International Council for the
Exploration of the Sea

C.M.1979/H:5
Pelagic Fish Committee

REPORT OF THE MACKEREL WORKING GROUP

Charlottenlund, 23-27 April 1979

This Report has not yet been approved by the International Council for the Exploration of the Sea; it has therefore at present the status of an internal document and does not represent advice given on behalf of the Council. The proviso that it shall not be cited without the consent of the Council should be strictly observed.

x) General Secretary,
ICES, Charlottenlund Slot,
2920 Charlottenlund,Denmark.

CONTENTS

-o-o-o-

1. INTRODUCTION

According to a Council resolution at the 66th Statutory Meeting of ICES (C.Res.1978/2:42), the Mackerel Working Group met at Charlottenlund 23-27 April 1979 to:

a) assess the mackerel stocks in Sub-areas III, IV, VI, VII and VIII;

b) re-examine the need for an appropriate level of minimum landing size in Sub-areas VI, VII and VIII.

Further, the Working Group was asked by the Chairman of the Advisory Committee on Fishery Management (ACFM) of ICES to act on a request by the Commission of the European Economic Community (EEC) to the ICES to:

c) consider whether, on the basis of available scientific data, there is any biological justifications to ban the catching of mackerel less than 30 cm in industrial fisheries according to areas. Should such a minimum fish size be considered for human consumption fisheries?

The Working Group met with the following participating members:

R S Bailey	U.K. (Scotland)
E Bakken(Chairman)	Norway
H B Becker	Netherlands
A Corten	Netherlands
H Gislason	Denmark
J C Guéguen	France
H S í Jakupsstovu	Faroes
S J Lockwood	U.K. (England)
J Molloy	Ireland
Ø Ulltang	Norway

V Nikolaev attended the meeting as ICES Statistician.

Recoveries in Sub-area VII of mackerel tagged in the North Sea and recoveries in Division IVb from tagging southwest of Ireland indicate intermingling between the two stocks to a greater extent than previously assumed. It also raises the possibility of stock exchange. At present, estimates of the exchange cannot be made, mainly because it is uncertain what part of the western stock the tagged population represents. It is also possible that western stock mackerel are being tagged in the North Sea.

The Working Group decided to assess the two mackerel stocks as in previous assessments. Hence, the stocks are dealt with separately, and the total removal from each stock is calculated from catch and stock proportion by tag data for the northern North Sea and the northern part of Division VIa.

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 1968-78 are shown in Table 2.1. The figures for 1978 are provisional, while the 1977 figures were checked and revised where necessary. This revision, caused mainly by a change in the reported Dutch figures, has reduced the total 1977 catch from 269 000 tonnes to 261 000 tonnes. The provisional catch for 1978 is 154 000 tonnes, a reduction from 1977 of 107 000 tonnes, due mainly to restricted catches by Norway and Faroes. Their combined total fell by 47% from 225 000 tonnes in 1977 to 119 600 tonnes in 1978.

The ACFM recommended a TAC for 1978 of 145 000 tonnes, of which 100 000 tonnes should be western stock fish. To increase the probability of capture of western stock fish, ACFM also recommended that the TAC should be taken north of 60°N and west of 2°E. Despite this recommendation the distribution of the catch by area in 1978 was very similar to the distribution observed in previous years (Table 2.2). Detailed catch distribution data from Faroes, Norway and Scotland indicate that only 34 000 tonnes were taken in the area recommended by ACFM.

The seasonal distribution of the catches in 1978 from the North Sea, Skagerrak and Kattegat is given in Table 2.3. Again the distribution is very similar to that in recent years, 86% 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 1968-78 are shown in Table 2.4. Some revisions, made in the 1977 figures, have increased the catches for that year from 315 000 tonnes to 326 000 tonnes. The recommended TAC for 1978 for the western area was 450 000 tonnes, but the total catch was over 507 000 tonnes, an increase of over 35% on the 1977 figure. This increase was mainly due to the catches by Denmark, Faroes, Federal Republic of Germany, Ireland, Netherlands, and the United Kingdom. While the United Kingdom now takes over 62% of the total catch from this area, the biggest relative increase in catch during 1978 was recorded by the Federal Republic of Germany. Their catch increased from 446 tonnes in 1977 to 28 762 tonnes in 1978. The catch by USSR decreased from 16 000 tonnes in 1977 to zero in 1978.

The distribution of the catch from 1968 to 1978 by Sub-area is shown in Table 2.5. There was a big increase in the catches made in Sub-area VI, where the total recorded was more than double the 1977 catch. This increase has been caused mainly by the catches for the Danish, Faroese, Irish and Scottish fleets.

The seasonal distribution of the 1978 catches are shown in Table 2.3. There is a marked difference in the distribution between Sub-area VI and Sub-area VII. In Sub-area VI 97% of the total was taken in the third and fourth quarters, while in contrast the main fishery in Sub-area VII took place during the fourth and first quarter, 77% of the total catch.

2.3 Discarding

Last year's report (Anon., 1978) pointed out the possibility that an appreciable proportion of the catch may be discarded. If discards are not taken into account, they will introduce a bias in the mortality and stock size estimates. Although precise discard data are difficult to collect, nor are any available at present, the Group discussed the

reasons for discarding in an effort to estimate their importance. It was agreed that discarding is more widespread in those fisheries which are primarily human consumption fisheries as the larger fish in the population have a higher market value. There are also the problems of catches exceeding daily production capacity for freezer trawlers, daily or weekly quotas being exceeded in controlled fisheries and burst nets in both the human consumption and industrial fisheries.

Members of the Working Group estimated roughly the extent to which discarding occurs in the different national fisheries, and these were used to calculate a mean discarding figure for the international fisheries. It was agreed that it is not a significant problem in the North Sea area, but in the western area it is probably equal to 10% of the total international landings.

3. TAGGING RESULTS

3.1 Tag Returns

The number of tags returned by year class from the Norwegian industrial fishery in the North Sea are given in Table 3.1, together with corresponding catches in number calculated by applying corrections for magnet efficiencies.

A revision of the Norwegian tag data has resulted in amendments to the number recaptured and the corresponding catches for the years 1971-76 presented in last year's report (Anon., 1978). The higher number recaptured in 1977 presented here compared to last year's report is due to late reporting of tags from the plants.

3.2 Western Stock Catch in Division IVa

When estimating the North Sea stock component of the catch in Division IVa, the Working Group assumed that all 3 year old mackerel caught in Division IVa were from the North Sea stock.

For the older age groups, the proportion of the North Sea stock in the Division IVa catches was estimated by

$$P_{j+1} = p_j \cdot \frac{\Sigma r_{ij+1}}{P_{j+1}} \Big/ \frac{\Sigma r_{ij}}{P_j}$$

where P_j is the catch of the year class in year j effectively screened for tags, Σr_{ij} and Σr_{ij+1} the recoveries of fish of that year class in year j summed over all releases prior to year j, and p_j the proportion of the Division IVa catches belonging to the North Sea stock in year j. The estimated proportions are given in Table 3.2 for the years 1976-78.

This procedure is similar to that followed for last year's assessment.

3.3 Fishing Mortalities

Estimates of fishing mortality from tag returns were made by continuing the cohort analysis from last year's report on tag returns raised to the total international catch (Anon., 1978, Table 3.4). Raised tag returns for 1971-76 were taken from last year's report. For 1977 and 1978 the raising was done separately for Divisions IVa and IVb-c, by

assuming that tag densities in Norwegian catches were representative for Division IVa and that tag density in Divisions IVb-c for each release and year class is given by

$$\text{Tag density, IVb-c} = \text{Tag density, IVa}/p$$

where p is the estimated proportion of catch in Division IVa attributable to the North Sea stock (Table 3.2). The results are given in Table 3.3.

The 1978 Working Group concluded that F in 1977 was around 0.3. Starting with the estimated tagged population by 1 January 1977 (Anon., 1978, Table 3.4) and using the same natural mortality as arrived at in the 1978 analysis (0.122) and raised tag returns for 1977-78, fishing mortalities for the various releases in 1977 and 1978 were estimated. For the 1970-73 releases this procedure gave fairly consistent values of F in 1977 and 1978. (F_{78} = 0.21, 0.16, 0.18 and 0.21 for the 1970, 71, 72 and 73 release respectively.) For the more recent releases the fishing mortalities varied a little more. It was therefore decided to re-run the cohort analysis on tag returns by starting with a value of F = 0.19 (mean for 1970-73 releases) in 1978 for all releases. The results are shown in Table 3.4. The estimated tagging survivals for the various releases are indeed very consistent except for the 1973 release which seems to have had a higher tagging survival than the others.

It was concluded that this year's analysis more or less confirmed the estimates from last year and that F in 1978 was around 0.19. The new cohort analysis on tag returns gave a weighted mean F = 0.31 for 1977 compared to 0.30 assumed by the Working Group in 1978.

3.4 Tag Recoveries from Division VIa in Winter 1978-79

During the winter 1978-79 a fishery for mackerel took place in the northern part of Division VIa by Norwegian and Faroese vessels. The Norwegian fishery, mainly in January-February 1979, amounted to about 15 000 tonnes and the Faroese fishery, in November 1978 - February 1979, to about 21 000 tonnes.

In the text table below the number of North Sea and Celtic Sea tags per million fish effectively screened for tags for all year classes and for the 1969 and pre-1969 year classes is given for the summer/autumn fishery in Division IVa and the winter fishery in Division VIa, respectively:

	North Sea releases		Celtic Sea releases	
	All year classes	Pre-1969 and 1969	All year classes	Pre-1969 and 1969
Summer/autumn 1978, Div.IVa	3.85	6.68	0.92	1.68
Winter 1978-79, Div. VIa	9.77	15.35	4.93	8.80

These tag densities show clearly that a much higher proportion of both mackerel tagged in the North Sea and mackerel tagged in the Celtic Sea was present in the northern part of Division VIa in the winter as compared to that in Division IVa in summer/autumn.

If one estimates the proportion attributable to the North Sea stock by the method given in Section 3.2, one arrives at estimates of more than 100% of North Sea fish. If estimates are made from Celtic Sea tags, by the same method, this results in more than 100% western fish. This obvious contradiction reveals clearly that the migration pattern for mackerel is even more complicated than earlier assumed, and the Working Group recommends that a closer analysis of the tag returns is made in this respect.

The age distribution and growth pattern of the fish sampled from the winter fishery in Division VIa indicate, however, that the fishery was mainly based on mackerel from the North Sea stock.

In last year's report the Working Group recommended that in order to minimise catches of North Sea stock, the fishery should be allowed only north of 60°N and west of 2°E as the catches in this area would be predominantly from the western stock. The new evidence indicates a wintering area for the North Sea stock in Division VIa in addition to the Norwegian Deep, and the recommendation made last year is therefore only valid for the summer/autumn season.

