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Exploration of the Sea

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REPORT OF THE HERRING ASSESSMENT WORKING GROUP FOR

THE AREA SOUTH OF 62^{0}N

Copenhagen, 1 - 11 April 1986

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*General Secretary
ICES
Palægade 2-4
DK-1261 Copenhagen K
DENMARK

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1.1 Participants

A. Aglen	Norway
R. S. Bailey (Chairman)	UK(Scotland)
G. Biais	France
A. B. Bowers	UK (Isle of Man)
R. P. Briggs	UK (N Ireland)
A. C. Burd	UK (England)
J. Casey	UK (England)
V. Christensen	Denmark
A. Corten	Netherlands
O. E. Dahl	Norway
P. Degnbol (part-time)	Denmark
O. Hagström	Sweden
O. Halldorsson	Iceland
M. Heath	UK (Scotland)
S. A. Iversen	Norway
P. O. Johnson	UK (England)
K. Popp Madsen	Danmark
J. Molloy	Ireland
N. A. Nielsen	Denmark
A. Schumacher	Federal Republic of Germany
B Sjöstrand (part-time)	Sweden

Dr. E. D. Anderson, ICES Statistician, attended the meeting when necessary and provided statistical assistance.

1.2 Terms of Reference

The Herring Assessment Working Group for the Area South of 62^{0}N met at ICES headquarters from 1-11 April 1986 in accordance with C.Res.1985/2:3:9 to:

a) Assess the status of the herring stocks in Division IIIa, Sub-area IV (and, if possible, separately for Divisions IVa, IVb and Divisions IVc/VIId), Divisions Va and VIa and Sub- area VII and provide catch options inside safe biological limits for 1987;

b) Provide quarterly catch-at-age and mean weight-at-age data for 1985 for North Sea herring stocks as input for the multi-species VPA;

c) Provide data on the stock composition of herring catches in Division IIIa.

In addition, ACFM made a number of additional requests which are addressed in appropriate sections of this report.

1.3 Assessment Areas and Procedures

1.3.1 Assessment areas

The area sub-divisions used in the assessment of herring stocks by the Working Group are given in Figure 1.3.1.

1.3.2 General considerations

As a result of discussions about the level of predation mortality on herring in the North Sea, the Working Group decided to use a value of M of 1.0 for the 0-group (applicable to the second half of the year) and a value of 0.8 for the 1-group in all stocks where a value of this parameter is needed for these age groups in the assessments and predictions. The reasons for this choice of values are discussed in the chapter on North Sea herring (Section 2.2). Exceptions to this decision are referred to in appropriate parts of the text.

Following the meeting of the Herring Larval Working Group, new larval production estimates were provided for all areas covered by ICES' coordinated herring larval surveys. The full details of the methodology are available in the report of that Working Group, but a summary of the salient points and of discussions at the Herring Assessment Working Group is given in Section 2.5.

1.4 Safe Biological Limits

The request from ACFM to define safe biological limits was discussed by the Working Group in relation to each stock and in relation to herring stocks in general. If the relationship between stock and recruitment could be defined for a stock, then it would be appropriate to define a safe biological limit in terms of a minimum spawning stock size. It is clear, however, that this relationship cannot be defined at present, and indeed, that it may be different in different time periods. In this situation, the Working Group felt that the definition of safe biological limits might be obtained from the historic time series of stock parameters.

2 NORTH SEA HERRING

2.1 The Fishery

2.1.1 ACFM advice applicable to 1985

At its 1984 meeting ACFM recommended the following TAC's for 1985:

Divisions IVa,b	166,000 tonnes
Divisions IVc, VIId	62,000 tonnes

with up to 20% of the Divisions IVc, VIId TAC transferable to Division IVb.

Further recommendations included the continuation of the spawning closure off the northeast coast of England and, to protect juvenile herring, closure of the mixed fishery for herring and sprat in an area off the Danish coast from 1 July - 31 October.

2.1.2 Catches in 1985

The 1985 landings, including both officially and unofficially reported catches are given in Table 2.1.1 for the total North Sea and for each division in Tables 2.1.2 to 2.1.5. The total provisional estimate of catch was 529,969 tonnes compared with 317,263 tonnes in 1984, an increase of 212,706 tonnes.

Unallocated catches amounted to 69,475 tonnes compared with 64,487 tonnes in 1984. The Netherlands and unallocated catches include an estimate for discards amounting to 6% of the total.

Adult herring catches

A breakdown of catches of adult herring (2-ring and older) based on information supplied by Working Group members, is provided by ICES divisions and quarters of the year in the text table below ('000 tonnes). These were obtained from the sum of products of estimated numbers and mean weights at age.

Division	Quarter (1985)				Total
	I	II	III	IV	
IVa (W of 2^0E)	28.9	29.3	97.1	40.0	195.3
IVa (E of 2^0E)	11.7	89.7	3.1	1.8	106.3
IVb	6.8	11.7	64.3	7.6	90.4
IVc + VIId	11.6	0.3	0.2	54.8	66.9
Total	59.0	131.0	164.7	104.2	458.9

The catches of adult herring are mainly taken in purse seine fisheries and in trawl fisheries using a mesh size of not less than 32 mm. In addition to adult herring, these catches also contain a quantity of 1-group herring taken mainly in Division IVb. Approximately 160,000 tonnes of the catch taken in these fisheries were used for reduction purposes.

The combined catch for Divisions IVa and IVb amounted to 392,087 tonnes. No agreement was reached between management bodies (EEC and Norway) on a TAC or catch allocation for 1985. The TAC recommended by ACFM for this region (based on a fishing mortality rate $F_{0.1}$) was 166,000 tonnes.

Divisions IVc + VIId produced a catch of 66,863 tonnes, compared with the 62,000 tonne TAC recommended by ACFM.

Juvenile herring catches (O- and 1-group)

The following text table provides a similar catch breakdown for juvenile herring on data supplied by Working Group members ('000 tonnes):

Division	Quarter (1985)				Total
	I	II	III	IV	
IVa (W of 2^0E)	+	0.2	0.9	1.8	2.9
IVa (E of 2^0E)	-	0.2	2.0	1.5	3.7
IVb	9.6	1.4	42.8	7.8	61.6
IVc + VIId	+	-	-	1.1	1.1
Total	9.6	1.8	45.7	12.2	69.3

The total catch of juvenile herring (69,242 tonnes) shows an increase of 24,104 tonnes compared with the catch in 1984 (45,138), which was largely due to increased fishing on 1-group fish.

2.1.3 Catch in number

A breakdown of herring catches by age groups, time and area is presented in Tables 2.1.6 and 2.1.7, the latter providing a quarterly analysis by area from data supplied by Working Group members. Most countries supplied sampling data for their catches and all the major fisheries were covered. The totals for the year are compared with those over the period 1970-84 in Table 2.1.8.

