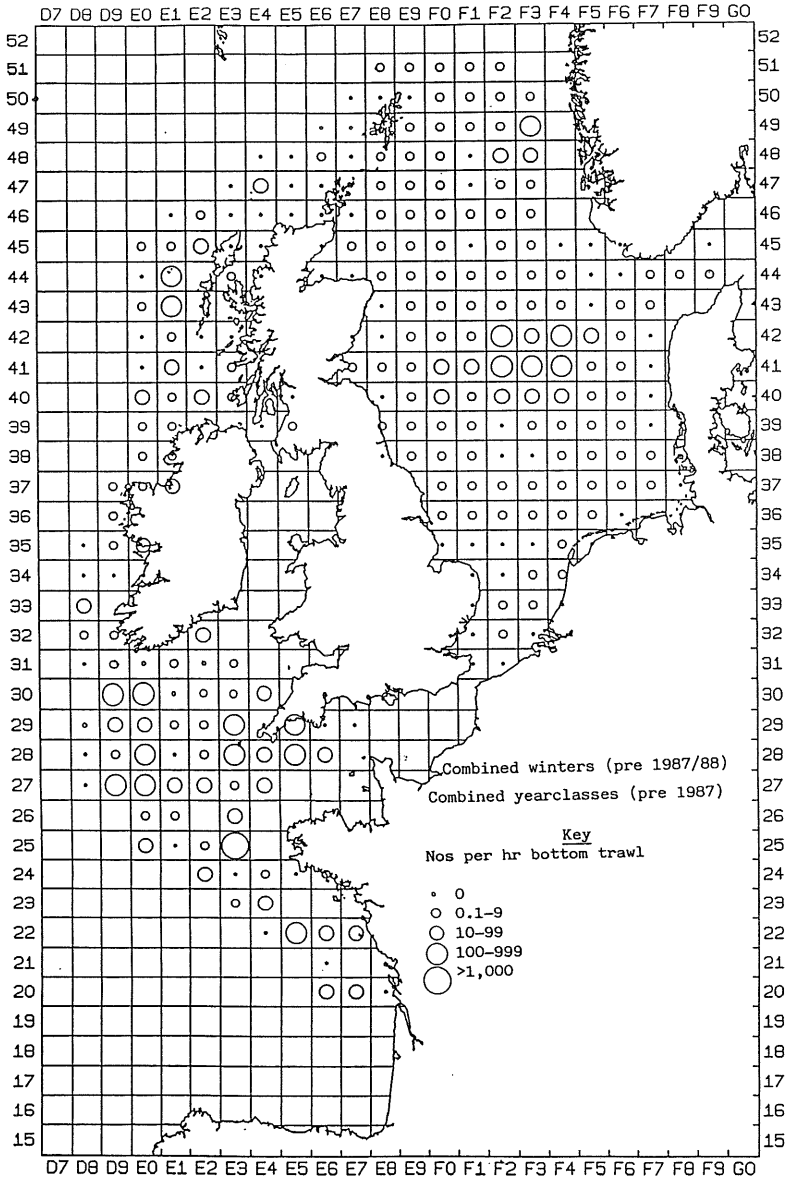
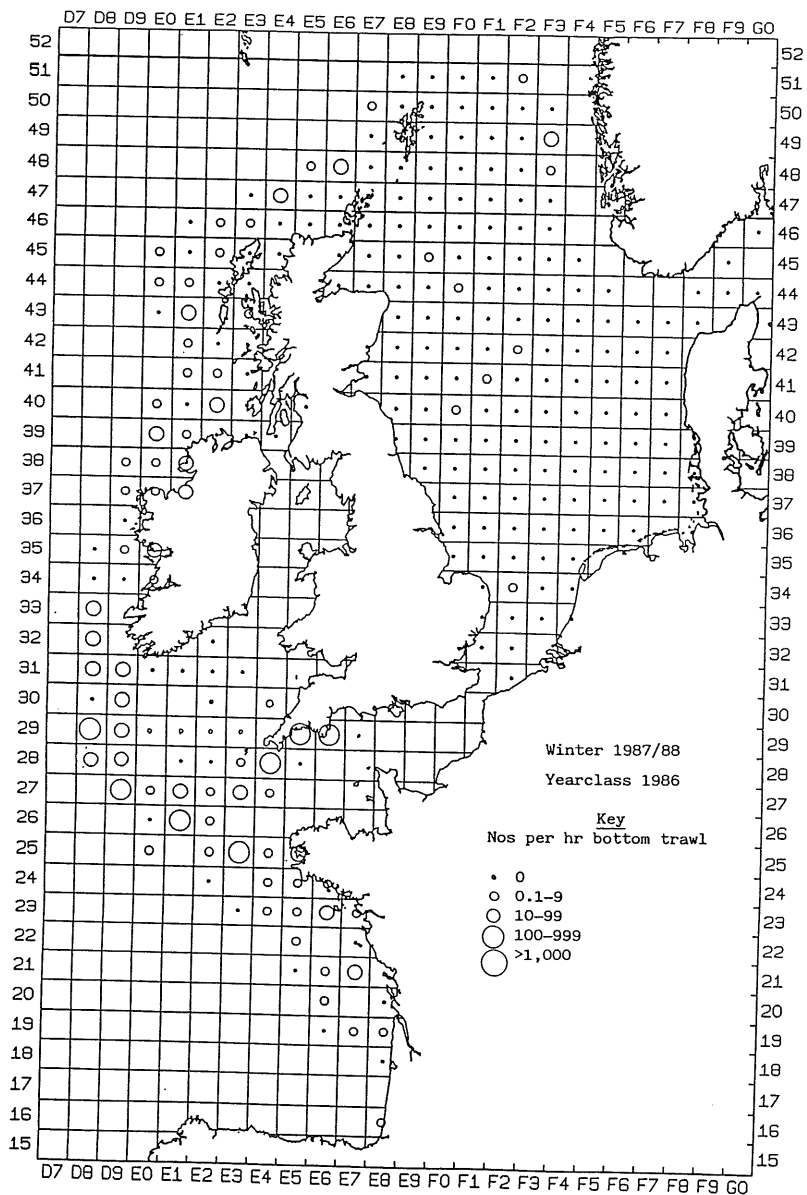


Figure 3.3 Distribution and abundance of first-winter mackerel (1989 year class) between October 1989 and December 1989 from research vessel surveys.

