International Council for the
Exploration of the Sea

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Pelagic Fish Committee

REPORT OF THE MACKEREL WORKING GROUP

Copenhagen, 28 April - 3 May 1980

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1. INTRODUCTION

Terms of Reference

At the 67th Statutory Meeting it was decided (C.Res.1979/2:41) that:

> "the Mackerel Working Group (Chairman: M. J. C. Guéguen) should meet at ICES Headquarters 28 April - 3 May 1980 to:
>
> 1) assess the mackerel stocks in Sub-areas III, IV, VI, VII, and VIII,
>
> 2) further consider the area and time period during which the fishery in Sub-area VI should be closed to protect the North Sea stock,
>
> 3) re-examine the period and area of closure in Sub-area VII to reduce the fishing mortality on juvenile fish.

The Working Group was specifically asked by the Chairman of ACFM to

- reconsider the whole question of the distribution of small fish (i.e. below 30 cm) in the area around Cornwall in order to provide support for any recommendation for a closed season in that area;
- reconsider the question of the origin of mackerel caught in the winter fishery in Division VIa in relation to the time and area which should be closed to mackerel fishing;
- reconsider the problem of discarding and possibly give more reliable estimates of discards.

Participation

The Group met with the following participants:

R. S. Bailey	United Kingdom (Scotland)
E. Bakken	Norway
A. Corten	Netherlands
H. Dornheim	Federal Republic of Germany
J. C. Guéguen (Chairman)	France
H. Hansen	Denmark
S. H. í. Jákupstovú	Faroe Islands
S. J. Lockwood	United Kingdom (England)
J. Molloy	Ireland
J. Shepherd	United Kingdom (England)
Ø. Ulltang	Norway

In last year's report (Anon., 1979a) , it was pointed out that alternative analysis of tagging results to estimate the mixing rate of the North Sea stock and Western stock in Division VIa in winter could result in contradictory conclusions. This year the situation was even more complicated because of the low number of tag returns in 1979 (see Section 3) and the Working Group was no longer able to assess the North Sea stock. It was then decided to assess the Western stock only, in the same way as in previous years. It was assumed that the estimated number of Western mackerel caught in the North Sea would not affect to any appreciable degree the final estimate of the total Western stock.

2. THE MACKEREL FISHERIES

2.1 The North Sea Area (Sub-area IV and Divisions IIa and IIIa).

The landings by each country for the period 1969-79 are shown in Table 2.1. The figures for 1979 are provisional, while the 1978 figures were checked and revised where necessary. This revision in the 1978 figures results in a reduction of the total catch of approximately 1 200 tonnes. The provisional catch for 1979 is approximately 158 500 tonnes which is slightly above that of the previous year. The catches for most countries remained at about the same level in 1979 as 1978. However, Norway increased her catch from about 87 000 to 96 000 tonnes in 1979, although about 5 500 tonnes of this was taken from Division IIa while the catch from the Faroes decreased from 34 000 tonnes to about 28 000 tonnes in 1979. The ACFM in 1978 recommended that the TAC in 1979 for the Eastern area (Divisions IIa, IV and IIIa)should be set at 145 000 tonnes and that 100 000 tonnes of this catch should be taken north of 60°N and west of 2°E. However, the fisheries carried out by the various countries were similar in location to 1978. This would suggest that only about 20% of the total catch was taken from the recommended area.

The seasonal distribution of the catches in 1979 from the North Sea, Skagerrak and Kattegat is given in Table 2.3. The distribution was again very similar to that in previous years with over 90% of the catch being taken in the third quarter.

2.2 The Western Area (Sub-areas VI, VII and VIII)

The landings by each country for the period 1969-79 are shown in Table 2.4. Some slight revisions have been made in the 1978 catches which have resulted in a decrease in the total catch for that year of about 3 000 tonnes. The provisional catch for 1979 is approximately 606 000 tonnes which is over 102 000 tonnes more than the previous year and the highest ever recorded for this area. This increase in catch came mainly from increases recorded by Norway (2 000 t in 1978 to 25 000 t in 1979) United Kingdom (England and Wales) (213 000 t in 1978 to 244 000 t in 1979) and Netherlands (51 000 t in 1978 to 62 000 t in 1979). In addition further catches of about 54 000 tonnes were unofficially reported but were not allocated on a national basis.

The ACFM in 1978 recommended that the TAC for 1979 for Division Vb and Sub-areas VI, VII, and VIII should be 435 000 tonnes. Thus the area recommended TAC was exceeded by 39%.

The distribution of the catches by Sub-area which is presented in Table 2.5 from 1969-79 shows that the increase in Sub-area VI, which first became apparent in 1978, continued during 1979, mainly as a result of increased Norwegian and Dutch catches. Although 82% of the catch is still taken in the third and fourth quarters, there was a considerable rise in the catch taken in the first quarter (13%) as a result of increased effort by Norway and Faroes in that area. There was, however, no apparent change in the seasonal distribution of the catches in Sub-division VII with over 80% of the total catch coming from the first and fourth quarters (Table 2.3).

2.3 Discarding

At the 1979 meeting of the Working Group very little direct information was available on discarding. Following a discussion of the problem individual members adjusted their national catch statistics by what they believed to be the

appropriate factor. No adjustments were made to catches in the North Sea but the adjustments made in the Western area were equivalent to 10% of the total international landings.

During 1979-80 two programmes were carried out to estimate, by direct observation, the rate of discarding in the Dutch fishery in the Celtic Sea, and the United Kingdom fishery off Cornwall. The results of these programmes were discussed by the Working Group and the appropriate discard rates were used to raise numbers at age caught in those fisheries where discarding is known to occur. The adjustments made to the numbers at age in Division VIa were equivalent to less than 1% of the total landings, and in Divisions VIIa-k they were equivalent to 8% of the total international landings across all age groups. No evidence was collected to suggest that discarding was selective on certain sizes. No adjustments were made in Sub-areas IV and VIII.

3. TAGGING RESULTS

Mackerel have been tagged with internal steel tags off south-west Norway in July-August every year since 1969 and in May south-west of Ireland since 1973. Details of the tagging technique and recovery system have been described in papers by Hamre (1970, 1975, 1978) and the applications for assessments by the Mackerel Working Group in previous reports (Anon., 1977 and 1978).

Tables 3.1 and 3.2 give the number of tags released in the North Sea and south-west of Ireland and the returns from the North Sea by year classes for all years. The tables also give corresponding catches corrected for efficiencies of the magnets retrieving tags at fish meal factories.

In 1979 a much lower number of tags were returned, because the quantity of mackerel used for industrial purpose was reduced. Further, the factories received an increasing amount of offal from plants filleting mackerel. Tags in the offal were recovered, but could not be related to quantities produced by the meal factories with any reliability. For these reasons, the total number of tags which could be used for calculations of tag densities in 1979 was only 67 from releases in the North Sea (Table 3.1) and 57 from the releases south-west of Ireland (Table 3.2). In previous years, e.g. in 1977, the numbers were 958 and 184 respectively. This decline in tag returns has resulted in a decline in precision of estimates based on the 1979 data. Irrespective of this the analysis of tag data, particularly the returns from Division VIa have shown that the results are not easily interpreted. This was described in last year's report. The main problem is the uncertainties of the relationship between the tagged population and the two mackerel stocks. The differences in tag densities between Division IVa and VIa can be explained by postulating a component of mackerel not being tagged, neither in the Western area nor in the North Sea. Until problems of this type have been solved, the tagging results cannot be utilized for assessments of the North Sea mackerel stock.

4. EGG SURVEYS

4.1 The North Sea

Since 1968, Norway has carried out investigations in the spawning area of the North Sea mackerel. During the first years, the surveys were limited to the area north of 57°N, but since 1973 the coverage of the spawning area has been more complete, extending south to 55°N.

The eggs from the samples were referred to two development stages: a) average 1-day-old and b) older. The egg development rate was measured experimentally by hatching eggs at different temperatures. With these data, the daily egg production over the survey area was estimated (Iversen, 1977). Sampling during the spawning period at a fixed position near the EKOFISK oil field (Bakken et al., 1977) indicates that the spawning intensity may be more or less constant throughout the main spawning period. Therefore, there is some reason for expecting a direct relationship between the estimated number of 1-day-old eggs and the spawning stock.

The annual index of egg abundance is compared in Fig. 4.1 with the size of the spawning stock given in the Mackerel Working Group Report for the period 1973-79 (Anon., 1979a). In general the egg abundance indices demonstrate a declining trend as do the stock estimates from the Working Group Report. The increase in egg index in 1975 cannot be fully explained, there seems to have been some errors in the allocation to development stages of the eggs.

However, it seems reasonable to conclude that the egg indices give evidence of a declining spawning stock in the North Sea.

These data illustrate the value of egg surveys for stock assessment and every encouragement should be given to improve and increase such surveys in the North Sea. This is particularly important bearing in mind the difficulties currently experienced with the reduced tag return data (see Section 3).

4.2 Western Area

During the period March to July 1980 the Western mackerel spawning grounds will be surveyed on seven occasions.

At the time of the Working Group meeting three cruises had been completed Preliminary examination of the samples for March - April indicate a similar distribution to that found in 1977 (Lockwood et al., 1978), i.e. relatively few eggs north of the Porcupine Bank (west of Ireland), but high concentrations at the edge of the continental shelf south-west of Ireland and west of Brittany.

In order that the results of these surveys can be used to assess the state of the Western mackerel stock expeditiously and with a view to using them in giving advice for 1981, it is essential that samples are worked up as rapidly as possible. To meet the request of the Chairman of ACFM, the Working Group recommends that participants in the surveys should send daily egg production estimates as soon as they are prepared, to Dr. S. Lockwood, who will be responsible for preparing a summary for the ACFM meeting in July 1980 and the total egg-production-spawning stock estimates in time for the ICES Statutory Meeting in 1980. Members of ACFM will then be able to compare these new data with the stock size estimates made in this report and reconvene the Mackerel Working Group if necessary.

5. CATCH IN NUMBERS, MORTALITIES AND STOCK SIZE

5.1 Catch in Numbers at Age

5.1.1 North Sea and Skagerrak

In former years catches from the North Sea and Skagerrak were split into North Sea stock and Western stock components by using results from Norwegian tagging experiments. For 1979 the tagging data were insufficient to make such a split and the catches in numbers at age could therefore only be reported on an area

basis (Table 5.1). The bulk of the catches in the northern North Sea (Division IVa) came from Norwegian purse seiners and for these catches age and length distributions were available. Length distributions and catches by statistical rectangles were also available for Faroese catches and these were converted into numbers at age by using Norwegian data. No length or age data were supplied for Danish or Swedish purse seine catches in the northern North Sea and Skagerrak. It was assumed that these catches had the same age composition as the Norwegian ones. Separate age compositions were available for the Norwegian driftnet catches, the Norwegian hook and line catches, the Scottish trawl and purse seine catches and the Dutch trawl catches. Other trawl catches in the area were converted into numbers per age by using the Dutch age composition.

Purse seine catches in Division IVb were converted into numbers by applying Norwegian age compositions from Division IVa. Norwegian catches constituted about 30% of the total purse seine catch in this area. Most of the other purse seine catches were taken by Faroese vessels. Dutch age compositions were applied to all trawl catches in the central and southern North Sea, except for the Scottish ones, for which separate age data were available.

The age compositions in Table 5.1 show that year class 1969 is still very predominant in the North Sea. The table also shows that year class 1977 was extremely scarce in the catches. Although this year class has not yet fully recruited to the fishery, it is probable that it will be low in the North Sea.

5.1.2 Western Area

Although there was a small revision of the 1978 total catch in the Western area (from 507 214 tonnes reported in the previous report to 503 913 tonnes), this was not sufficiently large to justify revising the catches in number for 1978.

The numbers at age in the Western area in 1979 were estimated from sampling data provided by:-

Division VIa: France, Ireland, Netherlands, Norway and Scotland

Divisions VIIa, b, c: France and Ireland

Divisions VIId-k: England, France, Ireland and Netherlands

Sub-area VIII: France

In Division VIa, landings were allocated to age by using the most appropriate sample data for the area and season. Faroese and Danish landings were allocated using Norwegian data in the first quarter and Danish landings using Dutch data in the second quarter. Landings in England were allocated using Scottish pelagic trawl data. Faroese, Norwegian and Danish landings in the last quarter (about 5 300 t) were allocated by using a sample from a purse seine landing in Scotland after checking that the length composition was comparable with those found in Norwegian and Faroese samples where no age data were available. The estimated numbers at age are given in Table 5.2.

In Divisions VIIa, b, c, French and Irish sampling data were used to allocate Dutch catches to age groups but in Divisions VIId-k Dutch sampling data were used to allocate Federal Republic of Germany catches to age groups. Danish and Norwegian purse seine catches were allocated using data from the English purse seine fishery in the first quarter of the year (when the catches were made). The Spanish catch in Sub-area VIII (estimated at 20 000 tonnes) was allocated to ages by French sample data.