The text table below summarises the total numbers caught at age over the most recent six years:

Millions of herring caught by age group (winter rings)

Year	0	1	2	3	4	≥5	Total
1980	792	161	108	92	32	26	1,211
1981	7,889	447	264	57	40	77	8,773
1982	9,557	840	268	230	34	34	10,963
1983	10,030	1,147	545	216	105	85	12,128
1984	2,189	561	987	417	190	152	4,496
1985	1,293	1,620	1,223	1,188	368	217	5,908

The contribution of O- and 1-group fish to the catch amounted to 49% in 1985, compared with 61% in 1984 and 92-95% for the years 1981-83. The catch of O-group fish shows a further reduction mainly due to enforcement of the 'sprat box' off the west coast of Denmark, although the catch of 1-group registered a three-fold increase on that of 1984.

The recruiting 1982 year class (2-group) contributed about 41% by number to the adult catch (excluding 0- and 1-group fish), whilst the 1981 year class (3-group) was nearly as well represented (39.7%). These two year classes thus made up 80% of the adult catch.

However, the relative catches of these two age groups show considerable differences between areas and quarters (Table 2.1.7). These are summarised in Table 2.1.9, where the percentage contribution of 2- and 3-group and older fish to the total adult catch is shown by division and quarter.

Description of fisheries taking 0- and 1-group fish

The largest catches of 0- and 1-group fish are taken in the eastern half of Division IVb, with smaller amounts in IVa.

0- and smaller 1-group fish are taken in the shallow water coastal fisheries by small vessels with a restricted working range using 16-mm mesh bottom trawls, whilst larger 1-groups are caught by larger industrial trawlers employing small-mesh trawls within the eastern half of the central North Sea. The large majority of these catches are used for reduction purposes.

Larger 1-group fish are also taken by purse seine in deeper water within the eastern parts of Division IVa and IVb, and in trawl fisheries primarily directed towards adult herring in other areas of the North Sea. They mainly appear in catches taken during the second half of the year.

In 1985, the largest catch of 0-group fish was taken during the third quarter in Division IVb, and 1-group catches peaked in the first and third quarters (Table 2.1.7).

2.2 Natural Mortality

The results from the ICES Stomach Sampling Project in 1981 and the analyses of these data in the Multispecies Working Group have formed the main elements in the discussion about natural mortality at the two most recent meetings of this Working Group. This year, the report of the *ad hoc* Multispecies Assessment Working Group (Anon., 1986) was available to the Working Group.

The text table below summarises the natural mortalities which have been used by the Herring Assessment Working Group since 1964, and the results of the Multispecies Working Group.

WR	Herring Assessment WG			Multispecies WG	
	1964-70	1970-83	1984-85	1984[1]	1985[2]
0	0.20	0.10	1.00	1.07	0.82
1	0.20	0.10	0.80	0.46	0.84
2	0.20	0.10	0.10	0.13	0.16
3	0.20	0.10	0.10	0.44	0.30
4	0.20	0.10	0.10	0.13	0.12
5	0.20	0.10	0.10	0.19	0.13
6	0.20	0.10	0.10	0.10	0.12
7	0.20	0.10	0.10	0.10	0.10
8+	0.20	0.10	0.10	0.10	0.10

[1] Anon. (1984a) key-run, mean 1974-83.
[2] Anon. (1986a) key-run, mean 1974-84.

Juvenile herring

The values of natural mortality rate used on 0- and 1-group herring were drastically changed at the meeting of the Working Group in 1984. Preliminary analyses of the data from the ICES Stomach Sampling Project suggested a much higher predation mortality than previously assumed and the new estimates were 1.0 on the 0-group and 0.8 on the 1-group.

The Multispecies VPA carried out in 1984 pointed to a lower mortality on the 1-group, and at the time the Herring Assessment Working Group met in 1985, doubts were raised on the procedure applied in the MSVPA. At the 1985 meeting of the Multispecies Working Group, the data base had been improved, and more appropriate weights at age for the prey in the stomach contents were used.

In order to evaluate the new estimates of natural mortality rate, tables showing detailed outputs from the MSVPA were inspected. Table 2.2.1 shows the quarterly predation mortality on herring in 1981 as estimated in the MSVPA in a run which differs only slightly from the key-run (on the third decimal of the estimates).

The predation mortality on the 0-group is equally distributed on the third and fourth quarters and is considerably lower in the second quarter. A very high predation mortality is observed for the 1-group in the first quarter followed by a lower predation in the second quarter and a virtually non-existent predation on 1-group herring in the third and fourth quarters of the year.

Table 2.2.2 shows the predation by each of the five species incorporated in the model, i.e., cod, whiting, saithe, mackerel and haddock.

The annual pattern of predation mortality on 1-group herring is caused by the heavy predation by whiting in the first quarter, less predation in the second quarter, followed by a shift to 0-group herring in the third quarter.

Even though this Working Group considers this variable predation to be possible, it was stressed that these results are based on only one year's stomach sampling and that sampling should be continued to verify and probably smooth the estimates of predation mortality.

Adult herring

The Multispecies Working Group asked for advice from the Working Group on the likely level of natural mortality on old fish and on a likely level of M1 (natural mortality that is due to factors other than predation by the five predators in the MSVPA). In last year's report of this Working Group, the estimates of natural mortality on old herring were reviewed (Anon., 1985). Several studies pointed to a natural mortality rate higher than the value of 0.1. Furthermore, preliminary analyses of M from acoustic surveys also indicate a value of M higher than 0.1.

However, the Working Group decided not to change M on old herring until new material is available to quantify the appropriate value. Such material might include stomach samples from periods with a high abundance of old herring.

The Working Group decided to use the same set of natural mortality rates as at its meetings in 1984 and 1985. The more recent MSVPA is in general agreement with the values of M used in 1984 and 1985, and the Working Group considers that it is not reasonable to change M each year when working with single-species assessments.

2.3 Recruitment

2.3.1 General remarks about the use of IYFS indices

At the last two Working Group meetings, preliminary indices from the International Young Fish Survey could not be updated because of problems in accessing the data stored in the ICES data bank. Although these problems still existed at the time of the present meeting, a copy of the data base for 1983-85 had been made available to the IJmuiden laboratory, and final indices had been calculated there using recently-developed programs. These final indices are given below, together with the preliminary ones available at previous meetings.

Year of sampling	Year class	Preliminary index (N/hr <20 cm)	Final index based on age data
1983	1981	1,910	1,797
1984	1982	2,714	2,714
1985	1983	3,768	3,227

It is seen that the preliminary indices based on the length groups <20 cm were a fairly good approximation of the final indices.

The updated series of IYFS indices since year class 1968 is given in Table 2.3.1.

In correlating IYFS indices with VPA estimates of 1-ringer recruitment for the total North Sea, two series of VPA estimates were used in last year's report. One series was based on a value of M = 0.10 for 1-ringed herring, and the other series used M = 0.80 for this age group. In this report, only the latter series is used (see Section 2.2).

The regression equation for the latter series, based on year classes 1968-80, given in last year's report, was

$$Y = 0.0046X$$

in which Y = VPA estimate of 1-ringers in numbers x 10^{-9} and X = IYFS abundance of 1-ringers in no/hour for the standard area.