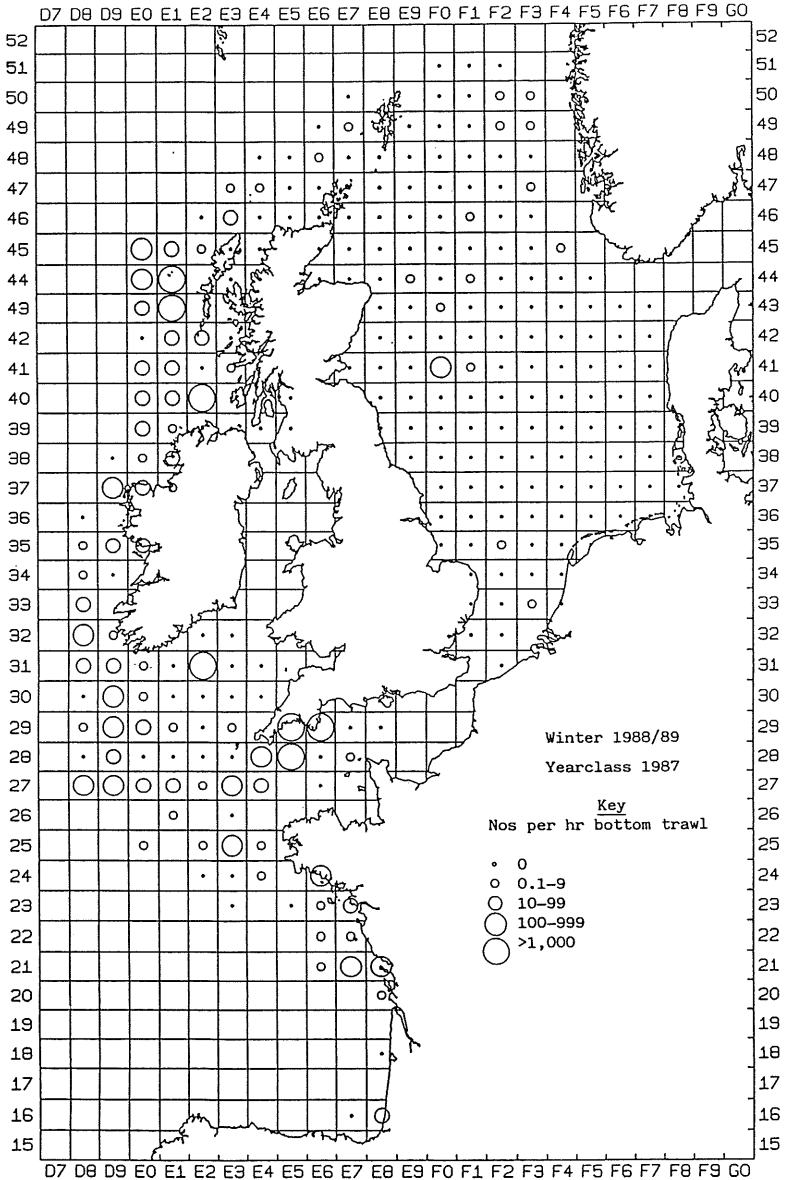


**Figure 3.4** Distribution and abundance of first-winter mackerel (combined year classes) between October and March for the winters 1981/82 - 1986/87 for western areas and 1959/60 - 1960/61, 1966/67 - 1986/87 for the North Sea and Skagerak. Data from research vessel surveys.