4. EGG SURVEYS

4.1 1977 Egg Survey Results

Following the 1978 Working Group the egg survey data were re-analysed using the log transformation ln $(n > 0)$ as advised by Ulltang in a working paper, presented to the Working Group. This re-analysis increased the egg production estimated from 1.61×10^{15} to 1.98×10^{15} (+ 30%, -20%) eggs with a corresponding increase in the estimated number of mature fish from $9\,346 \times 10^{6}$ to $11\,500 \times 10^{6}$ (Lockwood et. al., 1978).

During 1978 a further 44 fecundity estimates were made with ovaries from fish 28-38 cm, but predominantly 30-35 cm, caught along the edge of the continental shelf in the Bay of Biscay and the Celtic Sea. These estimates were combined with the data previously used (Lockwood, 1978) and a new fecundity/length relationship calculated. This is:

$$\text{Fecundity} = 8.8\ (\text{total length})^{3.02}$$

By applying this relationship to the combined Dutch, English, French and Irish Sub-area VII and Sub-area VIII catch length-frequency distributions for the period January to June 1977, a mean fecundity of 361 000 was calculated for the western stock.

Using the revised egg production and fecundity estimates a new stock size was calculated:

$$\frac{1.98 \times 10^{15}}{361\,000} \times 1.64 = 8\,995 \times 10^{6} \text{ mature fish.}$$

This compares favourably with the stock estimate of $8\,973 \times 10^{6}$ mature fish used in the VPA (Anon., 1978).

4.2 Proposed 1980 Survey

Following a recommendation made by the Working Group in 1978 (Anon., 1978) that further egg surveys be made in the future, an informal meeting was held at Lowestoft in February 1979 to plan a plankton survey to estimate the western mackerel spawning stock size in 1980. It was attended by representatives from England, France, Ireland, Netherlands and Scotland.

The overall strategy, sampling techniques and results for the 1977 Anglo-French survey were discussed. It was decided to extend the sampling area further west, to sample down to 200 m and to use a smaller plankton sampler, Dutch Gulf III or Lowestoft 20" TTN. Apart from these few changes the survey should follow the same basic approach as in 1977 (Lockwood et al., 1977).

The English, French and Scottish laboratories intend to contribute a total of six 3-week research vessel cruises during the period March to July. The Irish laboratory may extend the duration of the sprat egg survey (January-May) off the southern coast of Ireland and the Dutch offered to amend their Celtic Sea sampling programme in any way that will increase and improve the data input to the final stock estimate.

If the results of the cruises are not ready early enough, there is no chance that they can be used to calculate a TAC for 1981. To avoid this, the participating countries should be urged to prepare the results for ACFM to consider at the Statutory Meeting in 1980. So, if needed, ACFM could be in a position to make amendments to the TAC recommended by the Working Group at its possible meeting in 1980.

5. CATCH IN NUMBERS, MORTALITIES AND STOCK SIZE

5.1 Catch in Numbers at Age

5.1.1 North Sea stock

Catches in weight in the North Sea in 1978 were converted to catch in numbers at age, using the sampling data below:

Division IVa:	Norwegian, Dutch, Scottish
Division IVb:	Dutch, Scottish
Division IVc:	Dutch, French.

Norwegian data were used to raise Swedish and Faroese purse-seine landings, while Dutch data were used to raise English, German Democratic Republic, Federal Republic of Germany and Danish landings and also French landings in Divisions IVa and IVb. Norwegian age determinations separated only the fish less than 8 years of age. To obtain estimates of individual year classes older than this and in particular the 1969 year class, the 1977 age composition was used to split up fish 8 years old and older. The numbers of mackerel caught in the northern North Sea, Division IVa, were allocated to stock using the proportions given in Table 3.2.

As discussed in Section 3.4, Faroese catches in the northern part of Division VIa in November and December 1978 consist partly of North Sea fish. The proportion of each stock in these catches cannot be estimated with any precision, and the Working Group allocated them in the same proportions as the catches in Division IVa (Table 3.2).

Owing to a misallocation of about 8 400 tonnes of Dutch catch to the North Sea in 1977 which had in fact been taken in Sub-area VII, a small adjustment was needed to the catch in number figures for that year. Since most of them had been allocated to Division IVb in the previous report, the catch in number in Division IVb and c, tabulated in Table 5.1 of that report (Anon., 1978) was reduced in direct proportion and the new values are given in Table 5.1.

In addition, revised values of the proportions of North Sea stock in Division IVa catches (Table 3.2) necessitated a revision of the numbers at age in Division IVa belonging to the two stocks in 1976 and 1977.

Catches in numbers at age from the North Sea stock for 1978 and revised catches for 1976 and 1977 are given for each area in Table 5.1.

To extend the cohort analysis back to earlier years to provide further estimates of the stock and recruitment, catch in numbers were calculated in the following way: fish belonging to year classes older than the 1969 year class in the years 1972-75, which were combined in the previous report, were allocated to their respective age groups using the North Sea age compositions in Table 4 of Hamre (1978). Age compositions of the North Sea stock in the years 1969-71 were obtained using the North Sea age compositions given by Hamre (1978), assuming that the catches in number in the Shetland area and other areas in the North Sea were distributed in the same proportions as the catches screened for tags given in Table 8 by Hamre (1978). Then, by applying estimates of the proportion of the 1969 and summed pre-1969 year classes belonging to the North Sea stock in the Shetland area, it was possible to estimate the total number of North Sea stock which was allocated using Hamre's (1978) age compositions for the North Sea. Estimates of number at age obtained in this way are tabulated together with those of subsequent years in Table 5.4.

5.1.2 Western stock

The 1976 and 1977 catches in number at age of western stock fish taken in Division IVa were revised following the revised stock mixing ratio from the Norwegian tagging data, Table 3.2. The 1977 catch in number at age for Divisions VIa and VIId-k were also revised following revisions in the preliminary catches used in the 1978 report. Major amendments were made to the English (-2 277 tonnes), Dutch (+8 037 tonnes) and Irish (+4 438 tonnes) catches, for which sampling data were available. The remaining revision in catch was distributed across the age groups according to the sampling data used by the 1978 Working Group plus revised sampling data provided by the Dutch and Irish.

The numbers at age taken from the western stock in 1978 were estimated from sampling data provided by:

Division IVa:	Netherlands, Norway, Scotland
Division VIa:	Faroes, France, Ireland, Netherlands, Norway, Scotland
Divisions VIIa,b,c:	Ireland
Divisions VIId-k:	England, France, Ireland, Netherlands
Sub-area VIII:	France

The 1978 numbers at age of unsampled catches taken in Division VIa were raised by the combined sample data excluding the Scottish data. The Scottish data were kept separate until the final additions of catch at age were made as their catch was taken almost entirely within the Minch and their catches contained a higher proportion of younger fish than the international catch taken outside the Minch.

The numbers of fish from the western stock taken in Division IVa were estimated using the stock mixing ratios derived from the Norwegian tag return data, given in Table 3.2. These ratios were also used to allocate between stocks the Faroese catch from

Division VIa in the fourth quarter of 1978 as these fish included large numbers from the North Sea stock (see Section 3.4). The number of fish at age caught and landed by Divisions for each year 1976-78 are given in Table 5.2. For the purposes of the VPA (Table 5.4), the numbers of fish at age given in Table 5.2 for Divisions VIa and VIId-k and Sub-area VIII in 1978 were increased by 10% to account for those fish caught, but not landed due to discarding (Section 2.3).

5.2 Mean Weight at Age

For calculations of yield per recruit curves, a new set of weight at age data from 1978 was compiled. Data were available from England, Ireland and the Netherlands for Sub-area VII, and from Scotland, Ireland and the Netherlands for Sub-area VI. The new set of weights at age per quarter was calculated by weighting according to the landings in number from the three countries. The quarterly mean weight at age was then weighted by the landings in number per quarter to give an annual mean weight per age group in the landings for Sub-area VI and for Sub-area VII (Table 5.3).

For calculating TACs, no new weight at age data were considered. Stock biomass was calculated using the weights presented in the previous report of the Working Group (Anon., 1978). These data are as given in Table 5.3.

5.3 Assessment of the North Sea Stock

A cohort analysis was carried out on the catches in number of the North Sea stock given in Table 5.4. As in the previous year, M was assumed to be 0.15. Values of F in 1978 were obtained from cohort analysis carried out on tag returns as outlined in Section 3.3 and summarised in Table 3.4. On the 3 year olds and older, F was 0.19, and partial recruitment of 1 and 2 group fish was assumed to be the same as in the previous report for 1977.

The results of the analysis indicate that the spawning stock decreased from 650 000 tonnes in 1978 to a new low level of 500 000 tonnes at 1 January 1979. These results should be compared with those given in the previous report (Anon., 1978), which indicated that the spawning stock in 1978 was 470 000 tonnes. The difference is primarily due to the new estimates of the 1974 and 1975 year classes. The 1976 year class seems to be very poor and judging by the fact that the recorded catch of the 1977 year class in 1978 was zero, this year class must also be poor. This is supported by the results of the International Young Herring Survey, which are discussed in Section 6.2.

5.4 Assessment of the Western Stock

As in previous years, a cohort analysis was carried out using the number at age caught from the western stock (Section 5.1). A further 10% was added to the catches in number in Divisions VIa and VII d-k, and Sub-area VIII in 1978 to account for discards. The input values for the cohort analysis are given in Table 5.5.

It was agreed that when carrying out the cohort analysis, the stock of 3 year olds and older in 1977 should be the same as that estimated by the 1977 egg surveys, i.e., 9 000 x 10^6. Several runs were carried out until this constraint was satisfied. In addition, the exploitation pattern was kept the same as in 1978, i.e., full recruitment on the 3 year olds and older, 37% on the 2-group, and 2% on the 1-group. This, however, resulted in the 1976 year class being estimated to be approximately twice as strong as the next strongest in the period 1972-78. No independent evidence for such a

large year class is available but in Sub-area VII there has been some change in the age composition in the last two years (Table 5.2 of Anon., 1978). In 1975 and 1976, the percentage of 1- and 2-groups in the catches was 11% and 29%, respectively, whereas in 1977 and 1978 it was 43% and 36%, respectively. While this is no proof that the exploitation pattern has changed, this possibility cannot be ruled out, and it was agreed to proceed with caution and assume that recruitment is complete at 2 years of age. The results of the cohort analysis given in Table 5.5 were obtained in this assumption.

The results of the cohort analysis indicate that F in 1978 was higher than that previously advocated (Anon., 1978), 0.182 compared with 0.15. The 1976 year class appears to be a strong one, while the first estimate of the 1977 year class indicates that it may be rather weak. Spawning stock size appears to have remained reasonably constant.

6. RECRUITMENT

6.1 Stock/Recruitment Relationship

On the basis of the data from the VPA analyses (Tables 5.4 and 5.5) the Working Group investigated whether a stock/recruitment relationship could be demonstrated in either of the two mackerel stocks.