An updated VPA for the total North Sea was available during this meeting (Table 2.7.16), and the results of this were used to recalculate the regression of VPA estimates on IYFS indices for the year classes 1968-81. The resulting regression line (Figure 2.3.1) was:

$$Y = 0.0051X - 0.21 \quad \text{with } r = 0.88$$

As the intercept on the y-axis was not significantly different from zero, the regression time was forced through the origin, and the resulting equation was

$$Y = 0.0049X$$

2.3.2 General remarks about the use of Isaac-Kidd midwater trawl (IKMT) indices

Last year, a first attempt was made at quantifying the relationship between IKMT indices and VPA stock size as 0- ringers. For this purpose, a fairly rough IKMT index was calculated, using the uncorrected numbers per haul.

This year, more refined indices for previous years were available, which take into account the duration of each haul and the water depth. For the 1986 survey, however, such a corrected index is not yet available, and so the Working Group decided to continue the series of uncorrected indices for comparative purposes. It is desirable in future years to have a corrected index available at the time of the Working Group meeting. It is not expected, however, that the use of the corrected index will drastically change the results from the IKMT sampling. Figure 2.3.2 compares the two indices for year classes 1976-84.

In comparing IKMT indices with VPA estimates of year-class strength, two more values have been added to the VPA series of year-class strength as 0-group. The new VPA for the total North Sea (Section 2.7) gave values of 46.66 x 10^9 for year class 1982, and 43.91 x 10^9 for year class 1983.

The addition of two more years makes the regression between IKMT indices and VPA estimates significant (Figure 2.3.3), although the confidence limits around the regression line remain rather wide.

2.3.3 Year class 1982

This year class recruited to the adult fisheries in 1985. As can be seen from the age composition of the catch (Section 2.1) and the VPA for the total North Sea (Section 2.7), the prediction that this year class would be a strong one turned out to be correct. The strength of this year class as 1-ringers is now estimated to be 11.51×10^9 compared with a prediction of 11.38×10^9.

2.3.4 Year class 1983

The preliminary index of 3,768 fish/hour in last year's report has now been corrected to 3,227 fish/hour.

Using the above regression equation, the strength of the year class as 1-ringers at 1 January 1985 is now estimated to be 15.81×10^9 fish.

From the catch tables in Section 2.1, it appears that 1.62×10^9 fish of this year class were taken in 1985.

Applying an M of 0.80 on this year class during 1985, the year-class size at the beginning of 1986 is estimated to be 6.03×10^9, and the F on 1-ringers in 1985 at 0.16.

Split of total North Sea index into recruits to Divisions IVc and VIId (Downs) and other North Sea stocks

The proportion of total North Sea recruitment of the 1983 year class going to the Downs stock was estimated last year on the basis of both the English O-group surveys and the length distributions obtained during the IYFS. A Downs recruitment of 200×10^6 was chosen as an intermediate value between the estimate of 270×10^6 based on O-group surveys, and 120×10^6 based on IYFS length distributions.

The abundance of Downs herring of the 1983 year class in the O-group survey has been revised using additional otolith data (Table 2.3.2) and gives a value of 0.430×10^9 2-ringers (Figure 2.3.4). In the meantime, information on the abundance of O-group herring, presumably of Downs origin, along the Dutch coast has become available. This shows that the 1983 year class was the most abundant one in a series of observations starting in 1967. This supported the thesis of Burd and Hulme (1985) that the distribution of Downs year class 1983 as O-group had been shifted annually far to the east, and that the English O-group survey had underestimated the strength of this year class.

Lacking other reliable indicators about the strength of this year class in the Downs stock (the split based on IYFS length distributions is suspect - see next section), the Working Group decided to use the approximate ratio of spawning stock sizes (1:9) as the best way of allocating a proportion of total North Sea recruitment to the Downs stock. This resulted in a new estimate of Downs recruitment as 2-ringers of 0.6 x 10^9, which is close to the revised estimate of Downs herring from the O-group survey.

2.3.5 Year class 1984

Preliminary results from the IYFS in February 1986, based on length distributions and a limited number of age readings, provide an index of 3,613 fish/hour. The increasing trend in recruitment has, therefore, continued; the preliminary index for the year class 1984 is the highest on record, and is 13% above the final index for year class 1983, the next highest on record (Table 2.3.1). Using the regression equation Y = 0.0049X for predicting VPA stock size from IYFS indices, the strength of the year class as 1-ringers is estimated to be 17.70 x 10^9. The survey index of 3,613 lies way outside the range of IYFS indices on which the above regression equation has been calculated (Figure 2.3.1). The predicted value for year class 1984 should thus be treated with caution. This does not change the conclusion, however, that year class 1984 can be expected to be a very strong one.

Another estimate of the strength of the 1984 year class in the North Sea may be made on the basis of the English O-group survey. Table 2.3.2 gives the year-class indices for both the total coastal area and that portion assigned to the Downs stock. The regression for the total survey on the North Sea VPA values of 1-group is given in Figure 2.3.5. This regression is based on the 1967-76 year classes, i.e., those generated before the fishery closure. To test the applicability of this regression to the present situation, the position of the 1979-84 year-class estimates as given in the current VPA is given. The O-group index for the 1984 year class, as with the IYFS index, lies outside the range of the regression. The value of 1-group predicted is 25.844 x 10^9 compared with the IYFS estimate of 17.832 x 10^9.

The Working Group considers the IYFS estimate, which is based on far more intensive sampling, as the appropriate one to be used for prediction purposes.

Split of total North Sea index into recruits to Divisions IVc and VIId (Downs) and other North Sea stocks

Recruitment of 2-ringers to the Downs stock has previously been estimated both from the English O-group survey and from the IYFS length frequency distributions.

Estimate of the Downs component based on English O-group surveys

The regression of the Downs index on the new VPA recruitment estimate for Divisions IVc and VIId is given in Figure 2.3.4. The Downs estimates now refer to the area between Winterton and Margate (Table 2.3.2) (Burd and Hulme, 1985). The 1984 year-class estimate is the geometric mean of the individual stations. One station in this series accounted for 70% of the index. Even using this reduced mean, the index indicates that it is the highest recruitment since 1970. Using this index, a recruitment of 0.803×10^9 2-ringers in 1987 is predicted.

Estimate of the Downs component based on IYFS length frequency data

The Danish Fisheries Institute again provided summaries of the length distributions for all sampling areas based on results of IYFS submitted by the national institutes involved. The data comprised representative samples from all areas worked on the survey. Only very limited age/length keys were available, but these suggested that the length of separation between 1- and 2-group was at about 18 cm. This is less than in the previous years when it lay at about 20 cm. Percentage length distributions for each sampling area curtailed at about 19 cm to exclude 2-ringed fish have been analysed for mode separation using probability paper.

The modal lengths extracted in each herring sampling area are shown in Figure 2.3.6. Following the procedure of the previous Working Group, the Downs component was considered to be present in the areas to the south of the heavy line shown in the figure. The length distributions were combined and analysed using probability paper. The cumulative percentage distributions and the extracted modes are shown in Figure 2.3.7.