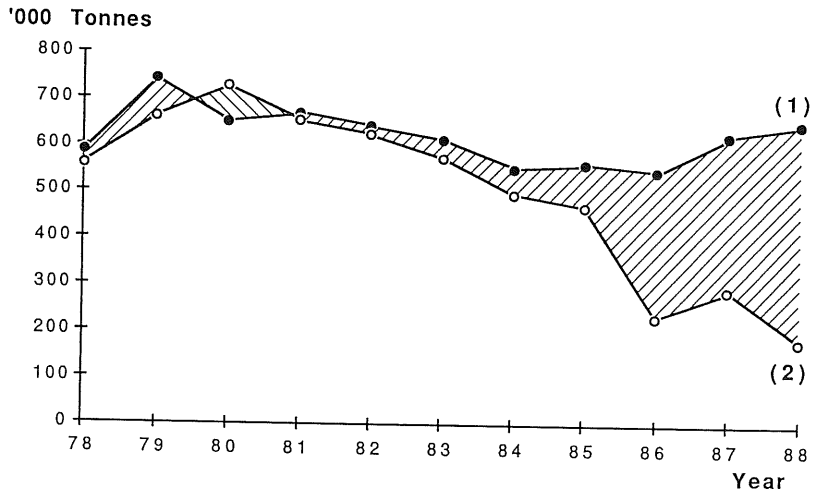




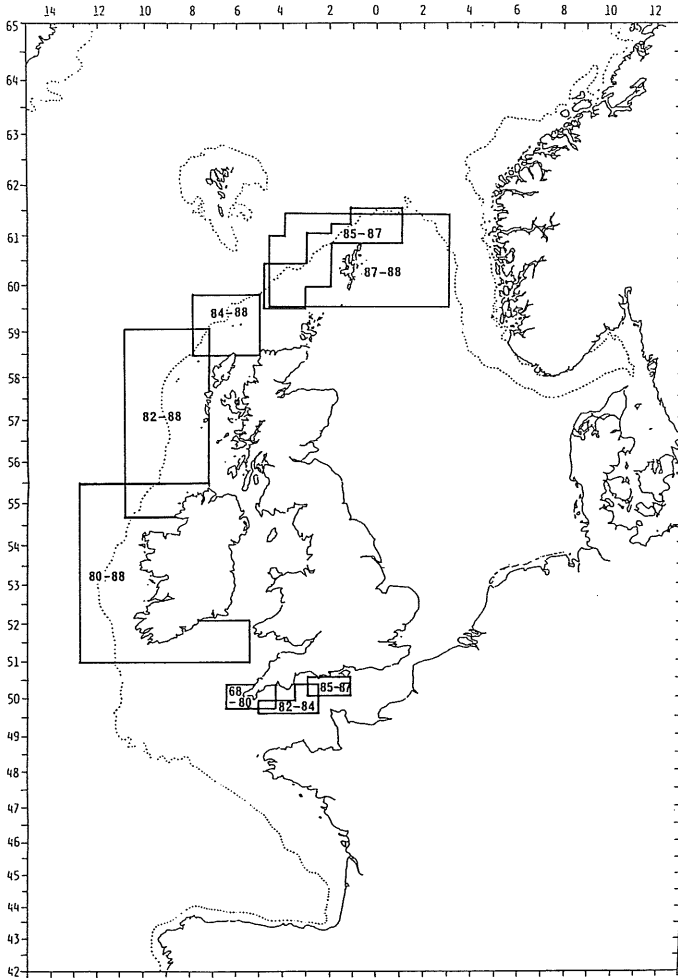
**Figure 4.1** Distribution and abundance of second-winter mackerel (1986 year class) between October 1987 and March 1988 from research vessel surveys.



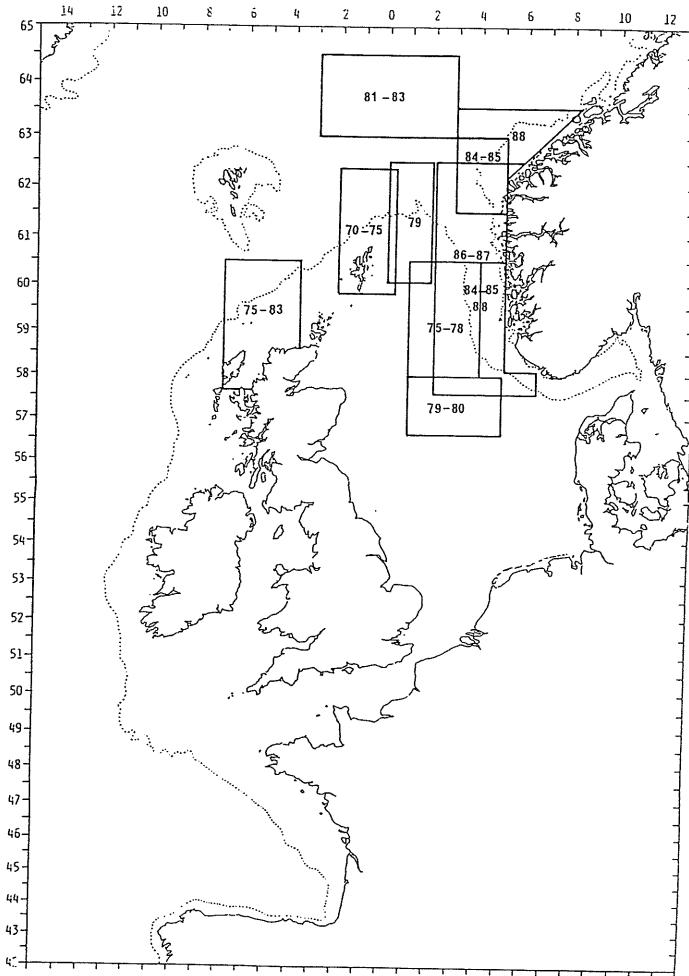
**Figure 4.2** Distribution and abundance of second-winter mackerel (1987 year class) between October 1988 and March 1989 from research vessel surveys.



**Figure 5.1** Catches in thousand tonnes of Western stock mackerel (1) and total mackerel catch in Sub-areas VI, VII and VIII (2).  
(Data from Anon., 1988a and 1989a)



**Figure 5.2** Shift in the position of the main Western mackerel stock fishery during winter. Compiled from Anon. (1985, 1988a and 1989a) and Walsh & Martin (1986).



**Figure 5.3** Shift in the position of the main summer fishery in which the Western mackerel stock have predominated in recent years.