The estimates of landings at age were raised by the appropriate factor in those fisheries where discarding is known to occur (see Section 2.3). Thus the total numbers at age in Table 5.2 include allocated landings, unallocated landings and also numbers discarded.

5.1.3 Western stock catches in Division IVa

As outlined above (Section 3), the results of the taggings are not fully understood, and further analyses of all data are needed. Estimates of the proportion of the catch from the North Sea in 1979 to be attributed to the Western stock was, however, needed to carry out a VPA for that stock. In the absence of other method, the tag data were used, in line with the method of the previous years. Any error resulting from this will be small relative to the size of the stock.

The proportions of the catch were calculated from tag densities in 1979 (Table 3.1) following the method given in the 1979 report of the Working Group (Anon., 1979a). Due to the very low number of tag recoveries in 1979, it was necessary to make the calculations on groups of year classes, i.e., pre-1969, 1969 and 1970-74. The relative tag densities 1979/1978 determined for the 1970-74 year classes were applied to the 1978 proportions for each year class. For the 1975 year class the proportions of the 1970-74 year classes were used. This was also the proportion found for the same age goup in 1978.

The following proportions of the catch in Division IVa taken from the Western stock were obtained.

Year Class	pre-69	1969	1970	1971	1972	1973	1974	1975	1976
Proportion	.76	.67	.60	.88	.79	.75	.39	.36	0

5.2 Mean Weight at Age

Mean weight at age in 1979 was estimated from sampling data provided by:-

Sub-area IV:	Netherlands, Norway, Scotland
VI:	Ireland,Netherlands, Norway, Scotland
VII:	England, France, Ireland, Netherlands
VIII:	France

Mean weights at age per quarter were calculated by weighting the weight at age data according to landings in numbers from the individual countries. The quarterly mean weight at age was then weighted by the landings in number per quarter to give an annual mean weight per Sub-area. The weight at age data are presented in Table 5.3. If these data are compared with those in previous reports (Anon., 1978 and Anon.,1979a), it is clear that weights at age vary year by year. If new weight at age data are used in each year's assessment, it will introduce an inconsistency into calculations which can be avoided without affecting the validity of the assessment. For this reason, it was decided to use weights at age tabulated in the 1979 report (Anon., 1979a).

Weight at age for the second quarter of the year in Sub-area VII were used for estimating spawning stock biomass. For raising catch in number to catch weight, a weighted mean weight at age was calculated. The weight at age in Sub-area VI and Sub-area VII for each quarter were weighted by the catch weight in the

appropriate area and quarter (Tables 2.3 and 5.3 in Anon., 1979a). These new weights at age are given in Table 5.4.

5.3 Assessment of the North Sea Stock

In previous years the assessment of the North Sea mackerel stock has to a great extent been dependent on the results of the Norwegian tagging experiments. The tag data were used to calculate the proportions of mackerel from the North Sea stock and from the Western stock in the catches. The data also provided estimates of input F for the VPA.

In the years before 1976 the catches of mackerel for industrial purposes were large and took place in two well separated areas in the North Sea, i.e., near Shetland and off southern Norway. The relation between the tag densities in the two areas provided the basis for estimates of stock ratios in the North Sea catches (Anon., 1977). In more recent years, the fishery has changed, and it is no longer possible to retain the calculation method. A new method (Anon., 1978) was developed which assumed that all mackerel aged 3 years and younger caught in Division IVa were from the North Sea stock. From this, the stock proportions were calculated for each year class by using the change in tag density from one year to the next.

The data on numbers of tags released and returned have also been used extensively to provide estimates of F, either for dominating year classes over a certain period of years, or for several age groups in the latest year. Improved estimates of both F and M were obtained by analyses of the recoveries raised to the total international catch by a cohort method (Hamre, 1978 and Anon., 1978).

The VPAs of the North Sea mackerel stock carried out annually have had the advantage of being based on independent estimates of the input parameters obtained from the results of the tagging experiments. At present, the Working Group is faced with much less reliable data (see Section 3).

Both because of the high variance associated with the low number of tag returns in 1979, and uncertainties about the stock composition, the Group was not in a position to estimate the 1979 catch in number from the North Sea stock. Consequently, there was no sound basis for a VPA, and a continuation of the procedure used in last year's assessment might yield misleading results. The Group found it better to defer the assessment of the North Sea stock until all available tag data have been further analysed.

Irrespective of this, all available information on stock changes (Egg Survey, Section 4.1) and recruitment (Section 5.1 and IYHS, Section 6.2) confirms the previous evaluation of the North Sea stock, i.e., a declining spawning stock and very poor recruitment from recent year classes. Although catches in the North Sea in 1980 will probably be greatly reduced the recruitment failure will cause the present stock situation to prevail or get worse, at least in 1980 and 1981. It must still be the objective of management to retain, in the North Sea, a spawning stock of a size sufficient to produce a year class which once again can increase the stock.

This spawning stock size cannot be specified because the present absolute stock size cannot be determined with any precision. The last assessment estimated the North Sea spawning stock biomass to be about 500 000 tonnes at 1 January 1979, and about 400 000 tonnes at 1 January 1980, assuming a catch of 84 000 tonnes from the stock during 1979. These estimates can only be revised when an analytical assessment based on re-analysed tag data or other sources has been carried out.

The tag data, particularly their validity for assessments, were discussed by the Group. It was felt that new and detailed analyses of all returns, both those deriving from the Norwegian fishery and those reported by other nations, were needed. It is also necessary to analyse data on returns from the North Sea of tags from English and Scottish experiments. It was not possible to carry out such analyses at the present meeting of the Working Group.

For this reason the Working Group proposes that a meeting should be called later in the year to carry out a detailed examination of all available tagging data. In this context it is particularly important to study whether tagged populations in the North Sea and south-west of Ireland are representative of the two main stocks.

This will involve compilation of tag return data together with catch information from several countries and tests of hypotheses of stock composition using modelling techniques. Preliminary work is planned to be carried out by members of the Group in the near future.

5.4 Assessment of the Western Stock

In previous years a virtual population analysis had been carried out using the numbers at age caught in the Western area together with numbers of fish from the Western stock caught in the northern North Sea (Division IVa) estimated from the Norwegian tag data. For reasons given in earlier sections the allocation of North Sea catches to stock in 1979 is probably less reliable than in previous years. The effect that this is likely to have on the Western stock assessment is very much less than its effect on a North Sea assessment. This is because the numbers represent an addition of only about 10% to the Western stock, so that even if they are seriously in error the effect on the estimates of current fishing mortality and stock size will be only a few percent.

Excluding the component of the North Sea catch of Western stock, however, would cause a discontinuity in the data series which would introduce an error and confuse the interpretation. The Working Group therefore decided to continue the procedure used in previous years for this stock (Section 5.1.3). The catch in numbers at age from each area for the most recent years are given in Table 5.2 and the total input to the VPA in Table 5.5.

The only data to base input F on were stock estimates by egg survey for 1977. Runs of the VPA were therefore carried out to obtain a value of input of F which resulted in a stock size of 3-year-olds and older in 1977 of 9 000 x 10^6.

In the 1979 analysis the input exploitation pattern was changed (the proportional F on the 1- and 2-groups was increased) because of the indication that exploitation had shifted towards the younger components of the stock. An early run of the VPA provided some support for this change in 1978 and so a new input exploitation pattern was agreed. The F value for the 0-group was substantially increased (see text table below) to 1.4 times its previous highest value, in order not to overestimate the 1979 year class, which nevertheless seems to be large.

	F as a proportion of F on adults
0-group	0.04
1-group	0.40
2-group	1.00
3-group and older	1.00

The results of the run of the VPA using these assumptions and meeting the constraints imposed by the 1977 egg survey are given in Table 5.5.

The procedure hitherto used of grouped year classes earlier than 1969 introduces some technical difficulties, especially when running standard computer programs. These difficulties and the resolution are set out for future reference in Appendix A.

The convergence of stock size estimates in the interior of the VPA table means that the egg survey now provides a less accurate calibration of current fishing mortality than hitherto. Nevertheless, VPA runs with F in 1979 set at 0.20 and 0.30, rather than the 0.25 finally adopted, showed that these 20% changes of F led to changes of about 10% in 1977 stock size. Thus the accuracy of the calibration is still adequate, at about half that which would be obtainable with an up-to-date egg survey.

The results indicate that fishing mortality in 1979 was about 0.25, almost exactly equal to that projected by the Working Group last year (since the total catch was very close to that expected). The exploitation pattern in 1978 is consistent with that assumed for 1979 and other fishing mortalities are virtually identical to those estimated in 1979, as would be expected since both analyses are calibrated to the same population size in 1977.

The new analysis confirms that the 1977 year class is very weak, lower than any other on record, at about 400 million (as 1-group). The 1976 year class is, however, now confirmed to be very strong (the largest on record) at almost 5 000 million (1-group). The 1978 year class appears to be strong, and first indications of the 1979 year class suggest that it may be even greater than the 1976 year class.

Spawning stock biomass (age 3 and older) has been calculated from the VPA using the weight at age for the stock given in Table 5.4, derived as described in Section 5.2. For the running plus-group formed by the pre-1969 year classes it was necessary to calculate suitable weights for the plus-groups. This was done in each case by taking a weighted average of the value for the next older plus-group, and the weight at age of the youngest fish in the new plus-group. The weights used for averaging were $1/(1-e^{-Z})$ and 1.0 respectively, since these would be appropriate where the population at age reduces under total mortality, Z, if recruitment were constant.

Taking F = 0.1 as a suitable value for 1972-1977 where these estimates are required, the weights used were 4.521 and 1.0. The results are set out below (rounded to the nearest 10 g).

Age	≥ 4	≥5	≥ 6	≥7	≥8	≥9
Stock weight at age (g)	380	410	440	470	490	510

Examination of Table 5.4 shows that these are very similar to the mean weight of fish 3 years older than the youngest in the plus group (where the comparison can be made) which approximately is as would be expected with Z = 0.25.

The results of the VPA indicate a considerable fall in stock size between 1978 and 1980. The reason for this is a combination of the effects of the weak 1977 year class and the overshooting of the recommended TAC in 1979 (Figure 5.1).

5.5 Problems of Stock Identity

As pointed out in earlier sections, if the problem of establishing the identity of mackerel from different stocks is not solved, the separate assessment of stocks as carried out at present may be misleading. There are fundamental problems in the interpretation of tag recovery data which have implications for the assessment of both the North Sea and Western stock. The suggestion in this report that there may be a component or components of one or both stocks which are not tagged needs to be considered in the light of earlier hypotheses that stock separation in mackerel is more complex (Bolster, 1974) (Corten and Van de Kamp, 1978).

With the sharp decline in the return of tags in 1979 and the reduced reliability of stock parameters derived from them it is of special importance to develop new techniques for the recovery of internal steel tags. A large number of tags has now been released into the population and these can only be utilised if mackerel for the human consumption market are screened for tags. New detection systems are presently being tested and all interested parties should be encouraged to employ the system as soon as possible.

Biological studies of stock separation and stock mixing should also be carried out. For this purpose, an evaluation should be made of several methods including estimates of L_1 from otolith measurements, other meristic characters, biological tags and the determination of gene frequencies using enzyme systems. These studies are likely to take some time and they should therefore be started as soon as possible.

6. RECRUITMENT

6.1 Stock/Recruitment Relationships

As stated in last year's report, the Working Group could find no clear evidence of a stock-recruitment relationship for either the North Sea or the Western stock.

However, examination of Figure 6.1 of last year's report shows that recruitment to the North Sea stock since 1970 has averaged only 450 million(as 1-group) from a spawning stock biomass averaging about 1 million tonnes. The equilibrium biomass per recruit with natural mortality only (Table 6.1) is about 2 600 g per recruit. Thus, at the recent level of recruitment, even in the complete absence of fishing, the spawning stock biomass would not be expected ever to grow beyond 1.2 million tonnes. The prospects for the recovery of the stock are therefore poor, even if it were possible to reduce fishing mortality to zero, unless and until a substantially better year class arrives.

For the Western stock the few available data are plotted in Figure 6.1 of the present report.

The biomass has not changed substantially during the period 1971 to 1977 for which reasonably reliable data are available, so it would be impossible to determine a stock-recruitment relationship, even if stock biomass were the primary determinant of recruitment, and stochastic variability very small.

In this situation the shape of the stock-recruitment curve at low levels of stock cannot be predicted. However the cautious approach is to assume that there will be a relationship at all stock levels lower than those observed (see Appendix B).

The highest recruitment per unit biomass observed is 0.00154 rec/g for the 1976 year class. Although recruitment per unit biomass at low stock biomass (the slope at the origin of a stock-recruitment curve) may be higher than this, there is no evidence to support such an assumption. One must therefore recognise that

the present lower level of stock may produce lower recruitment and that the stock will decline if the present fishing mortality rate is maintained. Using this approach the stock may collapse if the biomass per recruit falls below 650 g (the reciprocal of the estimate of recruitment per unit biomass), since the spawning population would, in the long run, be unable to replace itself.