A new regression of stock of 2-ringers derived from a VPA using the corrected Divisions IVc,VIId data base on the first components used by the previous Working Group using data in Table 2.3.3 has been calculated (Figure 2.3.8). The indices of abundance of the three modal groups and their stock sizes as 2-ringers derived from this regression are given below:

Modal length (cm)	Index nos./hrs.	Stock of 2-ringers x 10^9
9.9	520	0.101
12.2	1,653	0.119
14.7	888	0.107

Alternatively applying the IYFS/VPA regression to calculate a 1-ringer estimate based on the 9.9 cm mode and the appropriate values of F and M on 1-ringers, an estimate of 0.996×10^9 for 2-ringers is obtained.

As in 1984, the Downs recruitment is taken as the sum of the two smallest components. The estimates for the 1984 year class may be summarized as follows:

Stock in numbers x 10^9

Age	Total North Sea		Downs	
	IYFS	0-group	IYFS	0-group
1-ring	17.83	25.84	-	-
2-ring	-	-	0.220 0.996	0.803

In view of the rather subjective judgements used in splitting the IYFS length distributions, the Working Group decided to adopt the split based on English 0-group surveys as the best estimate for recruitment of Downs herring.

2.3.6 Year class 1985

Preliminary results of the IKMT sampling in February 1986 were available as uncorrected numbers per haul for most of the sampling area.

Figure 2.3.9 compares abundance and distribution of year class 1985 with the two previous year classes. Despite some large sampling gaps in the central North Sea in 1986, it can be concluded that year class 1985 was very similar to the preceding one. The main difference between the two year classes was the scarcity of larvae in the Skagerrak/Kattegat area in 1986.

The similarity between the two most recent year classes is also seen from the tabulation of mean numbers of larvae per rectangle in Table 2.3.4. The estimated abundance of year class 1985 over the total sampling area is even higher than the one for year class 1984.

Considering what was said in Section 2.3.2 about the relationship between IKMT indices and VPA estimates of year-class strength, it may be concluded that year class 1985 is likely to be a strong one in the North Sea.

2.4 Acoustic Surveys

2.4.1 Northern North Sea (Division IVa and Buchan area)

An acoustic survey of the northern North Sea and adjacent areas of Divisions IVb and VIa was carried out in the second half of July 1985 by research vessels from Norway and the United Kingdom. The survey and analysis procedures were the same as in previous years and the echo integrator values attributable to herring were converted to numbers of fish per unit area using the target strength/length relationship recommended by the Acoustic Survey Planning Group (Anon., 1983a):

TS per fish = 20 logL - 71.2 dB, where L is in cm

Estimated numbers at age and biomasses for each of the areas in Figure 2.4.1 are given in Table 2.4.1. In the western areas, 2-ringer recruits formed a large proportion of the total, whereas in the eastern area, 2- and 3-ringers were almost equally abundant. In the entire area surveyed, 30.1% of the 2-ringers were at maturity stages lower than stage 3. The total biomass was estimated to be 547,000 tonnes of which 435,000 tonnes were fish likely to spawn in 1985. The comparison with previous years is given in the text table below:

Spawning biomass (tonnes x 10^3)

Area	1982	1983	1984	1985
Orkney-Shetland	224	250	320	285
Moray Firth/Buchan	?	?	57	13
Fladen	?	?	76	73
Eastern area	?	?	13	43
Egersund Bank area	?	?	?	20

This provides no evidence of any increase between 1984 and 1985.

The numbers at age in 1984 and 1985 are given in Table 2.4.2 for the areas covered in both years. Estimates of Z obtained from these values are fairly uniform over age groups, with a weighted mean Z between 2-ringers and older in 1984 and 3-ringers and older in 1985 of 0.83.

The acoustic survey in 1985 covered almost the whole of Division IVa together with adjacent areas to the north, south and west. It is thus unlikely that any substantial concentrations were missed at the boundary of the area. In parts of the area surveyed, herring were observed close to the bottom. In those areas, it is, therefore, likely that the herring abundance is underestimated.

During November, a Norwegian research vessel carried out an acoustic survey in Division IVa and the eastern part of Division IVb. The survey grid in Division IVa was rather open and parts of the survey were influenced by bad weather. The area west of 1^{0}W was not covered at all. A considerable concentration of adult, spent herring was recorded on the northern part of Fladen ground, while rather little was observed in the rest of the surveyed part of Division IVa. Table 2.4.3 shows the estimated number of fish per age group. The estimates are based on TS = 20 log L - 71.2dB. The total estimate is considerably lower than the one from the July-August survey, and the age composition is less dominated by the 2- and 3-ringers. Those surveys are not quite comparable. Firstly, the effort used was nearly 5 times higher during July-August compared to November. Secondly, the proportion of the Division IVa stock staying outside the surveyed area might have been higher during November.

2.4.2 Eastern central North Sea (Division IVb east)

An acoustic survey was carried out in the Danish coastal area (see Figure 2.4.1) in July-August 1985 by a Danish research vessel. In this area, all herring sampled were 0- and 1-group. The target strength/length relationship used on this survey was:

$$TS/fish = 21.7 \log L - 75.5 \text{ dB}$$

For comparative purposes, the results of the survey were roughly converted to correspond to the TS/length relationship used in other areas of the North Sea (mean TS = -53.7dB in the Danish coast survey compared with -51.1dB for the same length distribution using the Planning Group TS/length relationship - a multiplicative factor of 1.82). They indicate a high abundance of 0- and 1-ring herring in a small area of the eastern North Sea.

The Norwegian survey in Division IVb east of 3^{0}E in November gave considerably lower but still rather high estimates of the 0-group (1984 year class). The results from both surveys are given below (millions of fish per age group):

Survey	Target strength/ length relationship	0-ringers	1-ringers
July-August	TS = 21.7 log L - 75.5dB	16,004	4,314
	TS = 20 log L - 71.2dB	8,793	2,370
November	TS = 20 log L - 71.2dB	3,723	153

2.4.3 Western central North Sea (Division IVb west)

The annual survey off the northeast coast of England (see Figure 2.4.1) was undertaken from 14 to 28 August 1985. The survey concentrated in an area extending from north of Whitby (54^{0}45'N) to south of Flamborough Head (54^{0}00'N), extending up to 15-20 miles off the coast. A limited survey was also undertaken in the Longstone area.

The spawning ground closure came into effect at midnight on 14 August soon after the survey commenced. At this time, a fleet of large trawlers (14 vessels) was operating 10-12 miles E/SE from Flamborough Head and moved just outside the closed area to continue fishing. A second fleet of about 17 trawlers was later encountered close to the 12-mile limit between Scarborough and Robin Hood's Bay. Catches of 35,500 tonnes were recorded from the area covered by the acoustic survey during August (Section 2.11.1, Figure 2.11.8).

In contrast to the 1984 survey, it proved difficult to demonstrate a progressive build-up of spawning concentrations over the period of the survey.