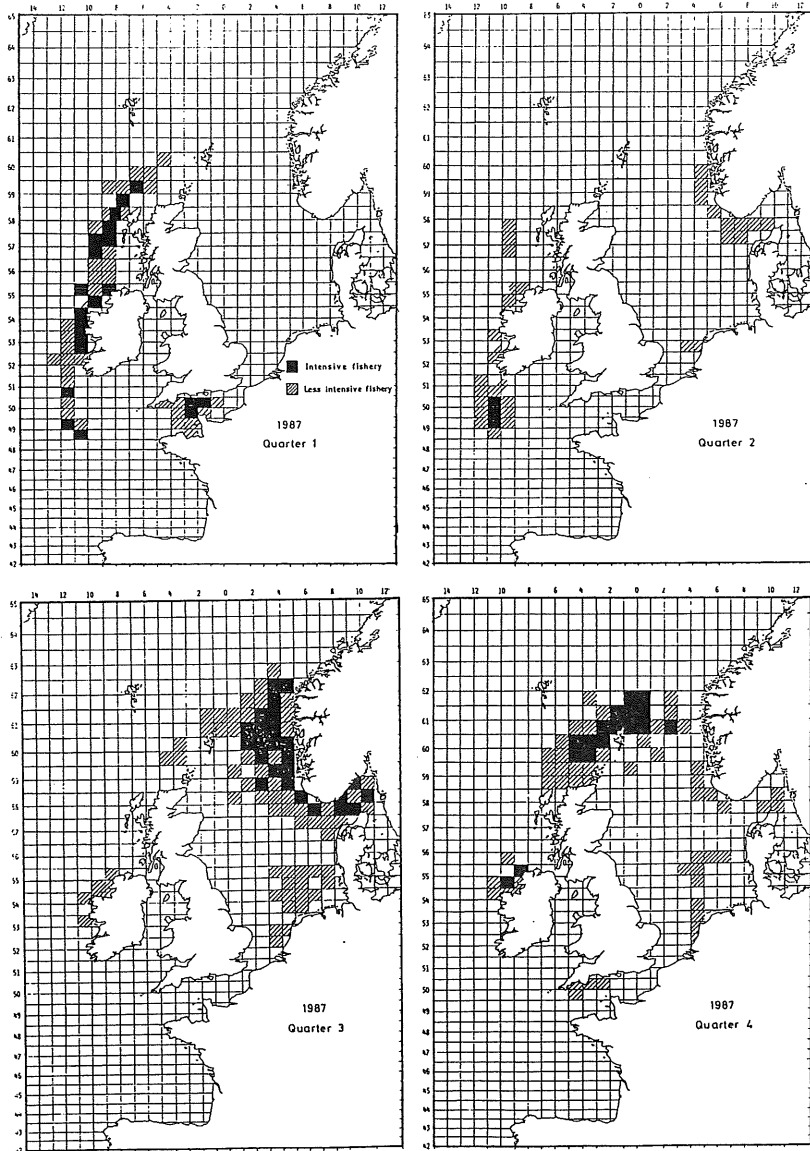


Figure 5.4 Distribution of mackerel fisheries, first - fourth quarter 1987.  
(from Anon., 1988a)