This potentially critical level of biomass per recruit would be reached with the present exploitation pattern if the fishing mortality (2-group and older) were maintained at a level exceeding about 0.17 (see Table 6.2).

With alternative exploitation patterns the potentially critical level is not reached until much higher levels of fishing mortality (see Section 8.2).

6.2 Recruitment Indices

Owing to lack of final data it was not possible to continue the recruitment index for the North Sea stock derived from the results of the International Young Fish survey given in Table 6.1 of the previous Working Group report. The numbers of 1-group mackerel caught in the 1980 survey, however, were very low indeed and so it can be concluded that the index is at a lower level than any of the values given in that table. This strongly suggests that the 1979 year class in the North Sea is very weak.

7. CATCH FORECAST

7.1 Prognosis of the North Sea Stock

Owing to inadequate data, no North Sea stock assessment was made. In 1979, ACFM expressed serious concern about the state of the North Sea stock because of the very reduced spawning stock and the fact that there was no evidence of a strong year class recruiting to the stock. As a result, they recommended that no mackerel fishing be allowed in the Eastern areas in 1980. Since the Working Group has not revised its previous assessment, it is not in a position to amend existing advice.

7.2 Prognoses for the Western Stock

The population estimates at 1 January 1980 from the VPA have been used to start prognoses for the stock, under two basic assumptions:

A) that the stock TAC of 354 000 tonnes is adhered to in 1980;

B) that the catch in 1980 is 550 000 tonnes (the best estimate the Group could make of the likely catch in the absence of enforcement).

The latter assumption (Scenario B) is considered much more likely, and represents a very similar assumption to that made last year and endorsed by ACFM, which is in fact proved to be very close to reality.

For all prognoses the exploitation pattern assumed was that used for starting the VPA and derived for 1978, i.e., 40% exploitation at age 1, and full exploitation thereafter. Recruitment at age 1 of the 1979 year class in 1980 was taken as the average for 1972 to 1979 (3 240 million), since the VPA indicates that the year class is large, as do observations of large numbers of 0-group fish taken on recent research vessel cruises in the western English Channel and Celtic Sea and in a French fishery in the Bay of Biscay, but no accurate quantitative estimate can be made. Recruitment of the 1980 year class in 1981, about which no information is available, was taken as 1 100 million, which is the lower 16 percentile (near less one standard deviation) of the observed distribution of recruitment (1972 to 1979) if this is assumed to be log-normal. This value is a statistically more stable estimate for a suitable cautious assumption than the 1 500 million previously assumed by the Working Group in the absence of information.

From the data available a lower recruitment is likely once every six years, on average, i.e., roughly once in the mean lifetime of the population. For each scenario prognoses were run for various fishing mortalities in 1981 between 0.10 and 0.25. Results for F = 0.10 and 0.15 are given in detail in Tables 7.1 (Scenario A)and 7.2 (Scenario B), and the results for catch in 1981 and spawning stock biomass in 1982 are summarised as requested by ACFM in Figure 7.1.

The results for Scenarios A and B (Figure 7.1.a and b) may be used to derive TACs for 1981 for any suitable value of fishing mortality. As said previously, the Working Group considers that Scenario B is more likely and also considers that its previous estimate of F = 0.15 (which is less than $F_{0.1}$, i.e., 0.18) as a suitable value for fishing mortality remains valid. On this basis it therefore recommends that the catch in 1981 should not exceed 353 000 tonnes, although other options may easily be derived from Figure 7.1. This advice is almost identical to that given last year, but the Group wishes to draw ACFM's attention to the Group's concern that catches have consistently exceeded recommended TACs by 20 to 90%.

The Working Group wishes to stress that actual fishing mortality in 1979 and that likely in 1980 are about 0.25, far in excess of the value of 0.15 which they consider advisable.

The graphs of Figure 7.1.a and b show little change in biomass through to 1982. This is however almost entirely because of the recruitment of two good year classes (1978 and 1979). The underlying situation is one of declining biomass (now estimated at 2/3 of its 1978 value) catches in excess of those recommended, and therefore increasing fishing mortality.

The Working Group does not consider that the stock is in immediate danger of collapse (i.e., in the next few years). The trend is however exactly that which has led to collapse in other fisheries, and the present level of catches cannot be sustained indefinitely.

This is clearly illustrated in Figure 7.1.c and d, which give estimates of long-term sustainable average catches, in contrast to the purely short-term assessment illustrated by Figure 7.1.a and b. Figure 7.1.c is based on the dangerous assumption that recruitment will remain at its average level (3 250 million) even if stock biomass is greatly reduced. Even so the sustainable average catch is no more than about 400 or 500 000 tonnes. This yield is however only attained at high fishing mortalities and low biomasses. where the possible effects of a stock recruitment relationship must be considered. If one incorporates the conceivable stock recruitment relationship discussed in Section 6.1 the situation is changed even more dramatically (Figure 7.1.d). This suggests that the stock could collapse under a fishing mortality of only 0.17 with the present exploitation pattern, with maximum sustainable yield of only 330 000 tonnes at a fishing mortality of less than 0.1.

The Working Group does not suggest that this is the real stock-recruitment relationship, or that management should be based on Fig. 7.1.d.
It is however entirely conceivable that this is the true situation: There is no evidence to deny it, nor is it even the most pessimistic assumption which could reasonably be made. The Working Group therefore wishes to stress most emphatically that they consider it essential that fishing mortality be reduced to not more than 0.15 as soon as possible, with long-term average annual

catches of not more than about 400 000 tonnes. If this is not done they consider that there is a very real danger of collapse in the future.

7.3 Area TACs for 1981

In Section 5.3 it is explained why an assessment of the North Sea stock could not be carried out. As a consequence of this, no options of TACs have been calculated. For the Western stock a series of TAC options were determined (Section 7.2).

The Group restricted the considerations of area TACs to those relating to the Western area only (Division Vb, Sub-areas VI, VII and VIII). Two area TAC options are put forward:-

a) the entire TAC for the Western stock to be taken in the Western area,

b) the stock TAC reduced by 17% to give an area TAC. This percentage is an average of the recommended Western stock TAC allocated to the North Sea area for the years 1976-1980.

On this basis the following options of TACs for the Western area for 1981 are:-

Scenarios	TAC 1981 Western Stock	TAC 1981 Western Area (Division Vb, Sub-areas VI, VII, VIII)	
A	381 000	a)	381 000
		b)	316 000
B	353 000	a)	353 000
		b)	293 000

As outlined in Section 7.2, Scenario A assumes that the TAC of the Western area for 1980 is adhered to, and Scenario B that the catch in this area in 1980 is 550 000 tonnes, i.e., exceeding the TAC by 55%. Both A and B scenarios given here are based on F = 0.15 on the fully exploited age groups, in accordance with previous recommendations from the Working Group.

8. EXPLOITATION PATTERN

8.1 Area and Seasonal Restrictions

8.1.1 Closure of the fishery in Sub-area VII

In the previous report of the Working Group (Anon., 1979a), attention was drawn to the potential gains in yield per recruit if the exploitation pattern in the western mackerel fisheries is changed to reduce exploitation on small mackerel. Some indications were given of seasonal change in the proportion of small fish

caught at different times of the year in the Cornish handline fishery and a table was given showing the percentage of fish less than 30 cm in the catches made by purse seiners and trawlers by month in this area.

These data were updated by the Working Group and a Sub-division was made by area. These areas are shown in Figure 8.1, rectangle B being the area defined in the 1979 ACFM report (Anon., 1979b), in which small fish are dominant outside the period mid-December to mid-February. For each of the areas mean monthly percentages of fish less than 30 cm in length are given in Table 8.1. For rectangle B - the only area for which the data are continuous- the mean monthly percentages are plotted for each component of the fishery for which data are available in Figure 8.2.

The results of this analysis show that in rectangle B the percentage of small fish tends to be rather high. There is some indication in all four winters of a decrease in this percentage in mid-winter, but the exact timing of this is not entirely consistent.

The available data for rectangles A and C indicate similar percentages of small fish, but there are not enough sampling points to evaluate the seasonal changes. The decrease in percentage of fish smaller than 30 cm in mid-winter could be due to immigration of larger fish, emigration of small fish or some combination of these.

Catch per unit effort data are not available for the purse seine and trawl fisheries in this area, but using those in the local handline fishery (Dawson, 1979) demonstrated a marked seasonal change in abundance of mackerel in the "large" market category (over 450 g), (Figure 8.3). Although the handline fishery may not be fully representative of all fisheries in this area, the Working Group considers that it provides a valid index of changes in abundance of large fish. On this basis they conclude that there is an immigration of large fish into the area in mid-winter which join the existing population of smaller fish and hence reduces the proportion of fish less than 30 cm in the catch.

As a consequence the fishing restrictions off Cornwall recommended by ACFM in 1979 optimise the catches of large fish but due to the seasonal increase of the total catch the absolute quantity of fish caught smaller than 30 cm will still be very high. It is therefore unadvisable to weaken the recommendation made.

8.1.2 Closure of the fishery in Division VIa

The Working Group was asked to reconsider the ban on mackerel fishing in Division VIa north of 56°N in the period from 1 November to 30 April. This ban had been recommended by ACFM (Anon., 1979b) in 1979 because of the need to reduce the exploitation of North Sea mackerel which was believed to constitute the major portion of the catches in that area during that period. The Working Group had available a discussion paper which examined some biological data and the tagging data relevant to this question. As a result it was considered that there was insufficient evidence available at the moment to determine the stock composition of these mackerel. Since ACFM has pointed out that it would not wish to prohibit fishery for mackerel in any area during any time period if there is no good reason to do so a continued prohibition of the fishery in this area would not be justified.

8.2 Alternative Exploitation Patterns

The Working Group discussed the draft of a paper (Lockwood and Shepherd, ICES Statutory Meeting 1980) which examines the long term effects on the stock of

a) the present pattern of exploitation,

b) a southern fishery limited to Divisions VII d-k plus Sub-area VIII

c) a northern fishery limited to Divisions VII a-c plus VIa.

In b) and c) it was assumed that no mackerel fishing occurs outside the area specified and as a consequence the results represent extreme situations.

Working with data derived from the previous Working Group report (Anon., 1979a) Lockwood and Shepherd calculated yield per recruit and spawning biomass per recruit curves for the three fisheries specified above (Figure 8.4.). These curves show that the southern fishery produces consistently less yield per recruit than the current mixed fishery. This is a consequence of the high proportion of young fish caught in the area (Table 5.2) and the slower growing component of the population described by Corten and Van de Kamp (1978). In contrast, the spawning biomass per recruit associated with a northern fishery is consistently higher than in the mixed fishery. The yield per recruit however does not show any gain until F exceeds 0.2. As the pattern of exploitation on age differs between the mixed and northern fishery a clearer comparison may be made by plotting the yield per recruit against spawning biomass per recruit (Figure 8.4.c.) It is then seen that a given yield will permit a higher spawning biomass per recruit in the northern fishery, or at a given level of biomass the yield is 30% greater in a purely northern fishery. A similar conclusion was reached by the Working Group in 1979.

In an effort to quantify these differences in terms of total yield and biomass, Shepherd's stock and recruitment model (see Section 6.1 and Appendix B) was incorporated into the calculations. The dimensions of these curves (Figure 8.5) will vary in part with the stock-recruitment parameters, but the value of F, at which under sustained fishing the stock might collapse, is totally dependent on this relationship. The relative differences are independent however and they show the same relative differences seen in Figure 8.4, i.e., an exclusively northern fishery will permit both a higher yield and a higher spawning stock biomass. In Figure 8.5.c a spawning stock biomass of about 3.5 million tonnes (a typical level during the mid-1970s) indicates a potential long-term yield of about 400-450 000 tonnes from the mixed fishery (this is very similar to the advice given by this Working Group in 1978 and the MSY calculated by Dawson (1979). At this level of yield for the mixed fishery a 30% increase could be obtained by fishing exclusively in the Northern area. This would be equivalent to approximately 150 000 tonnes more mackerel.

As in 1979, the Working Group recognised the potentital gain in both yield and biomass which might be realised by shifting the emphasis in the exploitation pattern away from the present pattern of fishing, with its dependence on young fish, to the Northern area, where old fish predominate. While any shift in exploitation pattern which ACFM may wish to consider would considerably alter the present pattern of the fisheries, it should be borne in mind that major changes in the pattern of fishing in the North Sea resulted from Hamre and Ulltang's (1972) assessment of the North Sea fishery. Whatever change might be considered, or recommended, to move effort away from the eastern Celtic Sea area,

it must also be born in mind that a component of the stock (Corten and Van de Kamp, 1978) probably never leaves the Celtic Sea area.