In the North Sea, no such relationship could be found over the range of stock sizes that were considered (Figure 6.1). The large majority of year classes have been very weak, no matter whether they were produced by a large or a small spawning stock. The only outstanding year class, 1969, was generated by a spawning stock of approximately 1.2 million tonnes. It cannot be excluded that good year classes could be produced by a spawning stock below this level.

Data on stock and recruitment for the mackerel in ICNAF Subarea 3-6 were available from Anderson and Paciorkowski (1978) as given in Figure 6.2. Also for this area no relationship can be determined. Strong year classes, however, were produced at rather low levels of spawning stock. The outstanding year class, 1967, resulted from a spawning stock of about 500 000 tonnes which is in the lower part of the range of spawning stock.

On the basis of the available data, the Working Group was unable to define a critical level of spawning stock size for the North Sea below which recruitment may be impaired.

For the western stock, only very few years of observations are available. In all these years, the spawning stock size was over 3 million tonnes, and it seems that variations in recruitment during this period were not dependant on the spawning stock.

6.2 Recruitment Indices

No research vessel surveys are mounted specifically to estimate recruitment to the mackerel stocks. Walsh (1977) nevertheless showed, on the basis of only seven years' data, that there is a weak correlation between the mean catch of 1-group mackerel on the International Young Herring Survey in the North Sea and the cohort analysis estimate in the North Sea stock. The correspondence between the two series of estimates, however, was not complete: the 1969 year class was large in both estimates, but the 1970 year class was well represented on the surveys, but weak in the cohort analysis. Subsequent year classes were weak by both estimates. At the most it

seems possible that the survey may provide an indication of extreme year classes.

Walsh (in prep.) has also provided an index of strength of the 1976 and 1977 year classes (Table 6.1). Both were poorly represented in the Young Herring Survey, both in the area south of 59°N, which provides the longest series of data, and in the larger area south of 62°N. On a probability basis it, therefore, seems extremely unlikely that either of these year classes are strong in the North Sea stock. Taking the estimates at face value they may be no higher than those of the previous 5 years.

7. CATCH FORECAST

7.1 Prognosis of the North Sea Stock

A prognosis was made for the North Sea stock using the stock in numbers in 1979 taken from Table 5.4. Since the evidence from catch in numbers and the International Young Herring Survey (Section 6.2) indicates that recent recruitment has been very poor, the number of 1-group (1978 year class) was assumed to be equal to the poorest year class on record (85×10^6). Similarly, since no catch of the 1977 year class was made in 1978, this was also assumed to have been 85×10^6 at one year of age. The exploitation pattern in 1979 was assumed to be the same as that used for input to the cohort analysis in 1978.

Prognosis of the stock at 1 January 1980 was made on the assumption that 85 000 tonnes will be taken from the stock in 1979. 85 000 tonnes are equivalent to 15% (Anon., 1978) of the 100 000 tonnes recommended by ACFM to be taken in the northwestern North Sea plus the additional 45 000 tonnes of the TAC assumed to be taken in other parts of the North Sea plus 25 000 tonnes already taken in 1979 by Norwegian and Faroes vessels in the northern part of Division VIa and assumed to belong to the North Sea stock. This required a mean F of 0.19. On this basis, the spawning stock biomass in 1980 will decrease from 505 000 tonnes to 394 000 tonnes (Figure 7.1).

As explained in the previous section, there is no evidence from the stock/recruitment relationship on which to calculate a spawning stock below which recruitment is likely to decrease. Rebuilding of the stock is entirely dependent on the occurrence of one or more strong year classes, and there seems at present no alternative but to manage the stock on the basis that recruitment will remain poor. On this basis, a prognosis to 1981 was made on two alternative assumptions:

1) assuming no catch from the stock in 1980. This would be tantamount to a complete closure of the North Sea fishery;

2) assuming an F of 0.15 in 1980, i.e., the same F as that used in the western stock.

The prognoses on these two alternatives are given in the text table on p.11.

In either case, the spawning stock would fall below its 1980 level unless recruitment is stronger than that assumed. By Option 2 a stock TAC of 53 200 tonnes could be taken from the stock in 1980. The spawning stock in 1979 is estimated to be lower than any previous year for which we have VPA data, and it will decrease further in 1980. This gives rise to serious concern.

Age	F in 1979	Catch in number x 10^{-6}	Stock in number 1980 x 10^{-6}	OPTION 1 F in 1980 = 0	OPTION 2 F in 1980 = 0.15		
				Stock in number 1981 x 10^{-6}	F in 1980	Catch in no. 1980 x 10^{-6}	Stock in no. 1981 x 10^{-6}
1	.01	0.8	(85)	(85)	.008	0.6	(85)
2	.13	7.8	(72)	73	.10	6.4	73
3	.19	8.7	(52)	62	.15	6.7	56
4	.19	24.6	38	45	.15	4.9	39
5	.19	29.0	109	33	.15	14.1	28
6	.19	19.8	128	94	.15	16.6	81
7	.19	4.2	88	110	.15	11.4	95
≥8	.19	77.0	359	385	.15	46.5	331
Catch tonnes x 10^{-3}		84.1				53.2	
Spawning stock tonnes x 10^{-3}			394	378			326

Due to uncertainties about the critical spawning stock level, it is preferable that no catches of the North Sea stock are taken in 1980 (Option 1). If a limited fishery is allowed, it should be managed at a low level of F, in no case higher than by Option 2 (F = 0.15).

7.2 Prognosis of the Western Stock

A prognosis was made for the western stock, using the stock in numbers in 1979 taken from Table 5.5. Since the low estimate of recruitment of the 1977 year class is heavily dependent on the input F in the cohort analysis, the number of 1 group was assumed to be approximately the next lowest value, i.e., 1 500 x 10^6. As in the cohort analysis recruitment is assumed to be complete at two years of age.

Prognoses of the stock in 1980 were made on two assumptions:

A) that the catch from the western stock in 1979 will be 660 000 tonnes. This includes 85 000 tonnes expected to be taken in the northwestern North Sea, an allowance for 10% discarding in the western area and an assumed increase in landings by some countries over their landings in 1978.

B) that the catch in 1979 will be equal to the TAC of 520 000 tonnes recommended to be taken from the western stock in the previous Working Group report (Anon., 1978).

The results of the prognoses are given in the text table on p.13.

On the first assumption, F on the 2 group and older in 1979 will be 0.24. Applying an F of 0.15 to the stock in 1980 will generate a catch of 354 000 tonnes. On the second assumption, F in 1979 will be 0.185 and using an F of 0.15 ($F_{0.1}$) in 1980 will generate a catch of 373 000 tonnes.

The need for a reduced TAC for 1980 compared with 1979 is due to the fact that the catch in 1978 greatly exceeded the TAC and to the likelihood that the 1979 catch will also be higher than that recommended by ACFM.

Age	ASSUMPTION A					ASSUMPTION B				
	F in 1979	Catch in number 1979 x 10^{-6}	Stock in number 1980 x 10^{-6}	F in 1980	Catch in number 1980 x 10^{-6}	F in 1979	Catch in number 1979 x 10^{-6}	Stock in number 1980 x 10^{-6}	F in 1980	Catch in number 1980 x 10^{-6}
1	.09	120	(1 500)	.055	75	.068	92	(1 500)	.055	75
2	.24	83	1 180	.15	153	.185	65	1 206	.15	156
3	.24	519	282	.15	37	.185	411	298	.15	39
4	.24	392	1 769	.15	229	.185	310	1 869	.15	242
5	.24	224	1 334	.15	173	.185	177	1 409	.15	183
6	.24	238	764	.15	99	.185	188	808	.15	105
7	.24	66	810	.15	105	.185	52	856	.15	111
8	.24	140	225	.15	29	.185	111	238	.15	31
9	.24	52	477	.15	62	.185	41	504	.15	65
10	.24	77	178	.15	23	.185	61	188	.15	24
>10	.24	194	922	.15	119	.185	154	974	.15	126
Catch, tonnes x 10^{-3}		658			354		520			373
Spawning stock, tonnes x 10^{-3}			2 467					2 607		

7.3 Area TACs for 1980

The stock TACs for 1980 are for the North Sea stock either:

1) zero, or

2) 53 000 tonnes.

For the western stock:

A) 354 000 tonnes, or

B) 373 000 tonnes.

In the first option for the North Sea stock, it is of course clear that no catch would be taken in the North Sea and the entire western TAC would be taken in that area. Assuming, however, that a TAC is accepted for the North Sea stock, it is necessary to calculate the quantity of western stock that will unavoidably be taken during its feeding period in the North Sea.

In the previous report the recommendation was given that the North Sea area TAC should be taken in the northwestern part of the North Sea to minimise the catches of North Sea stock. However, the calculations for 1980 in this report have been carried out on the assumption that the area distribution of catch within the North Sea will be the same as that observed in 1978. Using estimates of the expected mixing rate of North Sea and western mackerel in Division IVa, the catch of western mackerel associated with a North Sea stock TAC of 53 000 tonnes has been calculated.

North Sea catches outside Division IVa were assumed to come from the North Sea stock. The proportion of catches in Division IVa attributable to the North Sea stock was estimated by using the 1978 values for the 1973 and older year classes (Table 3.2). For the 1974, 1975 and 1976 year classes it was assumed that 30%, 20% and 60%, respectively, would come from the North Sea stock. 100% of the three year olds were assumed to be North Sea mackerel. A weighted mean of 36% for the catch in weight was then estimated from the estimated age composition in Division IVa in 1980 and weight at age data. 73% of the North Sea catch in 1978 was taken in Division IVa, and from the percentages it was estimated that 53% of the North Sea catch in 1980 would be North Sea mackerel.

From these calculations a North Sea stock TAC of 53 000 tonnes in 1980 would be associated with a catch of 47 000 tonnes from the western stock. The area TACs in 1980 would therefore be (tonnes):

	North Sea area (IIa, IIIa, IV)	Western area (Vb, VI, VII, VIII)
1) Assuming no North Sea stock TAC in 1980:		
and		
(A) Catch of 660 000 tonnes of the western stock in 1979	0	354 000
(B) Adherence to TAC of 520 000 tonnes of the western stock in 1979	0	373 000

continued

ctd.	North Sea area (IIa, IIIa, IV)	Western area (Vb, VI, VII, VIII)
2) Assuming a North Sea stock TAC of 53 000 tonnes in 1980:		
and		
(A) Catch of 660 000 tonnes of the western stock in 1979	53 000 + 47 000 = 100 000	307 000
(B) Adherence to TAC of 520 000 tonnes of the western stock in 1979	53 000 + 47 000 = 100 000	326 000

8. MINIMUM LANDING SIZE

8.1 The North Sea

Since 1970 the Norwegian fishery of mackerel for reduction purposes has been controlled by a minimum legal size of 30 cm. This regulation was later adopted by NEAFC and is currently observed by all North Sea fishing nations:

> "Mackerel smaller than 30 cm measured from the tip of the snout to the end of the tail fin may not be caught for purposes other than human consumption;
>
> landings of mackerel for purposes other than human consumption may consist of up to 20% by weight of under-sized mackerel".