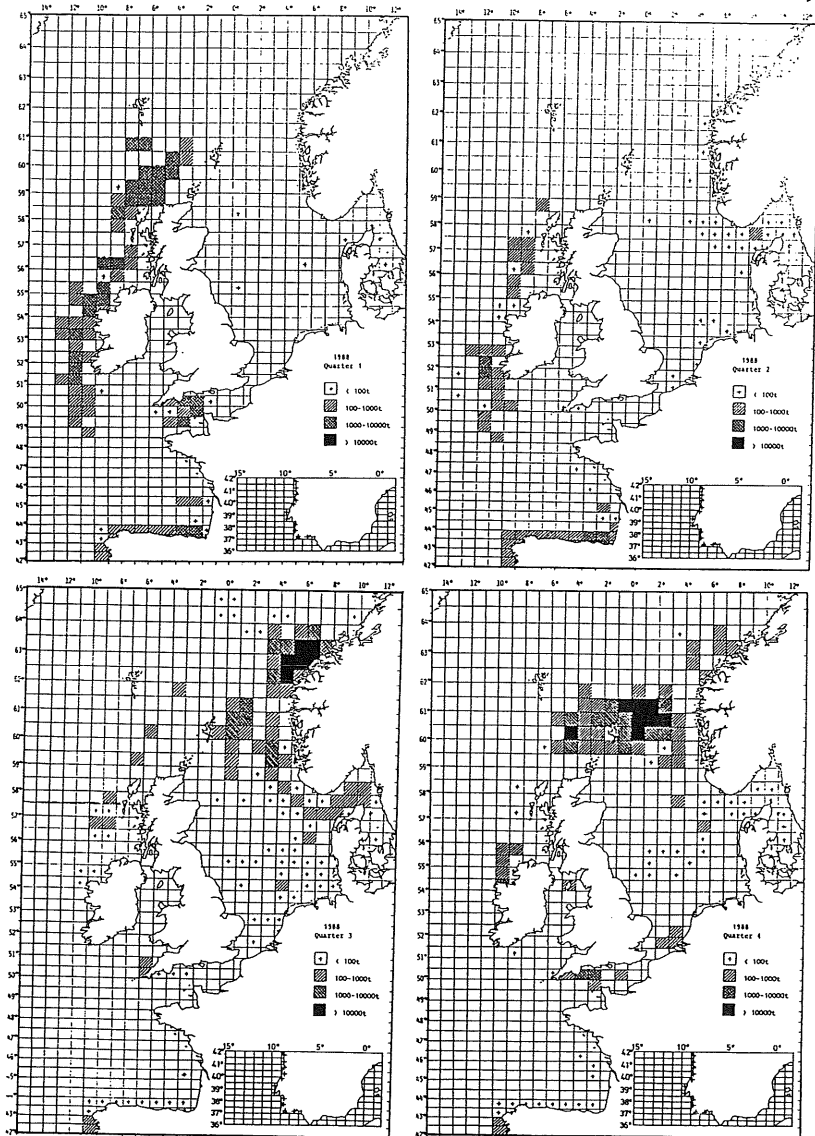
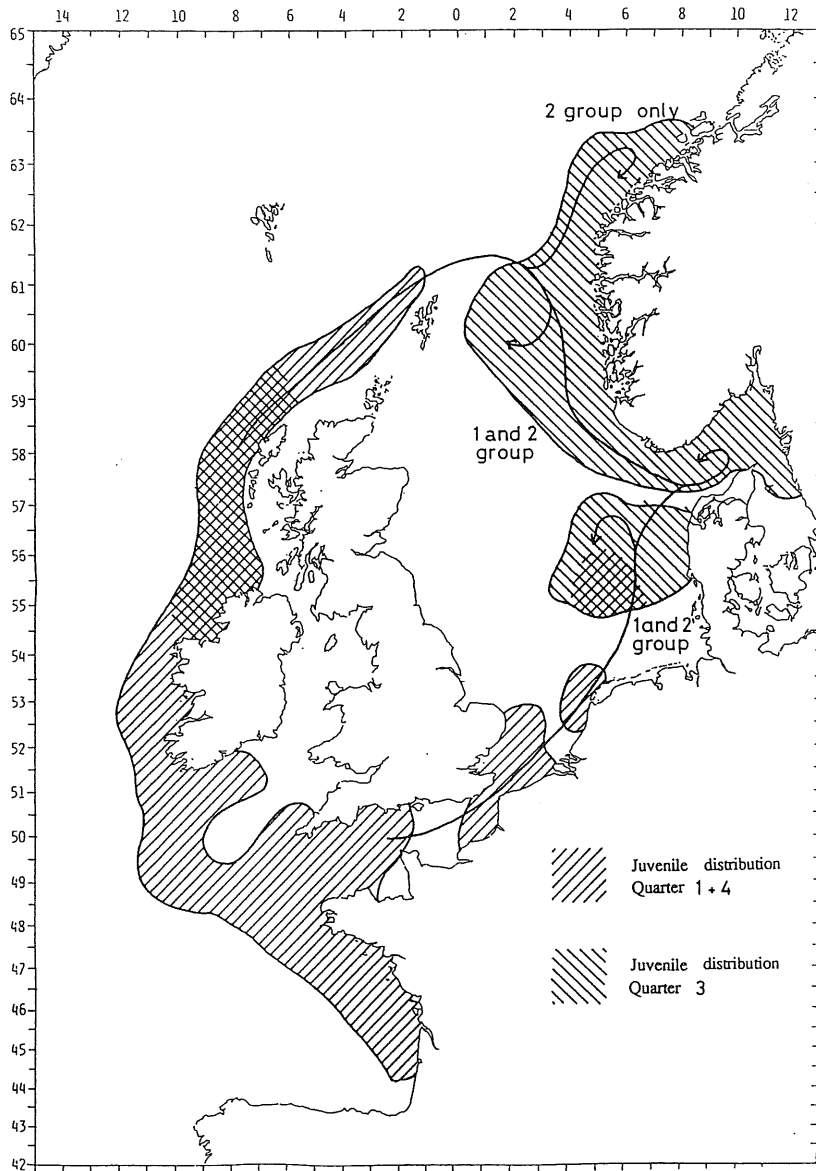
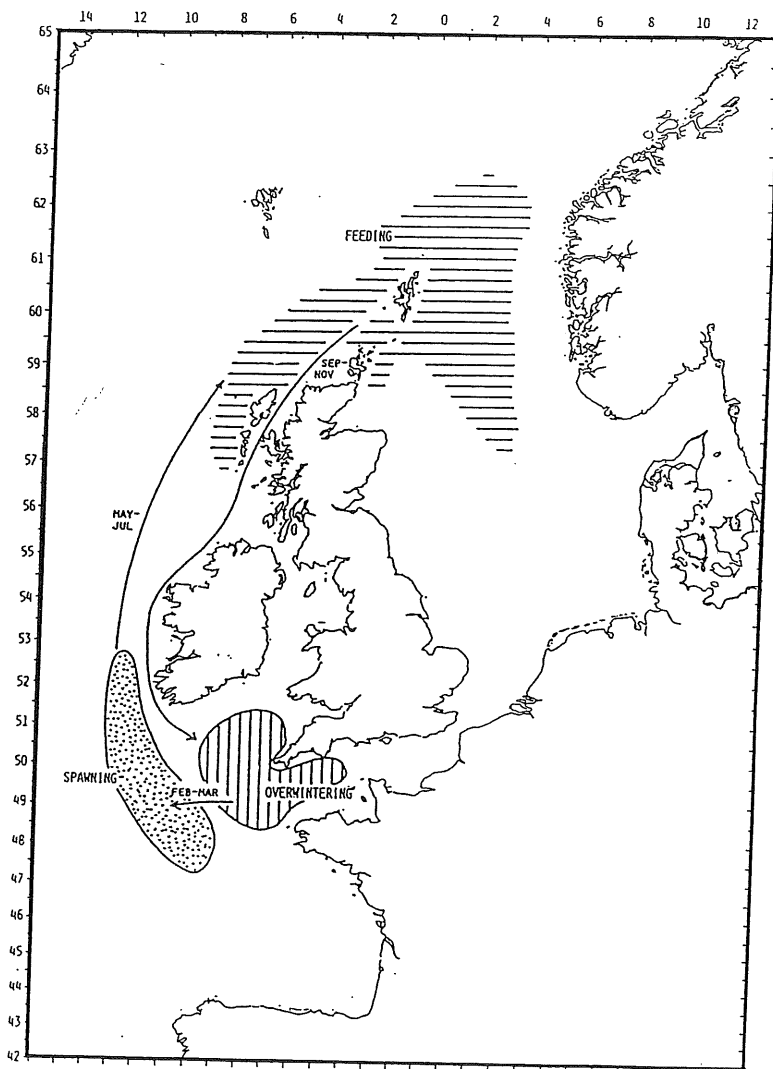


Figure 5.5 Distribution of mackerel fisheries, first - fourth quarter 1988.  
(from Anon., 1989a)



**Figure 6.1** Juvenile migration and distribution from both research and catch data covering the period 4th Quarter 1986 - 3rd Quarter 1989.