The length and age distributions of samples taken from the Longstone and three concentration areas off the Yorkshire coast (Whitby, Robin Hood's Bay and Flamborough) were all very similar and consequently were combined. Length and weight compositions by age groups are presented in Table 2.4.4.

The target-strength expression used was the same as that for the northern North Sea survey (Section 2.4.1). The overall mean length of 27.14 cm and mean weight of 166 g produced a target strength of -34.74 dB/kg.

Peak biomass estimates over the entire period of the survey amounted to 46,500 tonnes in the Whitby area, 41,200 tonnes off Robin Hood's Bay and 25,500 tonnes in the Flamborough area, giving a combined total of 113,200 tonnes. The maximum derived from a sequential run of surveys in the period 21-25 August, which covered all three concentration areas, was 103,400 tonnes. Very little was recorded in the Longstone area on 18-19 August except for a patch of larger 'plume' type shoals centered about 6-7 miles east of the Longstone Light.

It was evident that spawning was minimal over most of the survey period since the majority of fish caught were still in stage 5 maturity, and it appeared that fish had begun to aggregate in denser concentrations for a major spawning along the Yorkshire coast at the end of the survey on 27-28 August.

Local vessels reported very large concentrations of fish present off the Yorkshire coast during the first half of September and a commercial fishery by UK vessels developed at this time. A sample taken on 10 September showed all the fish in stage 6.

Herring larval surveys were undertaken off the northeast coast during September and October and back calculation of the likely spawning dates from larval production curves suggested that spawning commenced during the first week of August, but did not peak until the first half of September, which is in agreement with observations from the commercial fishery at this time.

The overall results of the September and October larval surveys in 1985 also showed a significant increase in spawning area compared with 1984.

The acoustic survey was relatively limited in time and area, and additionally appears to have covered a period of low spawning activity, which means that the acoustic biomass estimates can only be minimal. The maximum estimate (113,200 tonnes) was considerably less than that of 1984 (208,000 tonnes).

2.4.4 Southern North Sea and eastern Channel (Divisions IVc and VIId)

Two surveys were undertaken in the area shown in Figure 2.4.1, the first by R/V "Thalassa" from 11-23 November and the second by R/V "Clione" from 7-19 December 1985.

The first French survey of the Channel (11-14 November) extended to $00^{0}30'$E, and dense pelagic aggregations were located within the area west of Bassurelle Bank. The acoustic estimate of herring was 58,000 tonnes, these mainly in stage 5 maturity. The second Channel survey (16-20 November) covered much the same area as the first, extending a little further west (to $00^{0}10'$E). The acoustic estimate increased to about 85,000 tonnes. The very limited areas covered in the southern North Sea and Dover Straits on 14-15 November and 21-23 November produced estimates of 2,800 and 1,250 tonnes, respectively.

The English survey covered the eastern Channel from 7-15 December mainly within the French zone, extending to 00°40'W off the Bay of the Seine.

A fleet of large Dutch trawlers was operating during the period of the survey in an area bounded by 50°00'-50°30'N, 00°-1°00'E, the main fishery centred 25-30 miles off the French coast. These vessels caught an estimated 27,800 tonnes during December. The intensity of trawling effort in this area broke up the spawning shoals into a very fragmented state and acoustic densities were generally low. The only major concentration of spawning herring found was located 16.5 miles NW of Cap d'Antifer and, significantly, no commercial fishing operations were observed in this area. The acoustic estimate of spawning herring in the eastern Channel amounted to 53,000 tonnes, these mainly in stage 6 maturity.

The Southern Bight stage of the survey (15-19 December) recorded mainly spent herring in the area south of 52°N, these fish broadly distributed between the offshore Thames and continental coastal waters. The acoustic estimate for spent herring amounted to 69,000 tonnes.

Target strengths were determined for each area using the mean lengths and weights provided by samples taken during the survey. The values derived were -34.12 dB/kg for spawning fish and -33.57 dB/kg for spent fish. The basic target strength/length relationship referred to in Section 2.4.1 was used for both the French and English surveys. The recruiting 1982 class was clearly predominant (60-70%) in both the spawning and spent fish populations,and a comparison with the age structure derived from the French acoustic surveys and the Dutch and French commercial landings (Table 2.4.5) shows good agreement.

A summary of acoustic biomass estimates used by the Herring Assessment Working Group over the years 1981-85 in Divisions IVc and VIId is provided in Table 2.4.6.

2.5 Herring Larval Surveys

2.5.1 Herring Larval Survey Working Group report

At its meeting in 1986, the Working Group on Herring Larval Surveys South of 62°N (Anon., 1986b) reviewed the continued difficulties in calculating the annual larval abundance indices based on the abundance of only the smaller larvae. The major conclusion was that the very patchy distribution in space and in time of the newly-hatched larvae leads to very variable abundance indices. For instance, the time gaps between surveys may lead to hatching cohorts being completely excluded from the larval abundance indices, if they are not sampled within approximately 10 days of hatching.

Further, the Larval Survey Working Group evaluated the methods developed for estimating larval production, based on back calculation to the number of hatching larvae, from assumptions of linear growth in length and constant instantaneous mortality rates over the larval size range examined (6-16 mm). The Larval Survey Working Group adopted a modification of approaches presented by Burd (1985), Christensen (1985) and Lassen and Pedersen (1985), and estimated larval mortality rates and production for all areas and all years. The production estimates were based on an instantaneous mortality rate (z/k) of 0.4 per mm, and a growth rate of 0.35 mm/day for all areas and years. However, the present Working Group considered that the graphs of ln number/length indicated different area-specific natural mortality rates (z/k), and as a consequence, the Larval Survey Working Group estimates were recalculated using area-specific natural mortality rates. From present knowledge, it is not considered possible to use year-specific mortality rates for each area in the calculations. For all areas and years, a growth rate of 0.35 mm/day is used. This growth rate seems to give good agreement between calculated peak hatching periods and hatching periods estimated from other sources of information.

The growth rate of 0.35 mm/day falls into the upper range of growth rates estimated from the larval patch studies in the North Sea. The present Working Group recommends that further work on estimating mortality and growth rates of larvae should be encouraged.

The estimation procedure adopted assumed that all samples taken are random samples of the population. This is likely to introduce a bias in the case of directed sampling in high abundance areas. Indications are that this bias is likely to be small, but there was insufficient time available to examine this aspect more closely.

In order to calculate VPA-independent estimates of SSB from the larval production estimates, the Larval Survey Working Group examined the fecundity studies that are available for the North Sea stocks and for Division VIa N. The present Working Group adopted the procedure and used the ratio:

$$\frac{\text{Larval production estimate}}{\text{No. of eggs/kg SSB}}$$

to estimate the SSB. To optimise this estimation procedure in the future, it is important that effort should be directed to fecundity studies of the individual stocks.

The overall conclusion of the Herring Assessment Working Group is that the suggested method of larval production estimation seems to be a robust method that offers clear advantages over the larval abundance index method. Until further experience is gained with the production method, it is recommended that estimates based on both methods should be presented yearly to this Working Group. It is recommended that further development of the new production estimate method should be encouraged.