For the North Sea mackerel, Hamre and Ulltang (1972) made a study of the effects of various regulation measures on stock and yield. The main conclusions were:

The seasonal pattern of the fishery has a considerable effect on the yield per recruit and the spawning stock per recruit, especially when the fishing mortality is high and the younger age groups are unprotected. Fishing during summer and autumn is most favourable and may increase the yield and spawning stock by about 20% compared with an equal distribution of effort throughout the year. The winter fishery represents the most unfavourable fishing strategy.

The present seasonal distribution of catch, see Table 2.3, appears to be reasonably close to the optimum of stock and yield.

The gain in yield per recruit obtained by increasing age at first capture is rather small at low level of fishing mortalities. This parameter, however, affects the size of the spawning stock, especially when the stock is heavily exploited. Nearly 50% increase in stock size may theoretically be obtained by increasing age at first capture from 1 to 3 years, when the fishing mortality is at the present level of 0.2.

A more detailed summary of these findings is given in the 1974 Working Group report (Anon., 1974).

On this basis there appears to be justification for the maintenance of a minimum landing size. Furthermore, there are no biological reasons for the restriction of the regulation on the industrial fishery. In

the late 1960s more than 75% of the total catch was utilised for reduction purposes. In the recent period, an increasing proportion is used for human consumption. For 1978 this proportion is estimated to exceed 50%.

As outlined in other parts of the report, recruitment to the North Sea stock of mackerel has recently been very low, and the stock of adult fish is small. If a strong year class appears, the proportion of undersized fish in the catches is likely to increase. To obtain full protection of the youngest age groups the exemption for undersized fish (20%) should be reduced.

8.2 The Western Area

The western mackerel stock is exploited by two fisheries, the winter fishery in Sub-area VII and the summer fishery in Division VIa and Division IVa. As the western stock spawning and nursery area is found in Sub-area VII, the catches made there include an appreciable proportion of small, immature fish, 37% less than 3 years old, and age at first capture, t_c, is 1 year (t_c = 1, as aged on 1 January). In contrast, less than 1% fish caught in Division VIa are less than 3 years old and t_c = 3. The VIa mackerel represent the faster growing part of the stock (Corten and van de Kamp, 1978), and they are consistently larger than fish caught in Sub-area VII at the same time of year (Table 5.2). These difference are reflected in the yield per recruit curves calculated with separate data from the two areas.

8.2.1 Yield per recruit

Western area yield per recruit and spawning biomass per recruit curves are presented here, Figs. 8.1 and 8.2, for mackerel caught in Div.VIa and Sub-area VII, using growth data presented at this meeting (Section 5.2 and Table 5.3). Curve A describes the yield and spawning biomass per recruit using data from Sub-area VII in the summer (Apr.-Sep.), Curve B refers to the same area during the winter (October-March), and Curve C describes the improved yield and spawning biomass per recruit in Sub-area VII, if a minimum size of capture of 30 cm (effectively t_c = 3) is applied to the winter fishery. Curve D describes the yield and spawning biomass per recruit in Division VIa under the present pattern of exploitation.

When comparing yield per recruit curves for the summer and winter in the same area, it is reasonable to expect an improved yield in summer resulting from the annual growth increment. When comparing Curves A and B in Figure 8.1, the reverse of the expected picture is seen; this is due to the large, faster growing fish leaving Sub-area VII in the spring and moving north to Division VIa. The small, slow growing fish remain in Sub-area VII (Corten and van de Kamp, 1978), and the gain from their annual growth increment is not sufficient to make up for the apparent loss resulting from the migrations of the larger fish. The movement of the larger, faster growing fish in the population to Division VIa, plus their annual growth increment, gives an appreciably higher yield per recruit than is observed in either the existing winter fishery in Sub-area VII (+26% at F = 0.15) or in the winter fishery with a 30 cm minimum catch size (+23%).

A preliminary examination of these yield and spawning biomass per recruit curves indicates that there is the possibility of improving yield and/or spawning biomass per recruit, if the present pattern of exploitation is regulated to protect the young fish in the population.

8.2.2 Minimum landing size

In Sub-area VII 3 year old mackerel are about 30 cm; therefore the Curve C in Figs.8.1 and 8.2 assumed a 30 cm minimum capture size. If the number of fish less than 30 cm being caught can be significantly reduced, then there will be a slight gain in yield, 3-6% over the range of F recently estimated, but there will be a gain of 30-50% in the spawning biomass. To reduce the probability of capture of fish less than 30 cm requires an appropriate mesh size regulation, and the assumption that mesh selection will operate in the fishery. The members of the Working Group agreed that the density of shoals fished in Sub-area VII during the winter prevent mesh selection operating in the directed mackerel fisheries at least. Consequently, a mesh size regulation is unlikely to have any beneficial effect.

A minimum landing size of 30 cm will only be successful if it induces the fishermen to move away from areas where high catches of small fish are made to areas where the proportion of large fish is greater. The limited information available to the Working Group suggests that the fishermen fishing for the human consumption market do this already as far as they are able, as larger fish have a higher market value. This does not result in much difference in landings, however, as the winter shoals invariably contain a high proportion of small fish. This is one of the present causes of discarding in the fishery (Section 2.3), and the Working Group concluded that the introduction of a minimum landing size will increase the extent of discarding and consequently will not result in an appreciable increase in yield or spawning stock biomass.

8.2.3 Area and seasonal restrictions

With the present pattern of exploitation both yield and spawning biomass per recruit is significantly higher in the Division VIa fishery (Figures 8.1 and 8.2, Curve D) than in the Sub-area VII fishery (Curve B). A simplistic conclusion from this observation is that the western stock should be fished in the north during summer, and not in the south during winter. Apart from this being an impractical suggestion in economic terms, it ignores the yield to be gained by exploiting that part of the stock which never migrated as far north as Division VIa. A seasonal restriction applied to part of Sub-area VII may reduce the catches of young fish.

Corten and van de Kamp (1978) have indicated the movement of fast growing mackerel northward from Sub-area VII in the spring and back again in the autumn. Lockwood and Dawson (1976) have also described how the abundance of large mackerel, fish of 400 g or more, expressed as c.p.u.e. in the Cornish handline fishery, increases from very low levels in September-October to a peak about the end of December and falls again to a low level in March-April. The English trawl and purse-seine landings also show a tendency to include a lower proportion of small fish in December-January than they do in either October or March-April, as shown in the text table on page 18. If the winter fishery off the southwest of England was for a restricted period only then the number of young fish caught could be reduced.

% Mackerel less than 30 cm

Month	Trawl (incl. freezer + pair)	Purse seine	All gears
Oct 1976	64.5	57.3	58.1
Nov 1976	46.0	57.9	49.8
Dec 1976	39.9	48.0	40.9
Jan 1977	27.4	31.8	28.4
Feb 1977	17.7	25.5	19.5
Mar 1977	69.8	x)	68.5
Apr 1977	60.8	x)	32.7
Oct 1977	12.6	40.4	32.7
Nov 1977	55.4	58.9	55.1
Dec 1977	39.6	60.0	47.4
Jan 1978	37.8	29.3	31.0
Feb 1978	61.1	57.3	55.7
Mar 1978	x)	43.9	43.9
Apr 1978	43.9	40.6	43.0
Oct 1978	44.0	41.1	42.5
Nov 1978	48.9	51.2	48.4
Dec 1978	23.8	28.6	25.6
Jan 1979	27.8	30.3	x)
Feb 1979	30.5	34.7	x)

x) No data available.

The catch per unit effort data described by Lockwood and Dawson (1976) are now available for the period November 1972 - December 1978. By measuring the difference in minimum c.p.u.e. at the start of each season, the peak value and the minimum value at the end of each season, it is possible to calculate mean dates for the time when the abundance of large fish has reached any given proportion of the maximum. Thus, the period during which the abundance of large fish was 50% or more was mid-November to end of February, when the abundance was 75% or more mid-December to mid-February. These could be used as guide dates for a period during which non-selective fishing for mackerel could take place in the area off southwest England dominated by young fish, i.e., north of 48°45'N in Division VIIe and south of 50°15'N in Division VIIf.

9. REFERENCES

Anderson, E D and Paciorkowski, A L. 1978. A review of the northwest Atlantic mackerel fishery. ICES Symp. on Biol.Basis for Pelagic Fish Stock Management, No.11, pp.1-63, 19 tab., 21 figs. (mimeo.).

Anon., 1978. Report of the Mackerel Working Group. ICES, Doc. C.M.1978/H:4, pp.1-46, 17 tab., 5 figs. (mimeo.).

Anon., 1979. Report of the Advisory Committee on Fishery Management 1978. ICES Coop.Res.Rep., No.85, pp.1-157.

Corten, A and G van de Kamp. 1978. Different growth patterns in mackerel west of the British Isles. ICES, Doc. C.M.1978/H:8 (mimeo.).

Hamre, J. 1978. Biology, exploitation and management of the Northeast Atlantic Mackerel. ICES Symp. on Biol.Basis for Pelagic Fish Stock Management, No.32, pp.74, 15 tab., 18 figs (mimeo.).

Hamre, J and Ulltang, Ø. 1972. The effects of regulations of the mackerel fishery in the North Sea. ICES, Doc. C.M.1972/H:30, pp.1-4, 1 tab., 5 figs. (mimeo.).

Lockwood, S J. 1978. The fecundity of mackerel, Scomber scombrus L. ICES, C.M.Doc. 1978/H:9, 4 pp. (mimeo.).

Lockwood, S J, Coombs, S H and Guéguen, J. 1977. A preliminary report of the mackerel egg and larval surveys to the west of the British Isles and France in 1977. ICES, Doc. C.M.1977/J:9, pp.1-8, 1 fig., 2 tab., (mimeo.).

Lockwood, S J, Dawson, W A and Harrop, R T. 1978. The western mackerel spawning stock size estimate for 1977. ICES, Doc. C.M.1978/H:11, 9 pp. (mimeo.).

Walsh, M. 1977. Adolescent mackerel in the North Sea International Young Herring Surveys of 1975 and 1976. ICES, Doc. C.M.1977/H:29, pp.1-8, 3 tab., 4 figs. (mimeo.).