**Figure 6.2** Schematic outline of the migration pattern of the adult Western mackerel stock in the late 1970 s.

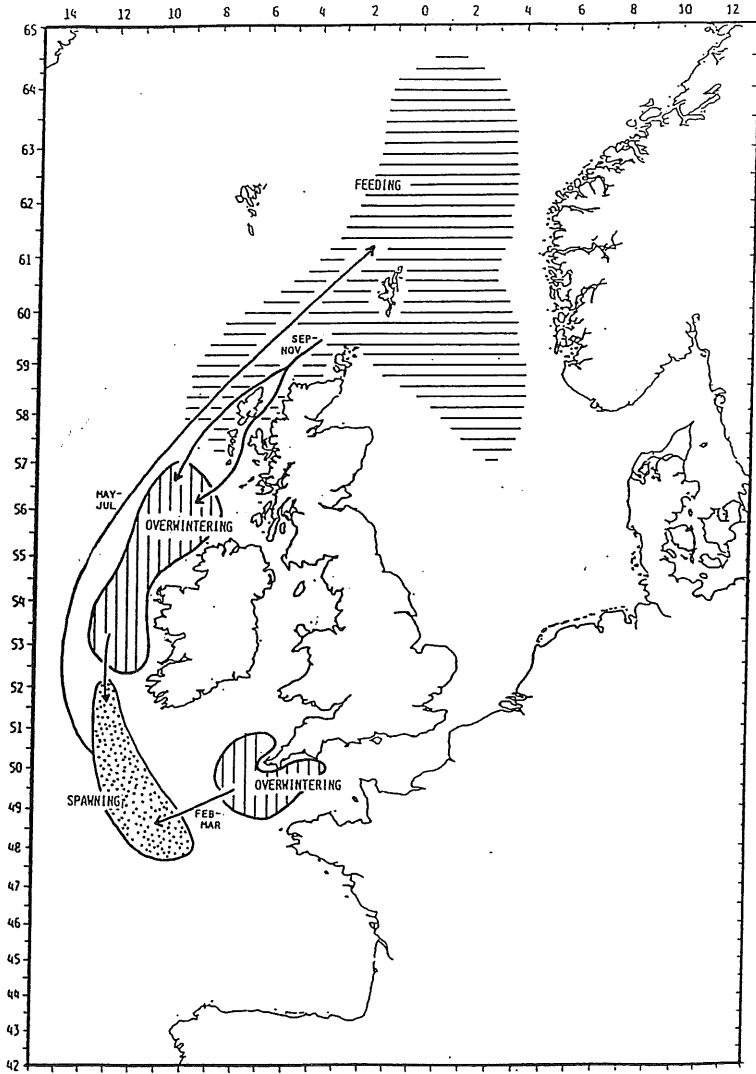
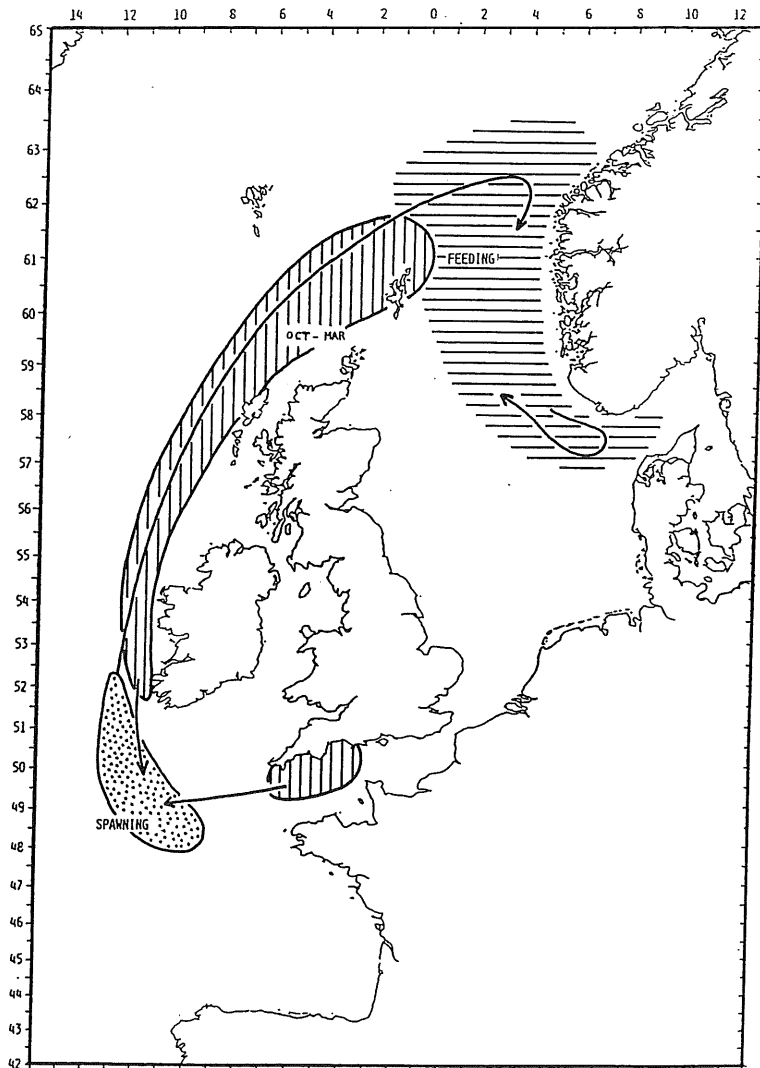


Figure 6.3 Schematic outline of the migration pattern of the Western mackerel stock (adults) in the early 1980 s.