9. INADEQUATE DATA AND SHORTCOMINGS IN RESEARCH

Inadequate Catch Statistics

In the North Sea no information was available about the quarterly distribution of the Swedish catches (3 900 tonnes). For the Western area no information was available about the quantity or distribution of the Spanish catches (estimated to be about 20 000 tonnes)which are likely to constitute about 80% of the total in Sub-area VIII. In addition, it was estimated that the amount of unreported catches amounted to about 54 000 tonnes which is about 8% of the total for the area.

Inadequate Age Data

No age distributions were available for the North Sea catches of Denmark (19 000 tonnes), Sweden (3 900 tonnes), France (3 620 tonnes). This represents approximately 17% of the total catch for which no age data are available and the catches may in fact be quite different from those of other countries. For the Western area no age data were available for catches from the Federal Republic of Germany (21 500 tonnes)and Spain (20 000 tonnes) and some difficulty was experienced in allocating the Dutch age data between Division VIa and Sub-area VII. It was also felt that for some countries the age data did not adequately cover the period at which the main catches were made.

Discards

Although an improvement has been made in collecting information from the United Kingdom fishery off Cornwall in Sub-area VII, an important amount of the total international catch is not yet covered by a sampling programme. Information about this aspect is particularly lacking from the catches made by the purse seiners. It is important that more information be collected about the rate of discarding as soon as possible.

Estimate of Fishing Mortality

The decrease in the number of tag returns has made it difficult to estimate F in the North Sea. This is discussed in more detail in Section 3.

Stock Differentiation

As stated in the main body of the report it has become impossible to estimate the degree of mixture between the Western and North Sea stock, or indeed, whether these two components are the only ones on which the fisheries are based. Further study of the tag returns might help to solve this problem. It is also felt that proper sampling programmes by all nations, with examination of length. age, weight, sex and maturity together with other biological characters, would help to differentiate between stocks.

Fecundity Data

There are inadequate fecundity data for North Sea mackerel which may be different from that of the Western area. Information about this aspect is required to make stock size estimates from egg surveys.

APPENDIX A

VPA INPUT DATA

As may be seen from Table 5.5 and previous Working Group reports, the mackerel catch-in-number data havehitherto been handled in an unusual manner, in that catches for all year classes before 1969 were added, producing a composite cohort which appears in the more usual tables now presented as a running plus-group. Erroneous results are produced if standard VPA programmes are run on these data, treating the catches of old fish (≥ 10) in recent years correctly, as plus-groups. The reason is that the formula used to produce initial population estimates from plus-group catches is designed to estimate the population of the individual youngest cohort. Catches of the individual ages are then added in to produce the correct result. Applying this to the running plus-group in the mackerel data is wrong, because the catches at younger ages are plus-groups and not catches of individual ages. The composite cohort must be treated as a single-cohort (i.e., the 'not-a-plus-group' formula must be used to start the calculation). This has been done correctly in previous Working Group reports, but cannot be done within present standard computer programmes. Whilst the results these give for other cohorts will be correct, the estimates of average F, total numbers and biomass will be incorrect. The correct results for the running plus-group may of course be obtained by using the 'not-a-plus-group' option, but the results for other cohorts will then be incorrect.

Correct results, therefore, require the construction of composite tables taking results from both options, or individual treatment of each cohort using a calculator.

Furthermore, the weight-at-age estimates for the running plus-group must be appropriate when calculating biomasses (since the ages of which it is composed change from year to year). This has already been discussed in Section 5.4.

APPENDIX B

SHEPHERD'S STOCK AND RECRUITMENT MODEL

The method used in Section 8.2 for raising estimates of yield per recruit and biomass per recruit to estimates of total yield and biomass is described in detail by Shepherd (in prep.) but is summarised here.

From the generalised stock and recruitment relationship:

$$R = aBf\ (B/K) \qquad \ldots\ldots (1)$$

he develops:

$$R = aB/(1+(B/K)_{\beta}) \qquad \ldots\ldots (2)$$

from which:

$$K = B^*/(aB^*/R^*-1)\ 1/\beta \qquad \ldots\ldots (3)$$

where:

B^* and R^* are "typical" current levels of biomass and recruitment. (4×10^{12} g) and 4×10^9 individuals respectively, see Table 5.5).

"a" is the slope of a line drawn through the origin just to the left of all available stock and recruitment data. It is assumed that the slope of this line will equal the slope of the stock recruitment curve at the origin, see Figure 6.1. The reciprocal of this parameter, 1/a, is the critical biomass per recruit (650 g). If B/R falls below this level, the model will predict stock collapse due to recruitment failure, see also Section 6.1

β is the degree of density-dependent compensation, in this case assumed to be unity.

By rewriting equation (3):

$$B = K(aB/R-1)\ \ 1/\beta \qquad \ldots\ldots (4)$$

thus biomass may be calculated over a range of F from the estimates of biomass per recruit.

Then: $R = B/(B/R)$ ..... (5)

and: $Y = R(Y/R)$ ..... (6)

and estimates of total yield over a range of F may also be calculated.

These estimates are shown in Figure 8.5.a-c.

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Table 2.1 Nominal catch (tonnes) of mackerel in the North Sea, Skagerak and Kattegat (IV and IIIa) 1969-1979. (Data for 1969-1977 as officially reported to ICES)

Country	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979[1]
Belgium	139	19	85	129	78	145	134	292	49	10	-
Denmark	10 851	26 753	17 590	2 023	7 459	3 890	9 836	27 988	21 833	18 068	19 171
Faroe Islands[3]	3 080	2 134	3 603	7 551	11 202	18 625	23 424	63 476	42 836	34 194	28 124
France	11 353	4 677	9 061	6 882	636	2 254	2 749	2 607	2 529	3 452	3 120
Germany, Dem.Rep.	399	51	166	346	214	234	141	259	41	233	-
Germany, Fed.Rep.[4]	1 161	225	407	374	563	270	276	284	-	284	335
Iceland	612	1 492	649	687	3 079	4 689	198	302	-	-	-
Netherlands	4 928	2 956	4 945	4 436	2 339	3 259	2 390	2 163	2 673	1 065	1 009
Norway[2]	683 045	278 631	200 635	160 141	298 877	255 132	241 533	207 867	182 200	86 826	96 190
Poland	12	205	130	244	561	4 520	2 313	2 020	298	-	-
Sweden	10 820	4 407	3 163	4 748	2 960	3 579	4 789	6 448	4 012	4 501	3 935
UK (England & Wales)	35	35	23	32	31	61	33	89	105	142	95
UK (Scotland)	231	148	616	395	2 943	390	578	1 199	1 590	3 704	5 272
USSR	12 516	718	2 600	611	17 150	8 161	9 330	1 231	2 765	488	162
Unallocated											500
Total	739 182	322 451	243 673	188 599	348 092	305 209	297 724	316 225	260 931	152 967	158 480

1) Preliminary

2) includes catches from Div. IIa (1973 - 21 573 tonnes, 1974 - 6 818 tonnes, 1975 - 34 662 tonnes, 1976 - 10 516 tonnes, 1977 - 1 400 tonnes, 1978 - 3 867 tonnes, 1979 - 5 470 tonnes)

3) includes catches from Div. IIa (1978 - 283 tonnes, 1979 - 6 tonnes)

4) includes 174 tonnes in Div. IIa in 1979

Table 2.2 Landings (tonnes) of mackerel by Division in the Norwegian Sea, Skagerrak and Kattegat, and the North Sea.

Year	Division				
	IIa	IIIa	IVa	IVb	IVc
1969	7	24 917	700 816	11 529	1 521
1970	200	32 410	257 328	26 674	5 988
1971	358	15 462	199 280	17 217	11 548
1972	88	5 961	174 387	5 596	2 309
1973	21 573	8 220	297 459	19 433	1 407
1974	6 829	6 218	275 499	12 163	4 511
1975	35 272	10 994	231 536	16 691	3 841
1976	10 526	8 880	271 833	21 641	3 355
1977	1 400	7 018	229 100	27 100	5 300
1978	4 056	9 623	110 542	30 451	1 720
1979*	5 650	6 612	101 705	42 182	1 838

*) Preliminary

Note:

Denmark	IVb	includes	IVa	1968-73 and in 1978
German Dem. Rep.	IVb	"	IIIa	1968-72
Norway	IVa	"	IVb	1968-72
Sweden	IVa	"	IVb and IIIa	1968-74
Sweden	IVb	"	IVa,c	1975
Sweden	IVa	"	IVb	1976-77
USSR	IVa	"	IVb,c	1968-73 and 1978
Sweden	IIIa	"	IVa,b	1978
Denmark	IVb	"	IVa,c	1978,79

Table 2.3 Landings of mackerel (tonnes) by quarters, 1979.

Fishing area	Quarters					Total
	I	II	III	IV	Not known	
IV and IIIa	21	5 506	140 250	7 525		153 302
VI	26 358	11 891	60 020	105 032	-	203 301
VII	184 543	17 398	20 175	156 555	92	378 763
VIII	403	1 600	1 084	593	20 000	23 680

Table 2.4 Nominal catch (tonnes of mackerel in the Western area (VI, VII, and VIII) (Data for 1969-77 as officially reported to ICES).

Country	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979*
Belgium	11	8	2	1	3	7	17	10	1	1	-
Denmark	-	-	-	-	-	-	-	3	698	8 677	8 535
Faroe Islands	-	-	-	-	635	8 659	1 760	5 539	3 978	15 076	10 609
France	31 356	42 899	33 141	35 354	41 664	37 824	25 818	33 556	35 702	34 860	31 510
German Dem.Rep.	9	130	93	214	1 733	2 885	9 693	4 509	431	-	-
Germany, Fed.Rep.	428	783	258	98	559	993	1 941	391	446	28 873	21 493
Iceland	-	90	86	74	52	-	21	10	-	-	-
Ireland	1 615	1 055	3 107	4 592	8 314	8 526	11 567	14 395	23 022	27 508	24 2[illegible]
Netherlands	4 441	3 828	3 837	6 166	7 785	7 315	13 263	15 007	35 766	50 815	62 39[illegible]
Norway	-	-	1 611	-	34 600	32 597	1 907	4 252	362	1 900	25 414
Poland	2 149	6 054	10 832	13 219	10 536	22 405	21 573	21 375	2 240	-	92
Spain	21 571	31 368	37 506	31 416	25 677	30 177	23 408	18 480	21 853	19 142	20 000**)
Sweden	-	-	-	-	-	-	-	38	-	-	-
UK (England & Wales)	2 692	3 374	4 791	6 923	13 081	21 132	31 546	57 311	132 320	213 344	244 293
UK (N.Ireland)	279	243	315	57	93	75	30	95	97	46	25
UK (Scotland)	402	807	805	1 412	5 170	8 466	16 174	28 399	52 662	103 671	103 160
USSR	6 147	13 555	36 390	71 249	65 202	103 435	309 666	262 384	16 396	-	-
Unallocated											54 000
Total, ICES memb.	71 100	104 194	132 774	170 775	215 104	284 496	468 384	465 754	325 974	503 913	605 744
Bulgaria	-	-	-	-	4 341	13 558	20 830	28 195	-	-	-
Rumania	-	-	-	-	-	-	2 166	13 222	-	-	-
Total	71 100	104 194	132 774	170 775	219 445	298 054	491 380	507 178	325 974	503 913	605 744

*) Preliminary

**) Working Group estimate

Table 2.5 Landings of mackerel (tonnes) by Sub-areas in the Western area.