Table 2.1 Nominal catch (tonnes) of mackerel in the North Sea, Skagerak and Kattegat (IV and IIIa) 1968-1978. (Data for 1968-1976 as officially reported to ICES)

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978[1)]
Belgium	77	139	19	85	129	78	145	134	292	49	-
Denmark	9 887	10 851	26 753	17 590	2 023	7 459	3 890	9 836	27 988	21 833	18 034
Faroe Islands[3)]	-	3 080	2 134	3 603	7 551	11 202	18 625	23 424	63 476	42 836	34 194
France	4 684	11 353	4 677	9 061	6 882	636	2 254	2 749	2 607	2 529	3 591
Germany, Dem.Rep.	349	399	51	166	346	214	234	141	259	41	233
Germany, Fed.Rep.	1 353	1 161	225	407	374	563	270	276	284	-	90
Iceland	352	612	1 492	649	687	3 079	4 689	198	302	-	-
Netherlands	5 986	4 928	2 956	4 945	4 436	2 339	3 259	2 390	2 163	2 673	1 062
Norway[2)]	779 084	683 045	278 631	200 635	160 141	298 877	255 132	241 533	207 867	182 200	89 613
Poland	1 629	12	205	130	244	561	4 520	2 313	2 020	298	-
Sweden	11 783	10 820	4 407	3 163	4 748	2 960	3 579	4 789	6 448	4 012	3 050
UK (England & Wales)	55	35	35	23	32	31	61	33	89	105	141
UK (Scotland)	583	231	148	616	395	2 943	390	578	1 199	1 590	3 658
USSR	6 094	12 516	718	2 600	611	17 150	8 161	9 330	1 231	2 765	557
Total	821 916	739 182	322 451	243 673	188 599	348 092	305 209	297 724	316 225	260 931	154 223

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)

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

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
1968	42	12 867	796 538	10 605	1 557
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*	4 153	4 620	113 381	30 754	1 751

* 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

Table 2.3 Landings of mackerel (tonnes) by quarters, 1978.

Fishing area	Quarters					Total
	I	II	III	IV	Not known	
IV and IIIa	3 589	8 194	129 697	7 946	647	150 073
VI	2 047	2 284	78 160	69 243	-	151 734
VII	124 126	42 131	14 308	152 111	2 033	334 709
VIII	251	891	909	735	18 000	20 786

Table 2.4 Nominal catch (tonnes) of mackerel in the Western area (VI, VII, and VIII) (Data for 1967-76 as officially reported to ICES).

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978[1]
Belgium	2	11	8	2	1	3	7	17	10	1	-
Denmark	-	-	-	-	-	-	-	-	3	698	8 381
Faroe Islands	-	-	-	-	-	635	8 659	1 760	5 539	3 978	12 136
France	34 896	31 356	42 899	33 141	35 354	41 664	37 824	25 818	33 556	35 702	36 758
German Dem.Rep.	95	9	130	93	214	1 733	2 885	9 693	4 509	431	-
Germany, Fed.Rep.	613	428	783	258	98	559	993	1 941	391	446	28 762
Iceland	-	-	90	86	74	52	-	21	10	-	-
Ireland	2 164	1 615	1 055	3 107	4 592	8 314	8 526	11 567	14 395	23 022	31 909
Netherlands	2 597	4 441	3 828	3 837	6 166	7 785	7 315	13 263	15 007	35 766	50 555
Norway	-	-	-	1 611	-	34 600	32 597	1 907	4 252	362	1 826
Poland	1 518	2 149	6 054	10 832	13 219	10 536	22 405	21 573	21 375	2 240	-
Spain	20 753	21 571	31 368	37 506	31 416	25 677	30 177	23 408	18 480	21 853	20 000[2]
Sweden	-	-	-	-	-	-	-	-	38	-	-
UK (England & Wales)	2 585	2 692	3 374	4 791	6 923	13 081	21 132	31 546	57 311	132 320	213 347
UK (N.Ireland)	151	279	243	315	57	93	75	30	95	97	26
UK (Scotland)	537	402	807	805	1 412	5 170	8 466	16 174	28 399	52 662	103 514
USSR	-	6 147	13 555	36 390	71 249	65 202	103 435	309 666	262 384	16 396	-
Total, ICES memb.	65 911	71 100	104 194	132 774	170 775	215 104	284 496	468 384	465 754	325 974	507 214
Bulgaria	-	-	-	-	-	4 341	13 558	20 830	28 195	-	-
Rumania	-	-	-	-	-	-	-	2 166	13 222	-	-
Total	65 911	71 100	104 194	132 774	170 775	219 445	298 054	491 380	507 178	325 974	507 214

1) Preliminary

2) Working Group estimate

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

Year	Sub-area	
	VI	VII + VIII
1968	5 064	60 847
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

* Preliminary.

Table 3.1 Number of recoveries (of mackerel tagged in the North Sea) 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.	1971	1972	1973	1974	1975	1976	1977	1978
Pre-1969	1969	4 187	56	9	24	17	7	6	3	0
	1970	2 420	40	25	48	28	16	12	7	3
	1971	2 450		57	87	71	42	24	21	2
	1972	2 126			113	88	49	33	35	7
	1973	1 518				98	70	37	32	7
	1974	1 344					51	23	34	4
	1975	1 048						20	40	5
	1976	304							13	3
	1977	1 363								9
	P_j		179.1	92.5	267.5	145.4	116.5	53.8	33.6	8.5
1969	1970	1 085		14	30	25	19	7	12	0
	1971	6 900		145	340	234	153	85	74	17
	1972	9 447			509	475	313	163	164	26
	1973	4 642				305	238	92	101	17
	1974	2 740					139	58	82	12
	1975	4 716						123	152	19
	1976	996							36	8
	1977	2 361								16
	P_j			70.1	172.2	187.5	115.9	93.2	64.4	14.7
1970	1971	0			0	0	0	0	0	0
	1972	245			10	14	7	2	4	0
	1973	702				43	34	14	13	2
	1974	185					9	6	5	1
	1975	423						11	13	2
	1976	70							2	1
	1977	217								1
	P_j				12.5	37.0	25.4	9.2	8.9	1.5
1971	1972	0				0	0	0	0	0
	1973	415				18	16	5	7	2
	1974	104					3	1	2	0
	1975	725						16	22	3
	1976	88							2	0
	1977	217								1
	P_j					21.2	29.6	39.4	27.8	6.6
1972	1973	0					0	0	0	0
	1974	82					4	1	1	0
	1975	625						14	16	3
	1976	105							4	1
	1977	414								2
	P_j						7.9	7.5	4.1	1.3
1973	1974	37						0	0	0
	1975	846						17	21	4
	1976	53							1	0
	1977	749								3
	P_j							13.9	18.1	7.9

continued

Table 3.1 (continued)

RELEASE			RECAPTURES							
Year class	Year	No.	1971	1972	1973	1974	1975	1976	1977	1978
1974	1975	1 612							36	9
	1976	146							3	1
	1977	1 537								8
	P_j								18.2	7.3
1975	1976	0								0
	1977	236								1
	P_j									4.1

Table 3.2 Proportion of catch in Division IVa attributable to the North Sea stock calculated from tag data.

Year class	Year		
	1976	1977	1978
Pre-1969	0.33	0.58	0.38
1969	0.48	0.77	0.53
1970	0.60	0.66	0.63
1971	0.15	0.31	0.19
1972	0.26	0.54	0.33
1973	1.0	0.95	0.39
1974		1.0	0.64
1975			1.0

Table 3.3 Tag recoveries from the Shetland area (Sh) and the northeastern North Sea (NS) for 1971-76 and Division IVa and Division IVb-c 1977-78 raised to total catch as number x 10^{-6} (C_T). Tagged in the North Sea. All year classes.

RELEASE		RECAPTURES															
Year	No.	Within season	1971		1972		1973		1974		1975		1976		1977		1978	
			Sh	NS	Sh	NS	Sh	NS	Sh	NS	Sh	NS	Sh	NS	IVa	IVb-c	IVa	IVb-c
1970	3 505	936	74	84	25	69	52	65	33	64	12	58	17	48	46	5	15	10
1971	9 350	558			160	353	232	515	169	369	51	333	160	127	231	18	92	19
1972	11 818	419					232	892	222	793	80	644	226	315	505	35	161	42
1973	7 277	814							116	731	75	645	193	182	402	38	153	57
1974	4 493	664									27	380	138	95	313	32	91	26
1975	9 995	1 419											218	456	776	119	248	112
1976	1 763	170													157	23	79	29
1977	7 094	596															220	98
C_T			386.2	134.8	224.3	235.5	428.8	370.7	422.8	312.0	255.4	364.1	335.7	315.6	448.2	50.3	777.9	63.7

Table 3.4 Results of analysis of North Sea tagging data by cohort method. All year classes, North Sea stock. Natural mortality = 0.122

TAGGING SURVIVAL	Year of release						
	1970	1971	1972	1973	1974	1975	1976
	0.68	0.65	0.71	0.85	0.68	0.64	0.67

NUMBERS OF TAGS PRESENT IN POPULATION AT 1 JANUARY	Year of recapture							
Year of release	1971	1972	1973	1974	1975	1976	1977	1978
1970	1 336	1 034	826	603	442	326	227	153
1971		5 156	4 082	2 910	2 070	1 471	1 032	679
1972			7 446	5 533	3 943	2 809	1 977	1 242
1973				5 041	3 665	2 567	1 919	1 285
1974					2 213	1 576	1 176	716
1975						4 603	3 440	2 203
1976							938	661

FISHING MORTALITY	Year of recapture							
	1971	1972	1973	1974	1975	1976	1977	1978
	0.13	0.11	0.19	0.21	0.22	0.19	0.31	0.19

Table 5.1 Catch in number x 10^{-6} of the North Sea mackerel stock by year classes.

Year class	1976		1977		1978		
	IVa + IIIa	IVb,c	IVa + IIIa	IVb,c	IVa + IIIa	IVb,c	VIa
Pre-1969	32.4	18.9	44.5	11.7	12.7	11.0	3.3
1969	110.8	7.8	122.4	3.5	35.2	5.4	2.7
1970	13.6	5.9	28.8	2.8	11.6	3.7	0.5
1971	13.4	20.4	19.8	6.8	5.2	7.9	0.2
1972	6.3	7.6	6.4	3.4	2.3	2.5	0.4
1973	47.5	22.2	42.2	12.1	15.4	10.7	0.7
1974	60.7	12.9	48.9	10.0	25.2	12.7	1.8
1975	-	2.7	9.4	9.9	24.3	9.8	0.6
1976	-	-	0.7	0.4	2.0	5.6	0.6
1977	-	-	-	-	-	-	-

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

Year class	1976			1977				1978[1]			
	VI	VII+VIII	IVa	VI	VIIa,b,c	VIId-k+VIII	IVa	VI	VIIa,b,c	VIId-k+VIII	IVa
Pre-1969	62.4	310.5	65.9	47.7	2.2	76.3	32.3	92.4	1.7	78.7	20.7
1969	17.1	142.6	120.0	11.7	0.3	40.9	36,5	22.0	0.4	24.9	31.2
1970	16.1	93.5	9.0	12.7	0.5	36.3	14.9	20.8	0.8	23.8	6.8
1971	27.9	185.2	75.7	23.5	0.6	72.0	43.9	34.6	0.6	82.7	22.2
1972	8.6	143.9	18.1	7.3	0.4	37.9	5.4	17.2	1.2	42.7	4.7
1973	18.8	303.5	-	27.1	0.9	135.8	2.2	45.3	1.4	166.2	24.1
1974	7.9	177.0	-	22.4	0.3	131.3	-	43.2	1.6	163.8	14.2
1975	0.1	279.3	-	12.5	0.2	276.8	-	31.6	0.9	353.9	-
1976	-	34.2	-	1.4	+	152.1	-	2.2	-	510.3	-
1977	-	-	-	-	-	2.0	-	0.02	-	28.4	-
1978	-	-	-	-	-	-	-	-	-	9.4	-

1) Without correction for discards (see Section 5.1).