**Figure 6.4** Schematic outline of the migration pattern of the Western mackerel stock (adults) in the later half of the 1980 s.

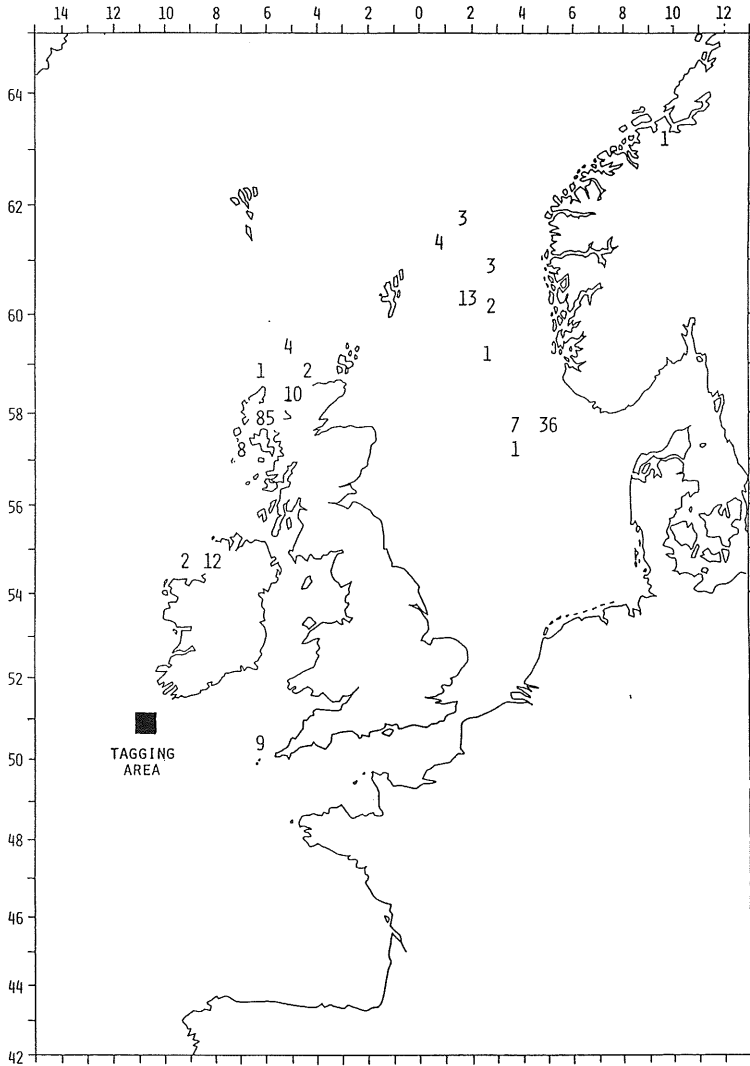


Figure 6.5 Number of tagged mackerel released in May and recaptured at known location later the same year, 1977 - 1981. Norwegian data.

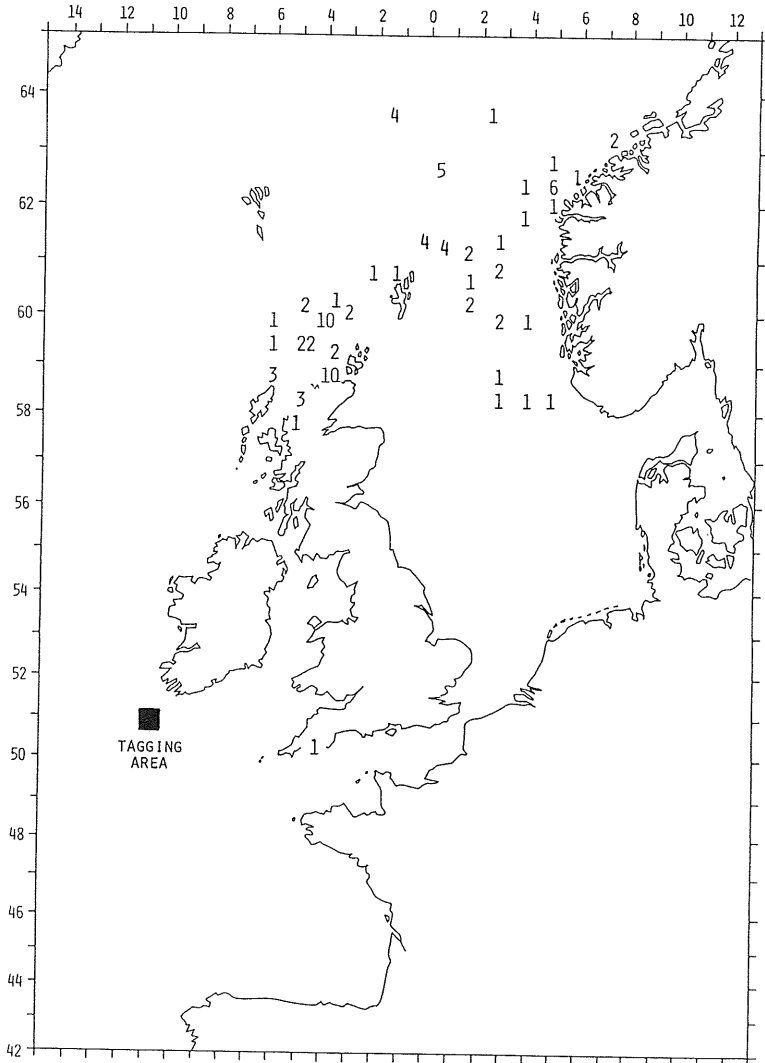


Figure 6.6 Number of tagged mackerel released in May and recaptured at known location later the same year, 1982 - 1988. Norwegian data.