2.5.2 Estimates of larval production

The results of a comparison of larval abundance indices (Saville and Rankine, 1985) and of the larval production estimates (LPE)

(Anon., 1986b) are given in Table 2.5.1. From the table, it is concluded that the estimates in most years and areas are correlated, and that the LPE method seems the least sensitive to variations in sampling effort, patchy distributions, etc. The LPE for Orkney-Shetland in 1977 is considered to be an overestimate possibly due to immigration from Division VIa N into the area. The LPE's for Buchan in 1979, 1980 and 1981 are considered likely to be overestimates due to immigration from the Orkney-Shetland area into the Buchan area. No significant spawnings were observed in these years in the area. In the central North Sea, the survey coverages in 1974 were inadequate to provide a reliable estimate. From preliminary investigations of the effects of stratification on the LPE, it seems likely that the estimate for Divisions IVc + VIId in 1983 is an underestimate. An estimate close to double the LPE value seems more likely.

2.5.3 Estimates of SSB

The estimated SSB's from the larval production estimates are given in Table 2.5.2 and Figure 2.5.1. It was expected that the estimates should be underestimates, as no corrections are made for egg mortality. It seems, however, that this is generally not the case. In some years, the SSB's estimated on the basis of larval production (assuming no egg mortality) indicate a stock size in excess of that estimated by VPA. Unless the VPA estimates for those years were seriously wrong (which is possible), it appears that the SSB estimate based on larval production may sometimes, for unknown reasons, overestimate the actual spawning stock size. Some caution must be exercised, therefore, in using SSB estimates derived from larval production as absolute measures of stock size.

The comparison of VPA stock sizes and SSB estimates based on larval production in Figure 2.5.1 should not be used as evidence for the usefulness of either to estimate absolute stock size. In some areas (Divisions IVb and IVc), VPA estimates and larval production estimates have not been obtained completely independently of each other.

2.5.4 Herring larval surveys in 1985

The sampling intensity in all areas in 1984 was at an acceptable level, being broadly comparable to that in the preceding years.

In the Orkney-Shetland area, surveys were carried out by the Federal Republic of Germany, Netherlands and Scotland resulting in satisfactory coverage of the standard area in both the first and second halves of the month. The natural mortality rate (z/k) for this area was estimated to be 0.24 for the area (std. dev.=0.01, r^2 = 0.98, 10-16 mm larvae).

In the Buchan area, surveys by Denmark and Scotland gave a good coverage of the larval distributions. The Danish survey was directed towards the high abundance area around the Aberdeen Bank and is thus not representative for the whole Buchan area. In consequence, it was necessary to exclude the Danish survey from the calculations of larval production, as the larval production estimate would otherwise be biased. In spite of the exclusion of the Danish survey, the larval production estimate is considered to be acceptable since the Scottish survey covered all the cohorts in the area. The production estimate is approximately 546,000 tonnes.

The larval abundance index, however, should not be seriously biased by the Danish survey as most larvae recorded were larger than 9 mm. It was not possible to estimate the natural mortality rate (z/k) probably due to the Danish effort distribution. Using the larval abundance regression given by Saville and Rankine (1985), the SSB in Division IVa including Buchan is estimated to be approximately 663,000 tonnes.

In the central North Sea, the standard areas were covered satisfactorily in all time periods by England and the Netherlands. It is evident from the larval distributions that a spawning ground on the Dogger Bank has now been reoccupied after some 20 years in which no spawning occurred. The standard area used in the calculation of the larval production estimate in 1985 was increased by approximately 17% as the larval concentrations extended to the south of the standard area. The natural mortality rate (z/k) was estimated to be 0.42 (std. dev.=0.03, r^2 = 0.96, 8-16 mm larvae). From the larval abundance index regression (Saville and Rankine, 1985), the SSB is estimated to be approximately 281,000 tonnes. The production estimate for the larger area is approximately 470,000 tonnes.

In Divisions IVc + VIId, England, the Federal Republic of Germany and the Netherlands conducted surveys. The coverage in time and space was satisfactory apart from in the first half of January when 16 stations in the Southern Bight were not covered owing to the weather conditions. The natural mortality rate was estimated to be 0.48 (std. dev.=0.03, r^2 = 0.98, 10-16 mm larvae). The SSB was estimated to be approximately 131,000 tonnes from the larval production estimate. No regression is accepted between larval abundance indices and SSB.

2.6 Tagging Experiment

A meeting was held in Aberdeen, UK in January 1986 to evaluate the results of the herring microwire tagging experiment carried out from 1983-85 in the Orkney-Shetland area. The report from this meeting and the full analysis of the results of the experiment were available in the form of working papers. The experiment demonstrated the practicability of both the tagging and monitoring method and provided estimates of monitoring efficiency, tag shedding and tagging mortality. The scale of the experiment in the context of the present North Sea stock size, however, gave insufficient tag recoveries to obtain precise estimates of stock size, and the Working Group was, therefore, not able to use the results to refine the assessment.

2.7 State of the Stocks

2.7.1 Division IVa

The spawning stock biomasses estimated from acoustic surveys and larval surveys during the years 1979-85 are as follows:

Year	Spawning stock biomass ('000 tonnes)	
	Larval production estimate (LPE)	Acoustic surveys
1979	141	-
1980	146	-
1981	113	197
1982	243	224
1983	373	250
1984	450	466
1985	601	434

The larval surveys indicate a 30% increase from 1984 to 1985, while the acoustic surveys indicate a small decrease. In view of the differences in the two series of estimates given above, several VPA runs were made using the catch in numbers at age and various F's for 1985 to find one which gave a reasonable fit to the means of the larval and acoustic survey values. The exploitation pattern used for these trial runs was based on the average of the two last years which fit well to the exploitation pattern arising from the acoustic estimate of number per age group (Table 2.4.2) and the catch in number per age group in 1985 (Table 2.7.1). The set of F's giving the best fit are given together with the resulting stock size in number in Tables 2.7.2 and 2.7.3, respectively.

The maturity ogive used for the VPA runs in previous Working Group reports assumes all 2-ringers to be mature. This year, a new maturity ogive was used which assumed 82% of the 2-ringers to be mature during the years 1972-84 and 70% in 1985. These figures are based on the samples taken during the acoustic surveys in July-August in the years 1982-85. The applied mean weights at age at the time of spawning were the same as in last year's report. The resulting spawning stock biomasses for the years 1972-85 are given in Table 2.7.3.

2.7.2 Division IVb (Bank stock)

Data from acoustic and larval surveys were available as independent estimates of the size of the spawning stock in Division IVb in 1985. The acoustic estimate of 113,000 tonnes is considered to be a gross underestimate since only part of the spawning area was covered and peak spawning did not occur until after the period of the survey (Section 2.4.3). The larval production estimate of 470,000 tonnes is thought to be a more realistic figure, although attention is drawn to the limitations of this method discussed in Section 2.5.3.