Table 5.3 Mean weight (g) at age by quarters calculated from 1978 data. $\bar{w}$ is the annual mean weight weighted by numbers landed per quarter.

		Age - Years											
		0	1	2	3	4	5	6	7	8	9	10	>10
Sub-area VI	Jan-Mar	no data available											
	Apr-Jun			179	232	265	294	334	311	374	510	342	465
	Jul-Sep			197	362	407	437	480	482	549	577	553	654
	Oct-Dec			290	333	370	377	427	438	512	523	510	624
	$\bar{w}$			239	342	386	412	454	467	533	556	535	641
Sub-area VII	Jan-Mar			121	207	255	276	356	336	493	480	464	543
	Apr-Jun		112	125	201	251	264	316	285	412	437	364	527
	Jul-Sep		118	170	217	242	264	311	294	405	421	369	467
	Oct-Dec	75	137	195	262	332	343	401	406	521	507	452	619
	$\bar{w}$	75	136	160	229	284	296	365	344	488	481	434	569

Overall mean weight at age ($\bar{w}$) from the previous Working Group report (Anon., 1978).

North Sea		Age - Years								
		0	1	2	3	4	5	6	7	>7
	$\bar{w}$		245[1)]	329	363	392	438	455	520	580
Western Area	$\bar{w}$	64	112	169	207	269	318	362	398	505

1) Oct-Nov only.

Table 5.4 The North Sea mackerel stock. Catch in number with fishing mortality rates and stock sizes as derived from cohort analysis (M = 0.15).

	Year class	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Catch in number (10^6)	1962 and older	624.0[1]	98.6[1]									
	1963	35.6	5.3	18.6[1]								
	1964	79.7	19.0	2.1	3.1[1]							
	1965	308.6	64.5	13.8	24.4	39.3[1]						
	1966	473.1	185.1	29.7	23.5	19.7	44.6[1]					
	1967	110.2	75.8	18.0	21.3	36.0	7.5	64.1[1]				
	1968	64.4	191.1	50.3	33.2	74.3	45.8	25.6	51.3[1]	56.2[1]	32.4[1]	
	1969		110.3	83.0	162.6	280.2	240.8	193.2	118.6	125.9	45.7	
	1970			0.8	35.6	37.6	39.9	27.8	19.5	31.6	16.1	
	1971				2.6	12.1	23.6	42.4	33.8	26.6	14.2	
	1972					4.5	18.7	16.2	13.9	9.8	6.0	
	1973						2.9	10.1	69.7	54.3	27.9	
	1974							11.9	73.6	58.9	40.8	
	1975								2.7	19.3	34.7	
	1976									1.1	8.2	
	1977										0.0	
	1978											
	Total	1 695.6	749.7	216.3	306.3	503.7	423.9	391.3	383.1	383.7	226.0	
Fishing mortality (F)	1962 and older	.900[1]	.351[1]									
	1963	1.181	.500	.094[1]								
	1964	1.053	.731	.150	.086[1]							
	1965	.445	.147	.040	.088	.181[1]						
	1966	.664	.560	.151	.163	.189	.178[1]					
	1967	.292	.316	.109	.171	.455	.151	.206[1]				
	1968	.067	.270	.100	.084	.257	.236	.190	.202[1]			
	1969		.035	.031	.075	.170	.204	.237	.212	.229[1]		
	1970			.001	.073	.097	.134	.124	.113	.256	.190[1]	
	1971				.006	.033	.079	.189	.214	.246	.190	
	1972					.028	.149	.177	.214	.218	.190	
	1973						.006	.025	.222	.254	.190	
	1974							.022	.174	.195	.190	
	1975								.009	.080	.190	
	1976									.014	.130	
	1977										.060	
	1978											
F ≥ 3 years		.707	.351	.094	.086	.181	.178	.206	.202	.229	.190	

(ctd.)

Table 5.4 (continued)

	Year class	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Stock size at 1 Jan (10^6)	1962 and older	1 120[1]	359[1]									
	1963	55	14	228[1]								
	1964	130	39	16	39[1]							
	1965	920	507	377	312	253[1]						
	1966	1 042	462	227	168	123	295[1]					
	1967	467	300	188	145	105	58	369[1]				
	1968	1 077	867	570	444	351	234	159	300[1]			
	1969		3 481	2 894	2 414	1 927	1 400	982	667	954[1]		
	1970			635	546	437	341	257	195	150	584[1]	
	1971				467	400	333	265	188	131	88	478[1]
	1972					173	145	107	77	54	37	26
	1973						524	448	376	260	173	123
	1974							587	495	358	253	180
	1975								318	271	215	153
	1976									85	72	54
	1977										(85)	(69)
	1978											(85)
Total		4 811	6 029	5 135	4 535	3 769	3 330	3 174	2 616	2 263	1 507	1 168
Spawning stock (≥ 3 years) biomass (10^3 t)		1 403	745	692	1 375	1 326	1 175	998	859	946	654	505

1) Including that year class and older fish.

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

	Year class	1972	1973	1974	1975	1976	1977	1978 [1]	1979
Catch in number (10^6)	Pre-1969	507.7	582.3	567.0	1246.2	438.8	158.5	210.8	
	1969	29.4	115.5	191.8	143.8	279.7	89.4	83.2	
	1970	12.1	64.0	108.5	192.2	118.6	64.4	56.7	
	1971	12.4	49.4	123.5	306.3	288.8	140.0	151.9	
	1972	1.6	33.8	24.3	94.5	170.6	51.0	71.9	
	1973	-	-	87.0	104.0	322.3	166.0	258.3	
	1974	-	-	1.3	52.5	184.9	154.0	243.7	
	1975	-	-	-	1.0	279.4	289.5	425.0	
	1976	-	-	-	-	34.2	153.5	563.8	
	1977	-	-	-	-	-	2.0	31.3	
	1978	-	-	-	-	-	-	10.3	
Total		563.2	845.0	1103.4	2140.5	2117.3	1268.3	2106.9	
Fishing mortality (F)	Pre-69	.064	.093	.116	.377	.208	.102	.182	
	1969	.011	.054	.114	.111	.306	.143	.182	
	1970	.007	.044	.094	.226	.200	.151	.182	
	1971	.003	.015	.046	.145	.188	.124	.182	
	1972	.001	.023	.020	.095	.235	.097	.182	
	1973	-	.000	.024	.034	.132	.088	.182	
	1974	-	-	.000	.019	.082	.087	.182	
	1975	-	-	-	.000	.071	.093	.182	
	1976	-	-	-	-	.007	.038	.182	
	1977	-	-	-	-	-	.004	.067	
	1978	-	-	-	-	-	-	.004	
$\bar{F} \geq 3$ years		.052	.078	.096	.239	.196	.104	.182	
Stock size at 1 Jan (10^6)	Pre-1969	8 761	7 070	5 547	4 249	2 508	1 753	1 362	977
	1969	2 769	2 356	1 921	1 476	1 137	721	537	385
	1970	1 854	1 584	1 304	1 022	702	495	366	263
	1971	4 069	3 490	2 958	2 432	1 810	1 291	981	704
	1972	-	1 575	1 324	1 117	874	595	464	333
	1973	-	-	4 012	3 373	2 806	2 117	1 669	1 197
	1974	-	-	-	2 980	2 517	1 995	1 574	1 129
	1975	-	-	-	-	4 369	3 501	2 746	1 970
	1976	-	-	-	-	-	4 397	3 642	2 613
	1977	-	-	-	-	-	-	517	416
	1978	-	-	-	-	-	-	-	(1 500)
Total		17 453	16 075	17 066	16 649	16 723	16 865	13 858	11 487
Spawning stock (≥ 3 years) biomass (10^3 t)		3 377	3 436	3 793	3 657	3 365	3 085	3 225	3 172

1) Landings in number in the western area in Table 5.2 raised by 10% to account for discarding (see Section 2.3).

Table 6.1 Recruitment indices of North Sea mackerel (from the International Young Herring Survey, measured as number of 1-group per 10 hours trawling in the North Sea) compared to estimated number from VPA (at 1 year of age, Table 5.4).

Year class	VPA, No.	IYHS Index	
		South of 59°N	South of 62°N
1969	3 481	6 536	-
1970	635	3 250	-
1971	467	13	-
1972	173	28	-
1973	524	14	12
1974	587	26	165
1975	318	3	4
1976	85	14	14
1977		8	23