Year	Sub-area	
	VI	VII + VIII
1969	4 760	66 340
1970	3 854	100 340
1971	10 213	122 561
1972	13 013	157 762
1973	52 166	167 279
1974	64 136	234 081
1975	64 849	416 538
1976	67 765	439 413
1977	74 829	259 111
1978	151 747	355 487
1979*)	203 301	402 443

*) Preliminary

Table 3.1 Number of recoveries (of mackerel tagged in the North Sea) in Norwegian catches from the North Sea. Catch expressed as numbers x 10^{-6} effectively screened for tags (P_j)

RELEASE			RECAPTURES								
Year class	Year	No.	1971	1972	1973	1974	1975	1976	1977	1978	1979
Pre-1969	1969	4 187	56	9	24	17	7	6	3	0	0
	1970	2 420	40	25	48	28	16	12	7	3	1
	1971	2 450		57	87	71	42	24	21	2	1
	1972	2 126			113	88	49	33	35	7	0
	1973	1 518				98	70	37	32	7	1
	1974	1 344					51	23	34	4	0
	1975	1 048						20	40	5	0
	1976	304							13	3	1
	1977	1 363								9	4
	1978	1 490									3
	P_j		179.1	92.5	267.5	145.4	116.5	53.8	33.6	8.5	2.7
1969	1970	1 085		14	30	25	19	7	12	0	0
	1971	6 900		145	340	234	153	85	74	17	4
	1972	9 447			509	475	313	163	164	26	1
	1973	4 642				305	238	92	101	17	3
	1974	2 740					139	58	82	12	1
	1975	4 716						123	152	19	5
	1976	996							36	8	3
	1977	2 361								16	7
	1978	2 587									5
	P_j			70.1	172.2	187.5	115.9	93.2	64.4	14.7	4.9
1970	1971	0			0	0	0	0	0	0	0
	1972	245			10	14	7	2	4	0	1
	1973	702				43	34	14	13	2	1
	1974	185					9	6	5	1	0
	1975	423						11	13	2	1
	1976	70							2	1	0
	1977	217								1	0
	1978	255									1
	P_j				12.5	37.0	25.4	9.2	18.9	1.5	0.6
1971	1972	0				0	0	0	0	0	0
	1973	415				18	16	5	7	2	0
	1974	104					3	1	2	0	0
	1975	725						16	22	3	1
	1976	88							2	0	0
	1977	217								1	0
	1978	472									1
	P_j					21.2	29.6	39.4	27.8	6.6	4.0
1972	1973	0					0	0	0	0	0
	1974	82					4	1	1	0	0
	1975	625						14	16	3	1
	1976	105							4	1	0
	1977	414								2	2
	1978	248									0
	P_j						7.9	7.5	4.1	1.3	1.3

... cont'd

Table 3.1 (continued)

RELEASE			RECAPTURES								
Year class	Year	No.	1971	1972	1973	1974	1975	1976	1977	1978	1979
1973	1974	37						0	0	0	0
	1975	846						17	21	4	1
	1976	53							1	0	0
	1977	749								3	2
	1978	1 989									3
	P_j							13.9	18.1	7.9	3.6
1974	1975	1 612							36	9	2
	1976	146							3	1	0
	1977	1 537								8	4
	1978										5
	P_j								18.2	7.3	4.5
1975	1976	0								0	0
	1977	236								1	0
	1978	1 894									1
	P_j									4.1	1.8
1976	1977	0									0
	1978	138									0
	P_j										0.3
1977	1978	19									0
	P_j										0.02

Table 3.2 Numbers of recoveries (of mackerel tagged southwest of Ireland) in Norwegian catches from the North Sea. Catch expressed as number x 10^{-6} effectively screened for tags (P_j).

RELEASE			RECAPTURES						
Year class	Year	No.	1973	1974	1975	1976	1977	1978	1979
Pre-1969	1973	3 979	21	35	23	13	8	3	2
	1974	6 990		90	110	34	30	7	3
	1975	6 938			82	47	27	4	4
	1976	5 652				27	21	6	1
	1977	7 342					25	8	6
	1978	5 766						7	8
	P_j		267.5	145.4	116.5	53.8	33.6	8.5	2.7
1969	1973	3 232	5	16	16	11	6	3	1
	1974	2 246		25	39	16	14	2	1
	1975	528			6	5	3	0	0
	1976	861				5	3	1	0
	1977	1 117					4	1	1
	1978	875						1	1
	P_j		172.2	187.5	115.9	93.2	64.4	14.7	4.9
1970	1973	580	0	3	3	3	1	0	0
	1974	341		3	4	2	2	0	0
	1975	1 030			8	10	3	1	1
	1976	700				4	2	0	0
	1977	924					3	1	1
	1978	713						1	1
	P_j		12.5	37.0	25.4	9.2	18.9	1.5	.6
1971	1973	414	0	3	3	1	0	0	0
	1974	451		4	4	5	3	0	1
	1975	1 206			9	11	4	1	3
	1976	1 776				14	7	0	0
	1977	2 773					11	3	4
	1978	2 932						2	5
	P_j			21.2	29.6	39.4	27.8	6.6	4.0
1972	1973	0	0	0	0	0	0	0	0
	1974	0		0	0	0	0	0	0
	1975	226			1	2	0	0	1
	1976	135				1	0	0	0
	1977	168					1	0	0
	1978	673						1	1
	P_j				7.9	7.5	4.1	1.3	1.3

...cont'd.

Table 3.2 (continued)

RELEASE			RECAPTURES						
Year class	Year	No.	1973	1974	1975	1976	1977	1978	1979
1973	1974	0		0	0	0	0	0	0
	1975	75			0	1	0	0	0
	1976	296				2	1	0	0
	1977	1 232					4	1	3
	1978	3 269						6	4
	P_j					13.9	18.1	7.9	3.6
1974	1975	0			0	0	0	0	0
	1976	54				0	0	0	0
	1977	476					1	2	1
	1978	2 211						4	2
	P_j						18.2	7.3	4.5
1975	1976	0				0	0	0	0
	1977	0					0	0	0
	1978	1 634						2	1
	P_j							4.1	1.8
1976	1977	0					0	0	0
	1978	96						0	0
	P_j								.3
1977	1978	0						0	0
	P_j								.02

Table 5.1 Catch in numbers ($\times 10^{-6}$) for North Sea and Skagerrak in 1979

Year class	IVa + IIIa	IVb, c	Total IV + IIIa
Pre-1969	30.6	9.9	40.5
1969	53.5	4.9	58.4
1970	3.5	0.6	4.1
1971	28.6	5.8	34.4
1972	11.4	1.8	13.2
1973	26.9	7.6	34.5
1974	38.2	10.0	48.2
1975	18.4	9.4	27.8
1976	5.3	6.0	11.3
1977	0.4	0.1	0.5
1978	-	2.3	2.3

Table 5.2 Catch in number (x 10^{-6}) of the Western mackerel stock by year classes.

Year class	1977				1978				1979[1]			
	VI	VIIa,b,c	VIId-k+VIII	IVa	VI	VIIa,b,c	VIId-k+VIII	IVa	VI	VIIa,b,c	VIId-k+VIII	IVa
Pre-1969	47.7	2.2	76.3	32.3	92.4	1.7	78.7	20.7				
1969	11.7	0.3	40.9	36.5	22.0	0.4	24.9	31.2	94.2[2]	0.5[2]	109.9[2]	59.1[2]
1970	12.7	0.5	36.3	14.9	20.8	0.8	23.8	6.8	38.0	0.1	30.2	2.1
1971	23.5	0.6	72.0	43.9	34.6	0.6	82.7	22.2	53.7	0.2	75.1	25.2
1972	7.3	0.4	37.9	5.4	17.2	1.2	42.7	4.7	36.3	0.2	41.3	9.0
1973	27.1	0.9	135.8	2.2	45.3	1.4	166.2	24.1	70.5	0.2	142.2	20.2
1974	22.4	0.3	131.3	-	43.2	1.6	163.8	14.2	68.7	0.3	133.3	14.9
1975	12.5	0.2	276.8	-	31.6	0.9	353.9	-	50.4	0.4	308.1	6.6
1976	1.4	+	152.1	-	2.2	-	510.3	-	19.4	0.3	582.7	-
1977	-	-	2.0	-	0.02	-	28.4	-	0.9	0.04	60.7	-
1978	-	-	-	-	-	-	9.4	-	1.5	0.02	349.6	-
1979	-	-	-	-	-	-	-	-	-	-	79.5	-

1) Including correction for discards (see section 2.3)
2) Pre-1970 year classes combined

Table 5.3 Mean Weight at Age by quarters calculated from 1979 data

	AGE - YEARS										
Sub-area IV	0	1	2	3	4	5	6	7	8	9	≥ 10
JAN-MAR	-	-	-	-	-	-	-	-	-	-	-
APR-JUN	-	-	318	306	332	261	355	417	405	510	567
JUL-SEP	-	-	384	323	401	480	459	486	533	536	651
OCT-DEC	-	201	303	273	411	479	434	495	441	516	603
$\bar{w}$		201	378	317	400	479	458	486	532	535	651
Sub-area VI											
JAN-MAR	-	-	280	317	384	429	411	476	423	501	556
APR-JUN	-	-	225	295	326	338	376	360	410	451	481
JUL-SEP	-	225	306	261	399	445	476	553	503	588	614
OCT-DEC	-	187	264	303	343	379	404	447	475	529	613
$\bar{w}$		193	269	285	367	410	425	454	464	539	580
Sub-area VII											
JAN-MAR	-	51	123	179	244	291	307	339	350	440	443
APR-JUN	-	86	134	160	213	250	275	324	321	396	434
JUL-SEP	62	135	220	228	256	300	315	357	335	443	395
OCT-DEC	67	147	221	249	322	380	388	439	424	466	528
$\bar{w}$	67	144	173	199	266	316	325	367	366	444	456
Sub-area VIII											
JAN-MAR	-	-	-	-	-	-	-	-	-	-	-
APR-JUN	-	79	161	189	208	285	301	292	362	393	423
JUL-SEP	42	123	148	239	291	353	308	316	402	468	715
OCT-DEC	-	-	-	-	-	-	-	-	-	-	-
$\bar{w}$	42	101	158	195	218	292	303	293	379	414	435

$\bar{w}$ is the annual mean weight weighted by numbers landed per quarter

Table 5.4 Mean weights at age used in the Western stock assessment (in g).

	AGE - YEARS									
	0	1	2	3	4	5	6	7	8	≥ 9
Annual Mean Weight in Spawning Stock	-	-	-	201	251	264	316	380	412	511
Annual Mean Weight in Catches		137	158	241	314	334	398	410	503	511

Table 5.5 The Western Mackerel Stock. Catch in number with fishing mortality rates and stock sizes derived from cohort analysis (M = 0.15)

	Age \ Year	1972	1973	1974	1975	1976	1977	1978	1979	1980
Catch in No. x 10^{-6}	0	1.6	0.0	1.3	1.0	34.2	2.0	10.3	79.5	
	1	12.4	33.8	87.0	52.5	279.4	153.5	31.3	351.1	
	2	12.1	49.4	24.3	104.0	184.9	289.5	563.8	61.6	
	3	29.4	64.0	123.5	94.5	322.3	154.0	425.0	602.5	
	4	507.7	115.5	108.5	306.3	170.6	166.0	243.7	365.5	
	5	↑	582.3	191.8	192.2	288.8	51.0	258.3	217.2	
	6		↑	567.0	143.8	118.6	140.0	71.9	233.1	
	7			↑	1 246.2	279.7	64.4	151.9	86.8	
	8				↑	438.8	89.4	56.7	154.2	
	9					↑	158.5	83.2	70.5	
	≥10	↓	↓	↓	↓	↓	↕	210.8	263.7	
	Total	563.2	845.0	1 103.4	2 140.5	2 117.3	1 268.3	2 106.9	2 485.7	
F	0	0.001	0.000	0.000	0.000	0.007	0.005	0.002	(0.01)	
	1	0.003	0.021	0.024	0.020	0.077	0.035	0.093	(0.10)	
	2	0.006	0.015	0.017	0.035	0.087	0.101	0.164	(0.25)	
	3	0.011	0.039	0.045	0.083	0.137	0.092	0.200	(0.25)	
	4	0.064	0.052	0.083	0.140	0.200	0.092	0.194	(0.25)	
	5	↑	0.093	0.109	0.195	0.180	0.080	0.192	(0.25)	
	6		↑	0.116	0.106	0.167	0.118	0.147	(0.25)	
	7			↑	0.377	0.289	0.122	0.172	(0.25)	
	8				↑	0.208	0.133	0.143	(0.25)	
	9					↑	0.102	0.168	(0.25)	
	≥10	↓	↓	↓	↓	↓	↕	(0.182)	(0.25)	
	Mean ≥3	0.051	0.076	0.093	0.228	0.189	0.102	0.184	(0.25)*	
Stock in No. at 1 January (x 10^{-6})	0	2 082.7	4 498.6	3 303.9	4 718.6	5 632.5	444.8	4 621.4	(6 603.0)	
	1	4 195.1	1.791.1	3 872.0	2 842.5	4 060.4	4 816.2	381.0	3 968.1	(7 331.0)
	2	2 080.9	3 599.3	1 510.3	3 252.0	2 397.9	3 236.2	4 003.2	299.0	3 090.4
	3	2 873.0	1 779.8	3 052.1	1 277.4	2 702.7	1 892.7	2 517.4	2 924.0	200.4
	4	8 759.0	2 445.5	1 472.6	2 512.6	1 012.0	2 028.0	1 486.5	1 773.8	1 960.0
	5	↑	7 068.8	1 997.9	1 167.0	1 879.2	713.3	1 591.9	1 054.1	1 189.0
	6		↑	5 545.1	1 542.1	826.8	1 350.4	566.7	1 131.3	706.6
	7			↑	4 248.1	1 194.2	601.9	1 032.7	421.3	758.3
	8				↑	2 506.7	769.5	458.5	748.4	282.4
	9					↑	1 751.8	573.6	342.2	501.7
	≥10	↓	↓	↓	↓	↓	↕	1 361.1	421.9	512.2
	Total ≥3	11 632	11 294.1	12 067.7	10 747.2	10 121.6	9 107.6	9 594.4	8 817.0	6 110.6
	Biomass (t x 10^{-3}) ≥3	3 907	3 870	3 950	3 679	3 237	2 944	3 030	2 509	1 963

* Input F values and inefficient estimates in parentheses.