It is important to note that large catches consisting of high proportions (65% by number) of immature 2- and 3-ring fish were taken in the Egersund Bank area (eastern part of Division IVb) during the third quarter of 1985. The greatest proportion was taken in September at a time when the spawning in the western part of Division IVb was at its peak. Large catches were also taken in the eastern area in 1984, although the proportion of immatures in these catches is not known. The Working Group considered that these fish would not have contributed to the spawning stock in either 1984 or 1985 and were, therefore, excluded from the catches used in the VPA for this area, but were included in the VPA for the total North Sea and for Divisions IVa and IVb combined (Sections 2.7.4-2.7.5).

A trial VPA run on 2-9+ ring fish was generated using an input F for 1985 equivalent to that used for 1984. Because of the strong recruitment to this fishery over the past few years and the lack of any stable exploitation pattern over this period, the mean exploitation pattern for the period 1972-74 from the initial run was smoothed and used to generate a series of VPA runs using a range of input fishing mortalities from F_{85}=0.1 to F_{85}=0.2. In order to tune the VPA, a regression of the spawning stock biomass from VPA [SSB(VPA)] on the spawning stock biomass estimated from larval production [SSB(LPE)] (Table 2.5.1) was calculated for the period 1972-76 prior to the closure of the fishery (Figure 2.7.1). Owing to insufficient coverage of the larval survey in 1974, this point has been omitted from the regression (Figure 2.7.1).

The regression based on these four points was then used to predict a spawning stock biomass for 1985. The estimated SSB(VPA) for 1985 for each of the VPA runs was then subtracted from this predicted value and the residuals plotted against input F (Figure 2.7.2). The point where the residuals are zero is at about F=0.16 and this value was, therefore, chosen as input F for 1985. Two further regressions of SSB(VPA) generated by F_{85}=0.15 and F_{85}=0.16 on SSB(LPE) for the whole time series of data from 1972-85 (omitting 1974) were then calculated in order to determine which of these was closest to that derived from the 1972-76 series. The results are presented in the test table below.

Spawning stock biomass 1985 ('000 tonnes)		Regression			
SSB(LPE)	SSB(VPA)	Data points	Intercept	slope	r
534	-	1972-76 (omit 1974)	12.46	1.11	0.91
494	534	F_{85} = 0.16 1972-85 (omit 1974)	1.24	1.05	0.94
528	570	F_{85} = 0.15 1972-85 (omit 1974)	-0.1	1.13	0.94

Both regressions based on VPA runs with input F_{85} of 0.15 and 0.16 give good correlations, have a slope of about 1.0 and an intercept close to the origin. Since the regression of F_{85}=0.16

predicts the same value for spawning stock biomass as that based on the short time series (1972-76), this value was chosen as input for the definitive run.

Results of VPA

The input catch in numbers for this VPA is given in Table 2.7.4. The results based on an input F_{85}=0.16 and a smoothed exploitation pattern for the period 1972-74 are given in Tables 2.7.5 and 2.7.6. Mean weights at age in the catch are presented in Table 2.8.2 and mean weights at age in the stock were assumed to be the same as in previous years.

The results indicate that the overall fishing mortality increased slightly in 1985 owing to an increase on 2- and 3-ring fish. The fishing mortality on age 4 and older shows a small decline. It is apparent that the spawning stock has continued to increase, although the increase between 1984 and 1985 is not as great as that between 1983 and 1984. The estimated spawning stock sizes over the period 1972-85 are plotted in Figure 2.7.3.

The estimates of spawning stock from this VPA differ markedly from those estimated in last year's report.

The Working Group draws attention to the problems that exist in estimating absolute stock sizes in a situation of a rapidly-expanding stock. All regressions used to predict either stock size or recruitment on the basis of survey indices (larval surveys, IYFS) are based on periods when both stock and recruitment were considerably smaller than they are at present. It is questionable, therefore, how valid these regressions are for predictive purposes in the present situation.

The problem is particularly great in the central North Sea (Division IVb), where the stock estimate is based entirely on the larval surveys. The resulting stock estimate of 530,000 tonnes requires an F value in 1985 which is conspicuously lower than the estimated F in Division IVa. The reason for this is not clear, but it could imply that a stock size of 530,000 tonnes in Division IVb is an overestimate.

2.7.3 Divisions IVc and VIId

The spawning stock biomass estimates provided by the French and English acoustic surveys (Section 2.4.4) were used to calculate input parameters for use in the VPA.

The peak estimates from the eastern Channel surveys in November and December were combined assuming that the difference in timing between the midpoints of the two surveys (24 days) was sufficiently great to reduce the chances of double counting to a minimum.

In this respect, it is of interest to compare the timing of the French and English acoustic surveys in relation to a weekly catch-per-unit-effort index derived from data supplied by French herring trawlers [using a method described by Robson (1966)]. This is shown in Figure 2.7.4. It is evident that the French surveys took place just prior to and into the week registering a major peak in cpue, whilst the English survey related to a secondary smaller peak towards the end of the fishing period.

The maximum estimate from the second French survey in November was 85,000 tonnes, whilst that from the English survey was 53,000 tonnes, giving a combined value of 138,000 tonnes. The English biomass estimate for spent herring in the Southern Bight of the North Sea (15-19 December) amounted to nearly 69,000 tonnes. Allowing for the difference in mean weight between spent and full herring could raise this estimate to around 76,000 tonnes of equivalent spawning fish, which is of the same order as the peak November estimate (85,000 tonnes) in the eastern Channel. The spent fish recorded in December could have originated from the spawning population covered by the French surveys in November.

The spawning stock biomass derived from the French survey was converted to numbers at age using age distributions from French commercial landings in November, and the English survey biomass was similarly converted using age distributions from the Dutch fishery in December. These age distributions were then combined and adjusted for catches in the last quarter to give population numbers at the end of the year. The catches in 1985 were then used to determine a fishing mortality coefficient for each age group (Table 2.7.7).

The spawning stock biomass at the end of the year was about 124,000 tonnes compared with 131,000 tonnes estimated from the larval production estimate (see Section 2.5). The VPA was thus run using input values of F derived from the acoustic estimates of stock size (Tables 2.7.8-2.7.10). The results cover the period 1964-85. Trends in yield and fishing mortality on 2- to 6-year-olds are presented for the years 1975-85 in Figure 2.7.5A. This indicates that F fluctuated around a value of 1.0 in the years 1980-83 and decreased to 0.6-0.7 in 1984-85, whilst the yield varied from just over 40,000 to nearly 70,000 tonnes in this period.

Changes in spawning stock biomass and recruitment from the VPA are compared with those from acoustic and larval surveys in Figure 2.7.5B. The VPA spawning stock estimate shows it in the range 45-55,000 tonnes from 1981-83 but then entering a sharply upwards trend from 1984-85, increasing to nearly three times the earlier level.

Larval production estimates of spawning stock biomass (Section 2.5.3, Table 2.5.2) suggest that the stock remained fairly constant from 1981-84 at around 105,000 tonnes (the 1983 value is an underestimate), increasing to 130,000 tonnes in 1985. The spawning stock estimates derived from acoustic surveys (summarised in Section 2.4.4) fall in the range 100-150,000 tonnes since 1981, with peak estimates in 1982 and 1983 and a decrease over the last two years.