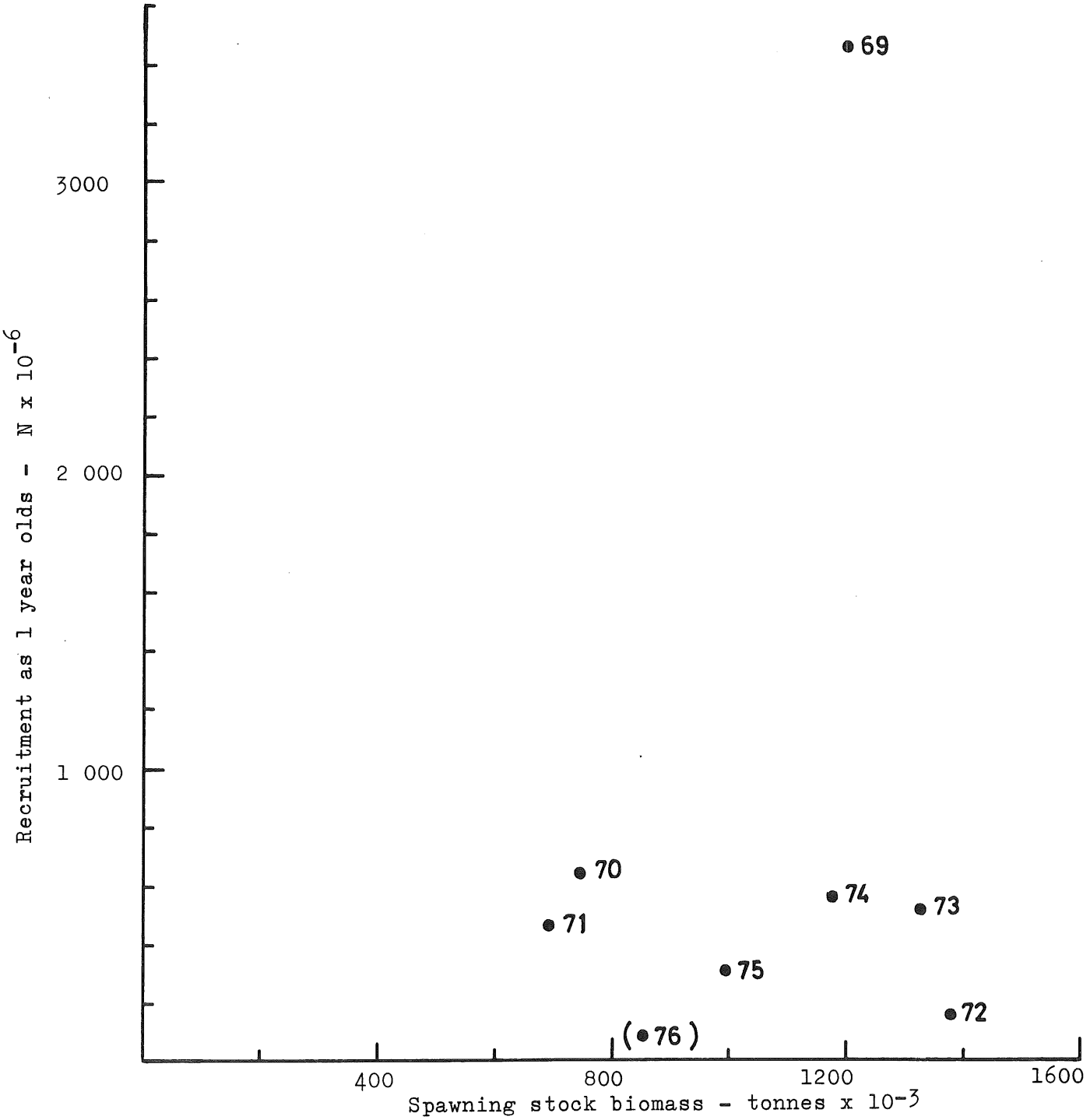


Figure 6.1 Recruitment in relation to the stock of North Sea mackerel. Data from VPA analyses (Table 5.4)[1]

1) The spawning stock in 1969 was reduced by 200 000 tonnes due to the catch taken in the first half of the year.

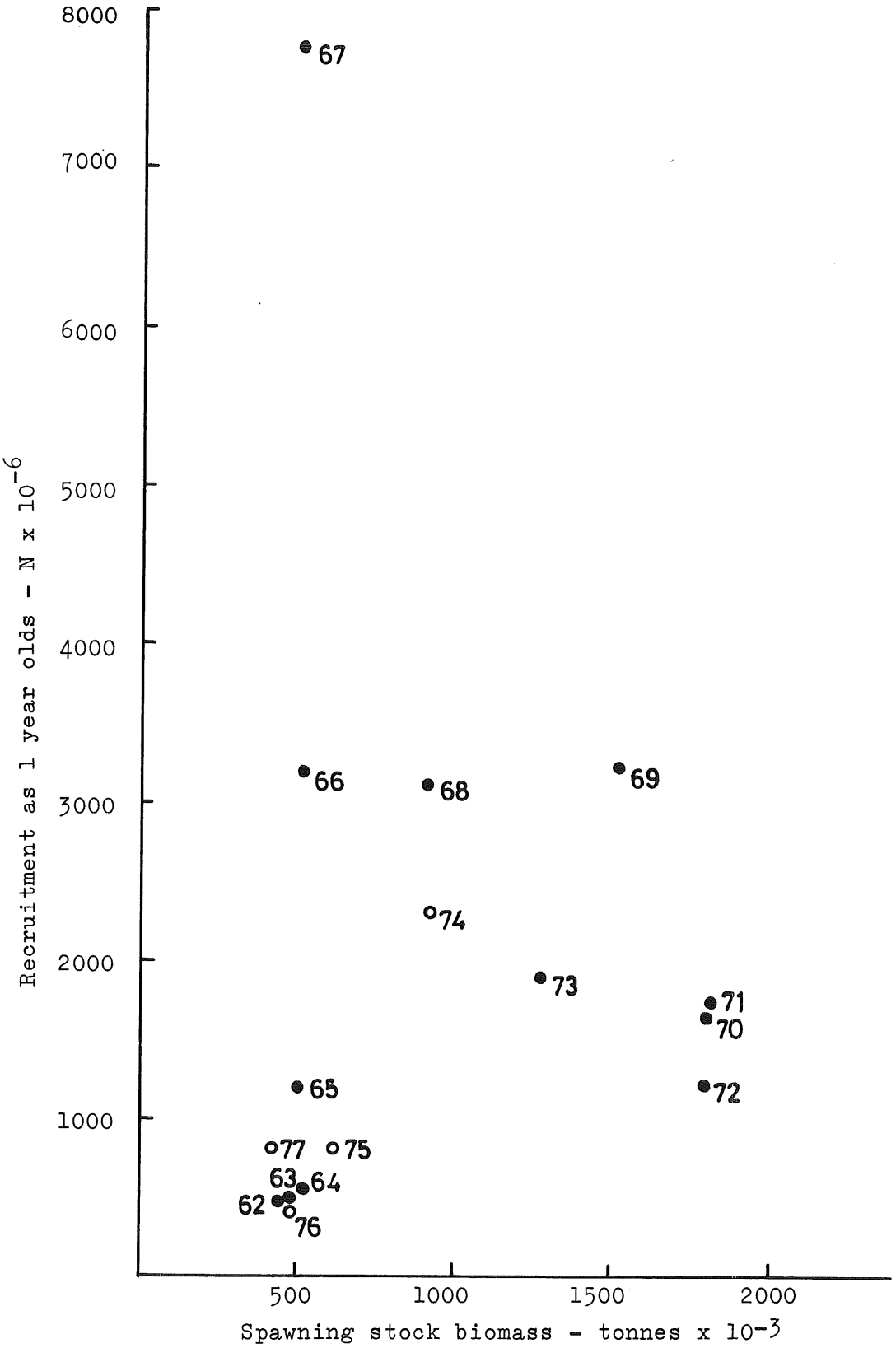


Figure 6.2 Recruitment in relation to the stock of mackerel in ICNAF Sub-area 3-6. Data from Anderson and Paciorkowski (1978).

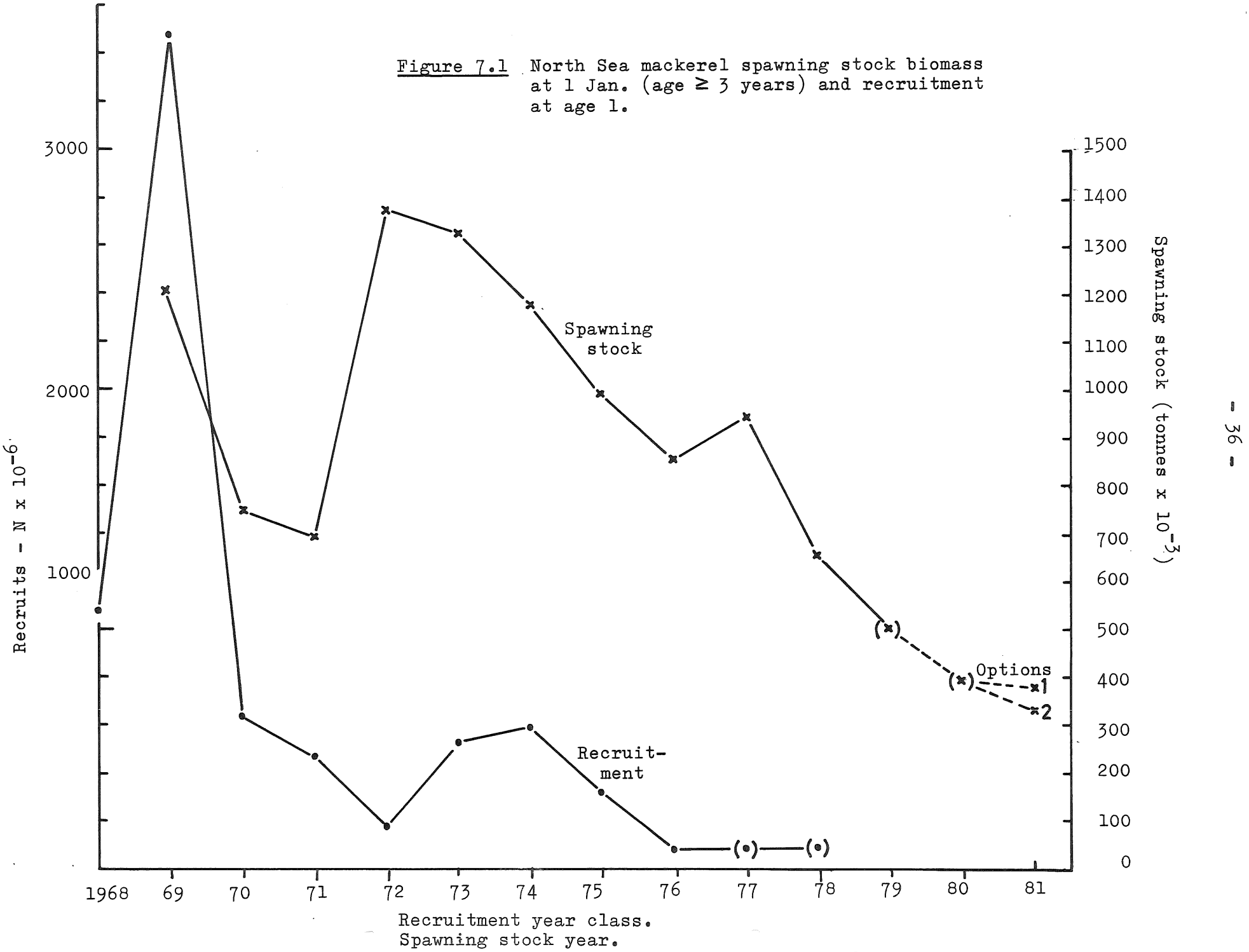
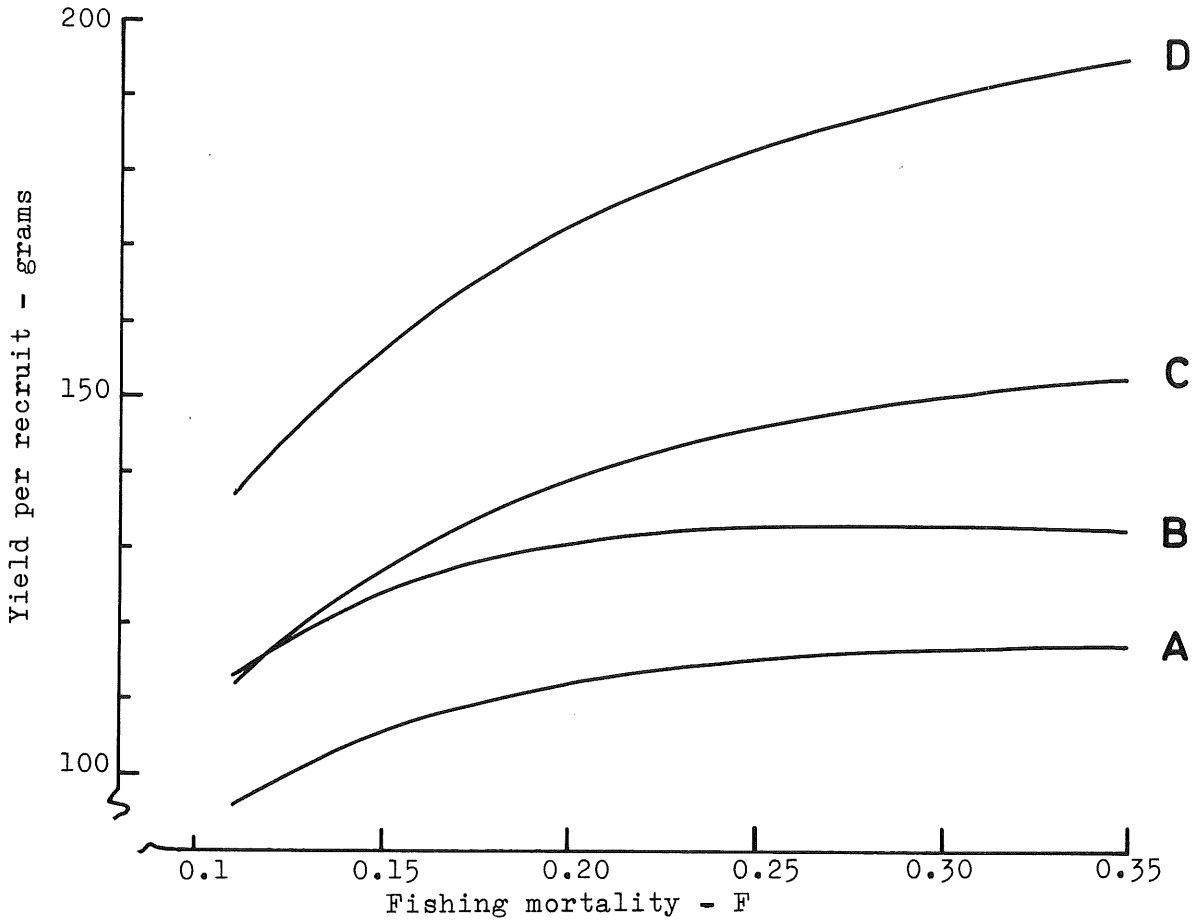