Table 6.1 North Sea Stock. Estimates of yield per recruit and spawning stock biomass per recruit over a range of values for F.

Age	1	2	3	4	5	6	7	≥ 7
Fract. Exploitation	0.33	0.67	1	1	1	1	1	1
Weight at age (g) (catch and stock)	245	329	363	392	438	455	520	580
Fract. Mature	0	0	1	1	1	1	1	1

M = 0.15

F	YPR	BPR
0	0	2 642
0.05	96.5	1 859
0.10	147.9	1 401
0.15	178.3	1 106
0.20	197.5	901
0.25	210.3	752
0.30	219.2	639
0.35	225.6	551
0.40	230.4	481
0.45	234.0	423
0.50	236.8	376

Table 6.2 Western Mackerel Stock. Estimates of yield per recruit and spawning biomass per recruit over a range of values for F, and estimates of total yield and biomass assuming a stock and recruitment relationship.

F	YPR (g/rec.)	BPR (g/rec.)	Assuming Stock-Rect. Rel.			Average Rect.	
			B (k tonne)	R_1 (million)	Y (k tonnes)	B (million)	Y (k tonnes)
0.00	0.00	2 005	10 700	5 320	0.00	6 496	0.00
0.05	76.1	1 331	5 350	4 020	306	4 326	247
0.10	112.7	952	2 380	2 500	281	3 094	366
0.15	131.4	716	512	723	95	2 327	427
0.20	141.3	558	-	-	-	1 814	459
0.25	146.4	447	-	-	-	1 453	476
0.30	148.9	366	-	-	-		
0.35	149.8	304	Critical BPR = 650 g/rec.				
0.40	149.8	257	Typical Biomass = 3.6×10^6 tonnes				
			Typical Rect.^{t} = 3.25×10^6 fish				
			Degree of compensation = 1.01				

Table 7.1 Prognoses for the Western stock. - Scenario A: TAC taken in 1980

Age	Stock Jan. 80	F 1980	Catch 1980	Stock Jan. 81	F 1981	Catch 1981	Stock Jan. 82	F 1981	Catch 1981	Stock Jan. 82
1	(3 240)	0.054	158.3	(1 100)	0.04	40.1	?	0.06	59.5	?
2	3 090.4	0.135	363.0	2 642.1	0.10	233.8	909.7	0.15	342.4	891.6
3	200.4	0.135	23.5	2 324.0	0.10	205.6	2 057.7	0.15	301.2	1 957.3
4	1 960.0	0.135	230.2	150.7	0.10	13.3	1 810.0	0.15	19.5	1 721.7
5	1 189.0	0.135	139.7	1 473.9	0.10	130.4	117.4	0.15	191.0	111.6
6	706.6	0.135	83.0	894.1	0.10	79.1	1 147.9	0.15	115.9	1 091.9
7	798.3	0.135	89.1	531.4	0.10	47.0	696.4	0.15	68.9	662.4
8	282.4	0.135	33.2	570.3	0.10	50.5	413.8	0.15	73.9	393.7
≥ 9	1 013.9	0.135	119.1	974.8	0.10	86.3	1 203.3	0.15	126.3	1 144.6
Catch weight (10^3 tonnes)			351			260			381	
Biomass $(10^3$ tonnes$)^{\geq 3}$	1 991			2 111			2 310			2 198

Table 7.2 Prognoses for the Western stock. - Scenario B: 1980 Catch = 550 000 tonnes

Age	Stock Jan. 80	F 1980	Catch 1980	Stock Jan. 81	F 1981	Catch 1981	Stock Jan. 82	F 1981	Catch 1981	Stock Jan. 82
1	(3 240)	0.09	253.7	(1 100)	0.04	40.1	?	0.06	59.5	?
2	3 090.4	0.22	568.3	2 553.8	0.10	226.0	909.7	0.15	330.9	891.6
3	200.4	0.22	36.9	2 134.6	0.10	188.9	1 988.9	0.15	276.6	1 891.9
4	1 960.0	0.22	360.4	138.4	0.10	12.2	1 662.5	0.15	17.9	1 581.4
5	1 189.0	0.22	218.6	1 353.8	0.10	119.8	107.8	0.15	175.4	102.5
6	706.6	0.22	129.9	821.3	0.10	72.7	1 054.4	0.15	106.4	1 002.9
7	758.3	0.22	139.4	488.1	0.10	43.2	639.6	0.15	63.2	608.4
8	282.4	0.22	51.9	523.8	0.10	46.3	380.1	0.15	67.9	361.6
≥ 9	1 013.9	0.22	186.4	895.4	0.10	79.2	1 105.3	0.15	116.0	1 051.4
Catch weight (10^3 tonnes)			550			241			353	
Biomass ≥3 (10^3 tonnes)	1 991			1 939			2 142			2 038

Table 8.1 The winter fishery off Cornwall: Percentage of fish less than 30 cm in the catches in rectangles shown in Figure 8.1.

Date of sampling	Rectangles				
	A	B_1	B_2	B_3	C
	NL Trawl	UK Purse seine	UK Trawl	NL Trawl	NL Trawl
OCT 76	-	57.3	64.5	-	-
NOV 76	-	57.9	46.0	-	-
DEC 76	-	48.0	39.9	-	-
JAN 77	-	31.8	27.4	-	-
FEB 77	-	25.5	17.7	-	-
MAR 77	97	x	69.8	57	47
APR 777	-	x	60.8	44	-
OCT 77	69	40.4	12.6	-	-
NOV 77	84	58.9	55.4	60	-
DEC 77	48	60.0	39.6	98	(99)
JAN 78	-	29.3	37.8	-	-
FEB 78	-	57.3	61.1	55	-
MAR 78	-	43.9	x	19	-
APR 78	-	40.6	43.9	40	-
OCT 78	52	41.1	44.0	78	-
NOV 78	48	51.2	48.9	52	-
DEC 78	29	28.6	23.8	10	-
JAN 79	-	32.5	31.1	-	16
FEB 79	-	43.5	26.1	46	-
MAR 79	65	58.3	41.1	34	55
APR 79	-	-	-	52	-
OCT 79	38	-	-	55	72
NOV 79	34	57.7	56.9	61	-
DEC 79	-	47.6	32.7	-	-
JAN 80	-	24	32	-	52[1]
FEB 80	-	38.5[2]	-	-	-

1) UK purse seine

2) Danish purse seine

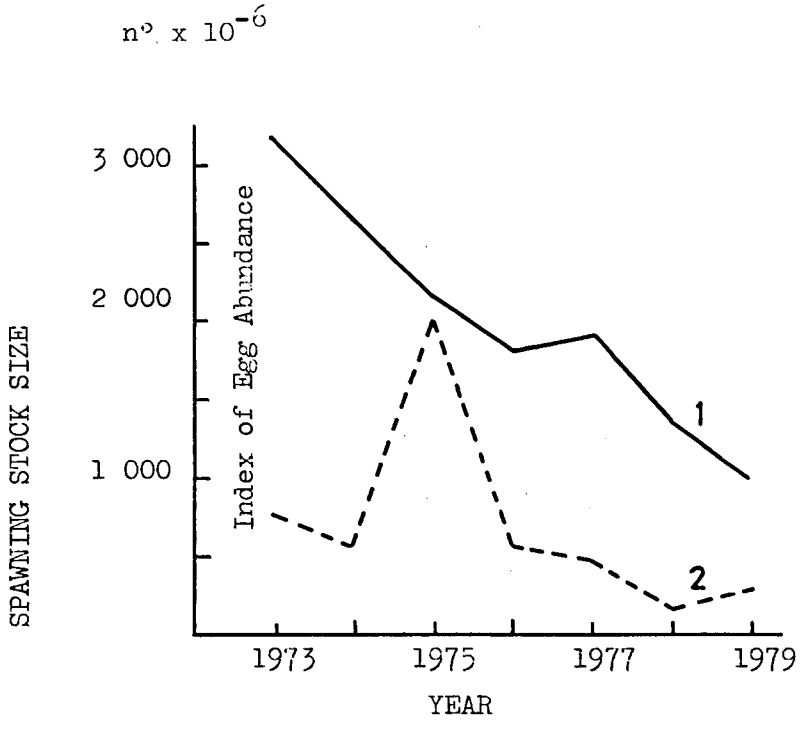


Figure 4.1 Recent trends in North Sea mackerel spawning stock size and egg abundance indices.

(1) Spawning stock size (Table 5.4, Mackerel Working Group report 1979a).

(2) Index of egg production in the North Sea (Iversen, pers.com).

Figure 5.1 Western Mackerel: Spawning stock biomass at 1 Jan. (age≥ 3 years) and resulting recruitment as year class size at age 1.

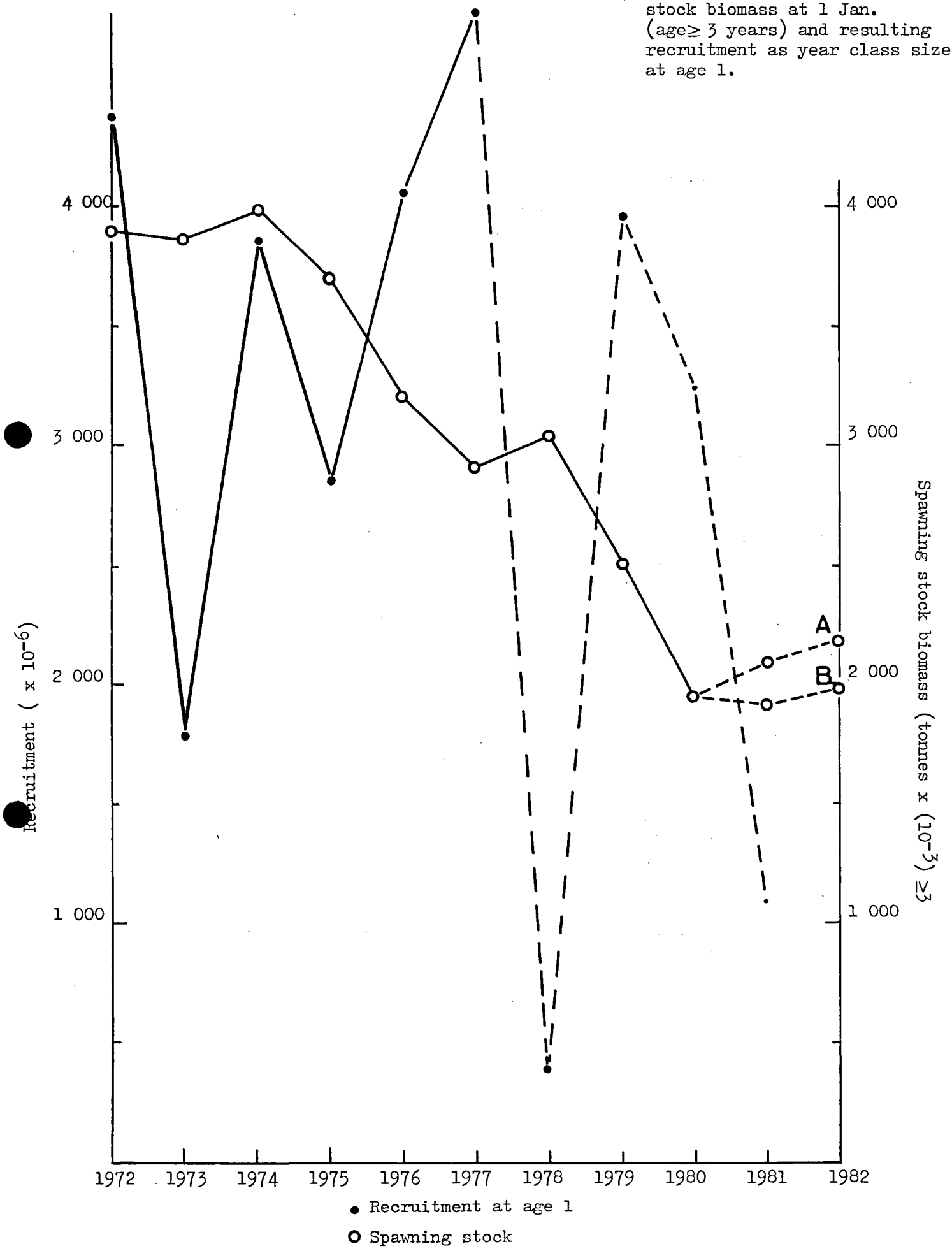


Figure 6.1 Western Mackerel Stock. Recruitment in relation to the stock.
Data from virtual population analysis (see Table 5.5).