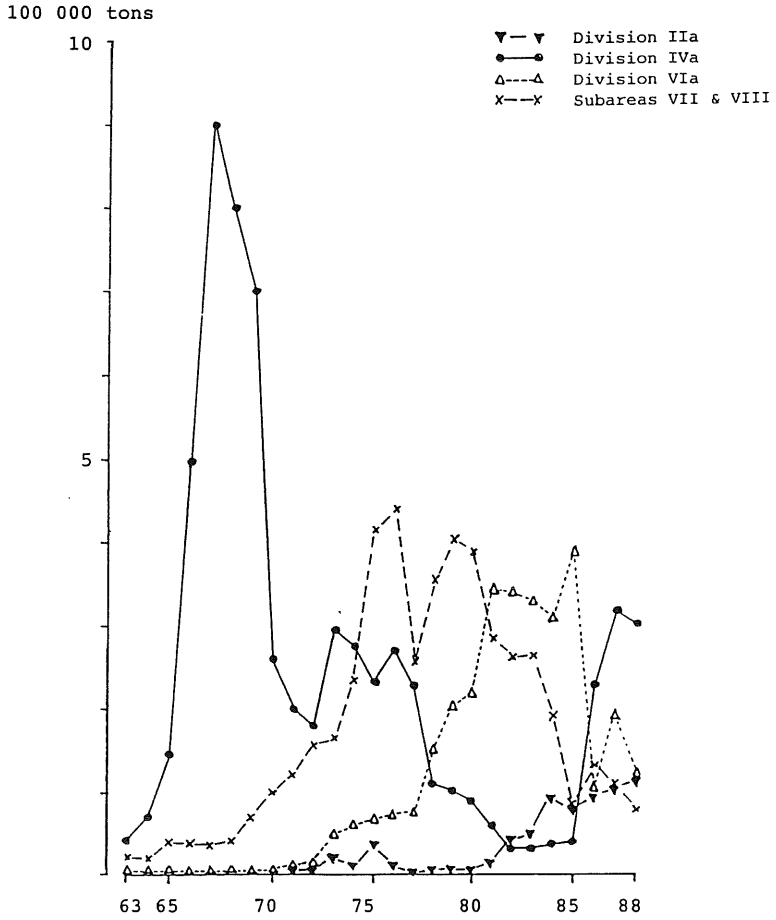


Figure 6.7 Yearly catches of mackerel by area.

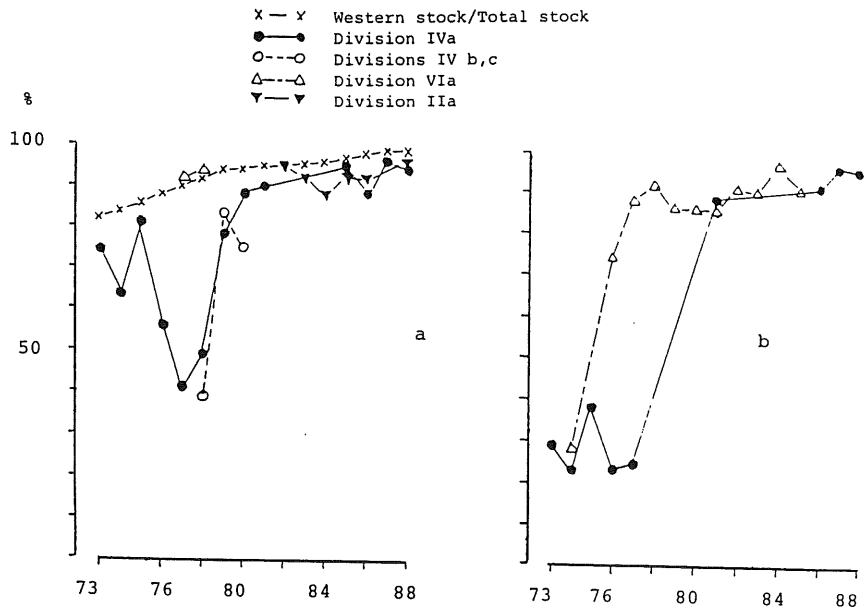


Figure 6.8 Fraction of Western mackerel in the catches and in the sea, third (a) and fourth (b) quarter.

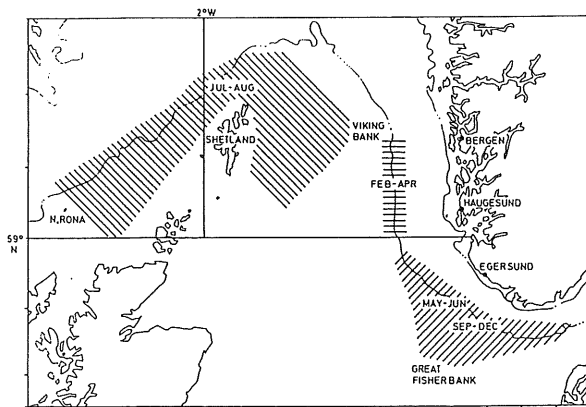


Figure 7.1 Main mackerel fishing grounds of Norwegian purse seiners by season, 1965 - 1975. (From Hamre 1980).