Figure 7.1 North Sea mackerel spawning stock biomass at 1 Jan. (age ≥ 3 years) and recruitment at age 1.



Curve	Area	Time	M	W_∞	t_o	K	t_r	t_c	Diff. from B as % of B	
									F=0.15	F=0.20
A	VII	Apr - Sep	0.15	620	-4.45	0.14	1	1	-17.4%	-14.1%
B	VII	Oct - Mar	0.15	650	-2.50	0.20	1	1	0	0
C	VII	Oct - Mar	0.15	650	-2.50	0.20	1	3	+2.8%	+6.4%
D	VI	Apr - Dec	0.15	740	-4.60	0.17	1	3	+26.2%	+31.8%

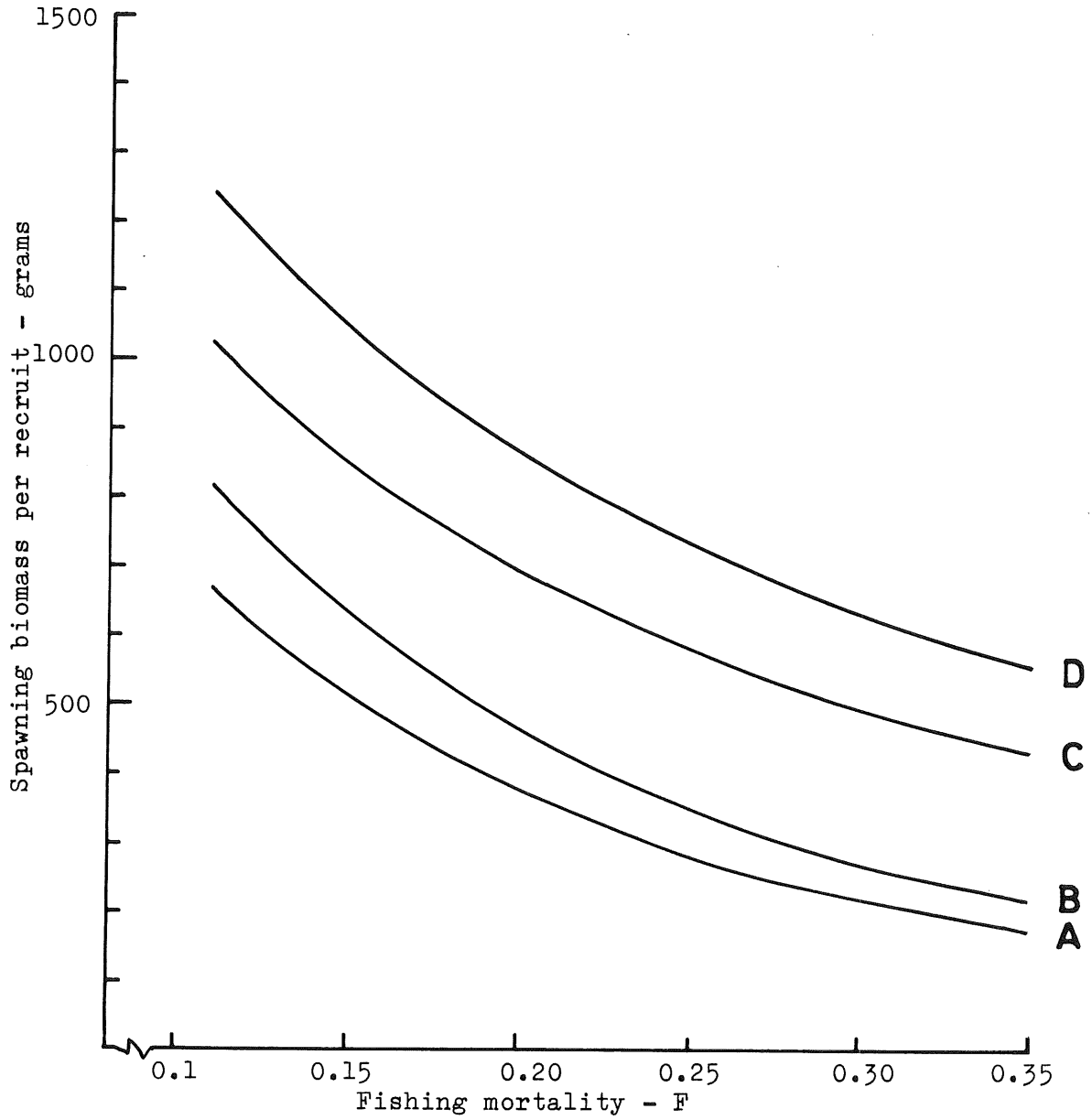
Figure 8.1 Western stock mackerel. Yield per recruit.

Curve A - growth data - summer fishery, Sub-area VII

Curve B - growth data - winter fishery, Sub-area VII

Curve C - as B, but assuming minimum size of capture = 30 cm, i.e., $t_c = 3$.

Curve D - growth data from fishery in Division VIa.



Curve	Area	Time	Diff. from B as % of B	
			F=0.15	F=0.20
A	VII	Apr - Sep	-18.5%	-18.6%
B	VII	Oct - Mar	0	0
C	VII	Oct - Mar	+35.0%	+49.2%
D	VI	Apr - Dec	+65.6%	+85.7%

Figure 8.2 Western stock mackerel, spawning biomass per recruit.

Curves A-D, as in Figure 8.1

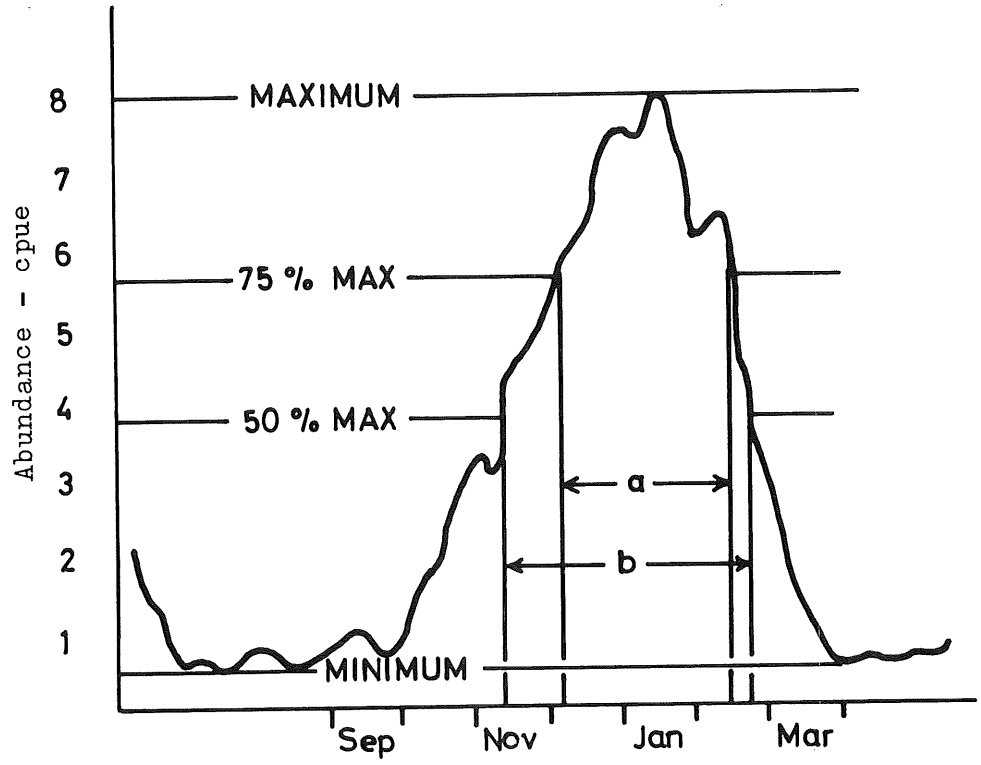


Figure 8.3 Diagrammatic representation of the seasonal change in catch per unit effort (cpue) of large mackerel (>400 g) in the Cornish handline fishery.

a. - Duration of season when abundance is 75% of the difference between minimum and maximum.

b. - Duration of season when abundance is 50% of the difference between minimum and maximum.