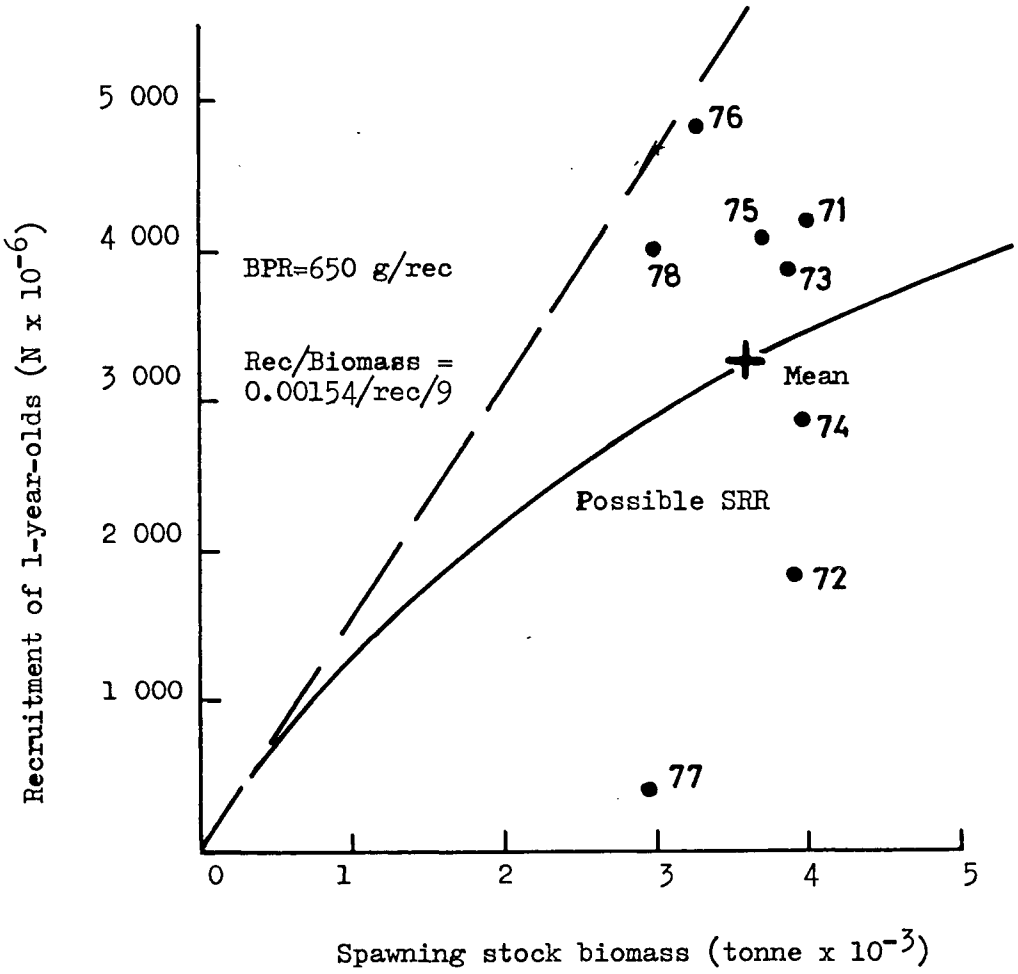


Figure 7.1 Prognoses for Western Mackerel Stock: Catch and Biomass

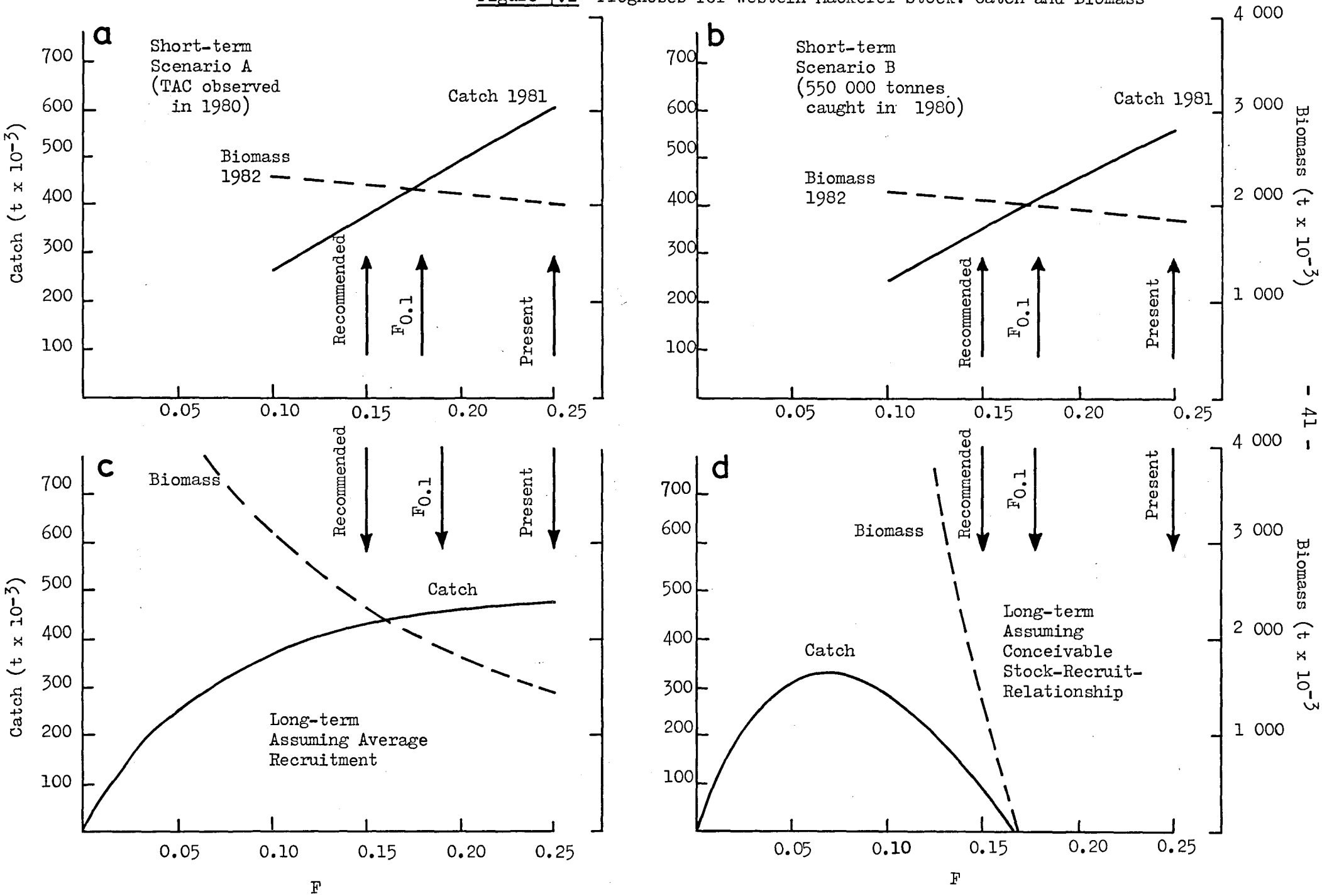


Figure 8.1 The areas of the winter fishery off Cornwall showing rectangles used in Table 8.1

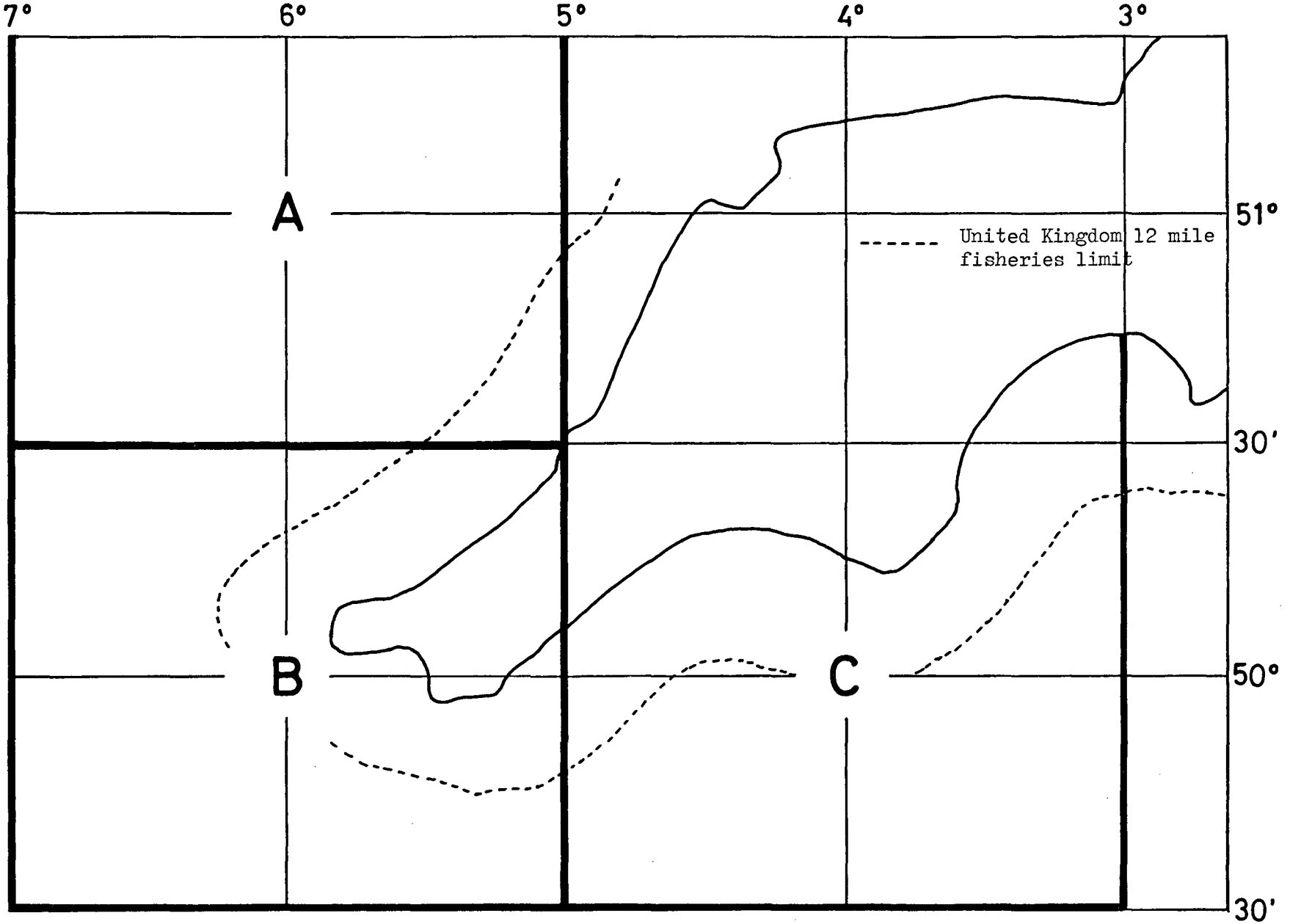
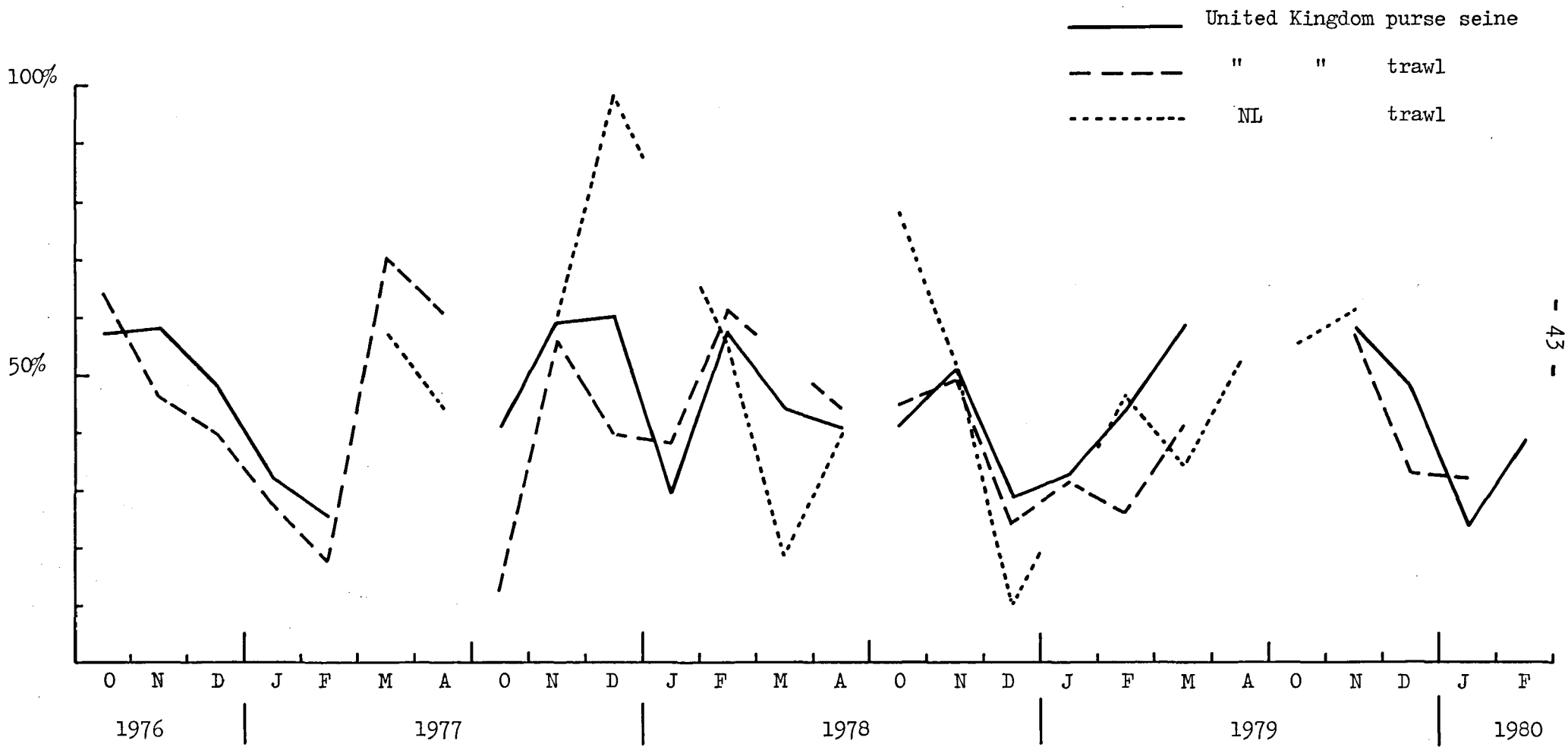


Figure 8.2 The winter fishery off Cornwall. Percentages of fish less than 30 cm in rectangle B.



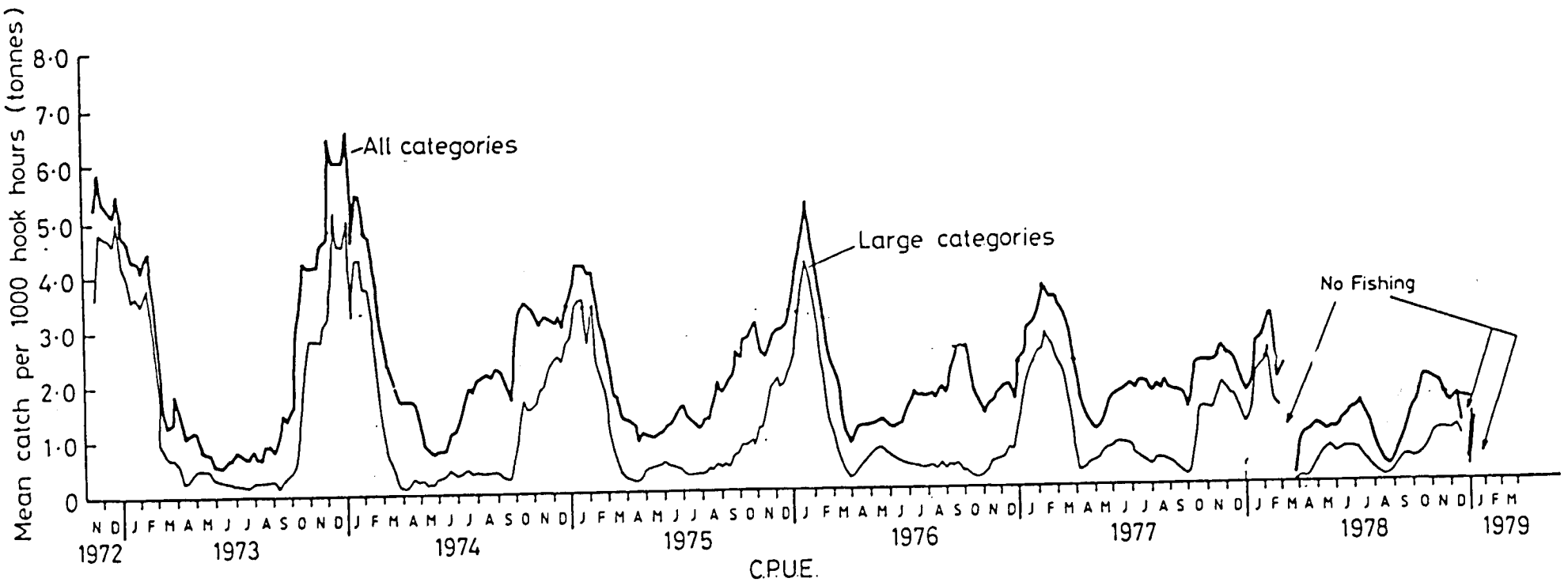


Figure 8.3. The south-west mackerel handline fishery: catch per effort (running five-week mean). (After Dawson 1979)

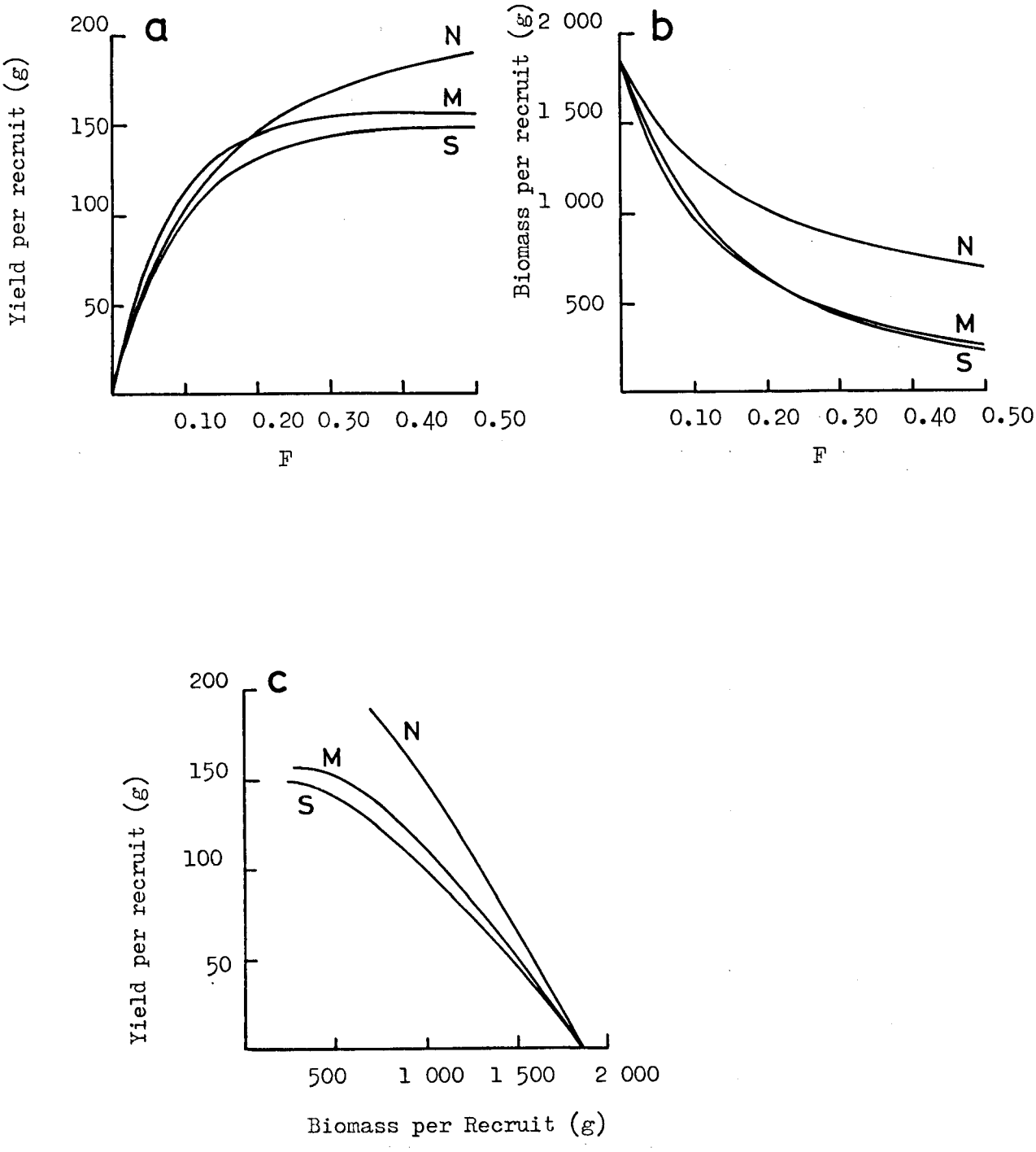


Figure 8.4. Yield per recruit and spawning biomass/recruit curves for the present mixed fishery (M), a Northern fishery (N) limited to VIa and VIIa-c and a southern fishery (S) limited to VIId-k and VIII

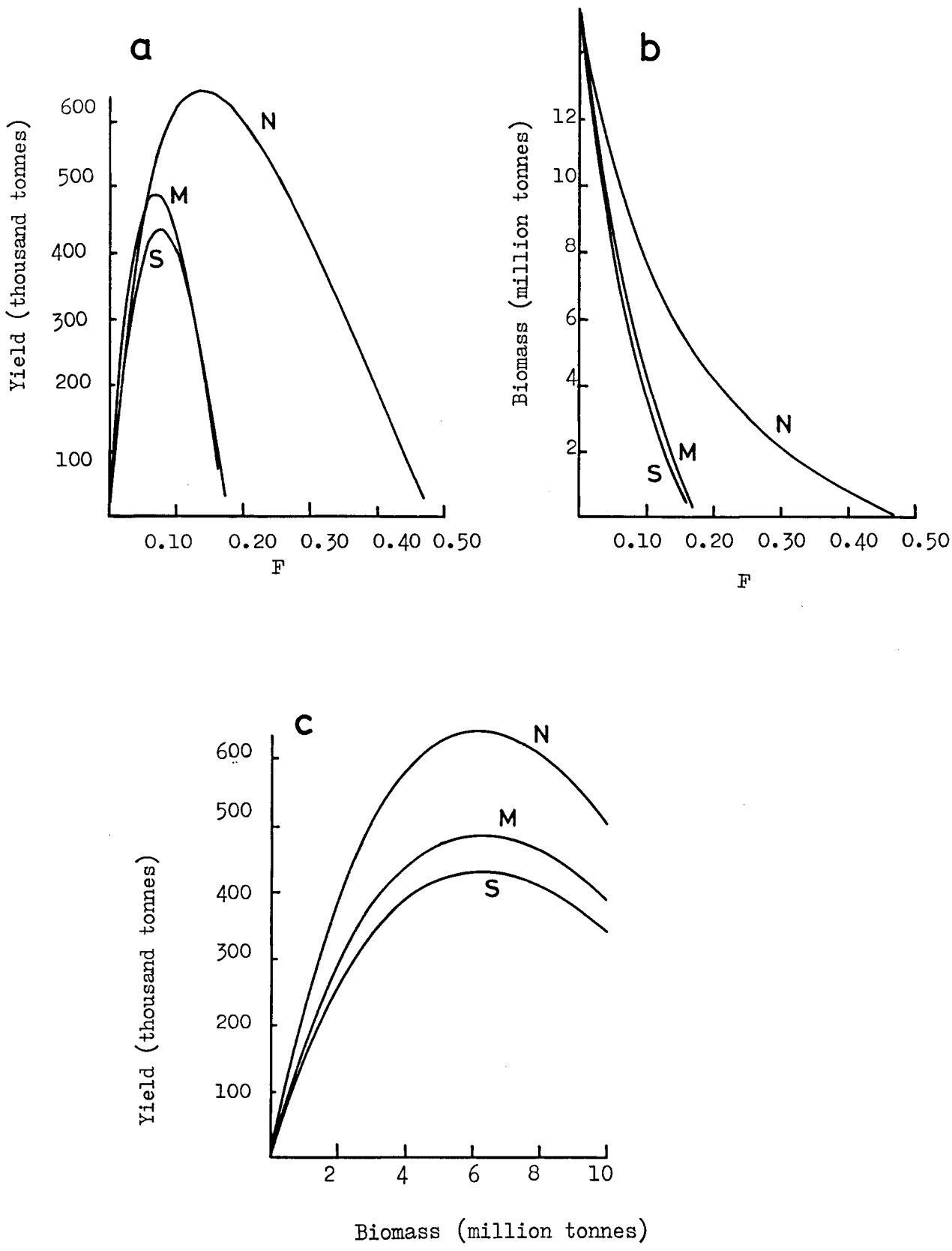


Figure 8.5. Total yield and total biomass for the present mixed (M) a northern fishery (N) limited to VIa and VIIa-c and a southern fishery (S) limited to VIId-k and VIII.