Further evidence for relative stock levels over the last three years is provided by abundance indices derived from French herring trawler cpue data. These were calculated using a method developed by Laurec and Fonteneau (1978) and show that the stock appears to have remained relatively stable:

French herring trawl abundance indices

Year	Index of abundance
1983	2.2
1984	1.82
1985	1.84

The 1985 Working Group report (Anon., 1985) drew attention to discrepancies between results of the VPA, direct stock estimates and levels of fishing effort. Concern was expressed that the spawning stock estimates provided by VPA showed that the stock had increased by a factor of three times over the years 1981-84, whereas estimates from larval and acoustic surveys did not register this trend. This situation remains much the same following the 1986 assessments.

One explanation offered last year was that catches in Divisions IVa and IVb included a component of Downs herring which could result in a much greater F on the Downs stock than that used in the VPA on the Divisions IVc,VIId catches. At present, there is no reliable means of estimating the proportion of Downs herring caught in other parts of the North Sea, and the VPA has been run entirely on catches from Divisions IVc and VIId. There has been a large increase in fishing effort in the north and central North Sea in 1984-85 and the possible effect of this on the Downs stock must be taken into account when advising a TAC.

The fishery has remained largely dependent on recruitment each season and in 1985 the recruiting 1982 year class contributed 59% by weight to the stock.

2.7.4 VPA of Divisions IVa and IVb combined

A combined VPA was done for Divisions IVa and IVb to provide the necessary outputs for management advice.

The values for weight in the stock by year class are the same as applied in last year's report (Anon., 1985). The maturity ogive used in the VPA for Division IVa was also applied for the combined VPA. The VPA was tuned to the sum of the spawning stock biomasses from the separate VPA's for Divisions IVa and IVb, and the input catch in numbers and outputs are shown in Tables 2.7.11-2.7.13 and Figure 2.9.1. The spawning stock biomass increased by about 90% from 1983 to 1984, mainly due to the recruitment of the strong 1981 year class. From 1984 to 1985, the spawning stock biomass increased by about 20%.

2.7.5 Total North Sea VPA

A VPA for the total North Sea was done for the period 1947-85 using the catches in number given in Table 2.7.14. The F's used for the oldest age group for the years 1947-59 are the same as given in Anon. (1977). The catch in numbers by age group is the sum of the catches in Divisions IVa, IVb and IVc + VIId. The VPA was tuned to the sum of the spawning stocks in 1985 given by the VPA's for the separate divisions. For all the years, all fish of 3-ringers and older were assumed to be mature. Different percentages of maturity were used for different periods for the 2-ringers:

1947-55:	70%
1956-71:	100%
1972-84:	82%
1985:	70%

A natural mortality of 1.0, 0.8 and 0.1 was applied for 0-ringers, 1-ringers and older fish, respectively. The input F for 0-ringers was calculated from the catch of 0-ringers in 1985 and the estimated number of 1-ringers from the 1986 IYF survey. Similarly, the input F for the 1-ringers was calculated from the estimate of 1-ringers from the 1985 IYF survey and the catch in 1985. The F's for the older age groups in 1985 were obtained by a slight increase of the F's used in the combined VPA for Divisions IVa and IVb to match the total spawning stock biomass in all stock components combined. The outputs from the VPA given in Tables 2.7.15 and 2.7.16 indicate an increase in the spawning stock biomass from the lowest level in 1977 of 54,000 tonnes to a level of 1.2 million tonnes in 1985, which is similar to the level in 1965-66. Since new values of M are being used on 0- and 1-ringers since the whole VPA from 1947 was published, the entire series is given in the tables mentioned above. Mean weights at age used in the whole series for calculating biomass are also given in Table 2.7.14.

2.8 Mean Weight and Maturity at Age

2.8.1 Mean weight at age in the catch

The mean weights at age in 1985 are presented by divisions and quarters in Table 2.8.1. These have been weighted by numbers caught.

A comparison is made in Table 2.8.2 to show the differences in annual mean weights for age in 1985 compared with the values derived for earlier years [Table 2.16 in Anon. (1985)] for use in the ICES stock prediction programme. It is clearly evident that in most divisions and age groups there has been an overall decrease in mean weight, with the exception of 2-group fish in Division IVa which registered an increase. The apparently large increments in the oldest age groups are probably an artifact due to the use of an upper weight limit in the pre-1985 data. It seems evident that the values previously used for stock prediction are due for revision.

To evaluate changes in mean weight more critically would require comparison on a quarterly basis, since the annual means are weighted by numbers caught in each quarter and are thus dependent on the distribution of catch over the year. A preliminary evaluation of available quarterly data provides some evidence of a decreasing trend in mean weight at age at least in some areas.

Partial recruitment

The recent large increase in herring stocks within the North Sea raises the possibility of a return to partial recruitment observed in earlier periods of high stock density.

The Report on the 1984 Herring Acoustic Survey in the Northern North Sea (Simmonds *et al*, 1985) provides data on maturity distributions from biological samples taken during the course of the 1983 and 1984 surveys. These show a fairly wide variation in the proportion of immature 2-ring fish between the sub-areas sampled, although these fish were generally less than 23.5 cm in length. If a few extreme proportions are excluded, the general range of immature 2-ringers was 0-25% in 1983, 10-27% in 1984 and about 30% in 1985 (Section 2.4.1). Less than 5% of the 3-ringers were immature.

Additional maturity data provided by samples from Norwegian commercial catches made in the Norwegian sector of Division IVb during September 1985 (15,242 tonnes) show a very high proportion of immature 2- and 3-ring fish as shown below:

% Maturity distributions in Norwegian catch September 1985

Mat. stage	2-ring	3-ring
1	1.3	-
2	29.7	8.1
3	35.1	56.8
4	16.2	-
5	6.8	18.9
6	1.3	2.7
7	2.7	2.7
9	6.8	10.8
<4	66.1	64.9

The age structure from this Norwegian fishery (1-ring 54.8%; 2-ring 35.6%; 3-ring 8.0%, older 1.6%) shows that it primarily exploited an immature population in which the 2- and 3-ring fish were also largely immature.

Assuming that these fish are from North Sea stocks suggests that they remained in the eastern North Sea and did not migrate towards the western spawning areas with the mature elements of the population.

A Norwegian catch of 4,782 tonnes was also recorded in the third quarter from Division IVa E and, although maturities are not available, the age structure (1-ring 43.3%; 2-ring 41.5%; 3-ring 13.1%; older 2.1%) suggests a similar situation.

It is also of interest to compare the mean lengths and weights of 2- and 3-ring fish from the Norwegian September fishery in Division IVb with those from the August fisheries in closer proximity to the spawning areas of the western North Sea:

Area	Country	2-ring		3-ring	
		L(cm)	W(g)	L(cm)	W(g)
NW North Sea	Netherlands	25.2	139	27.3	186
E. Shetland	Scotland	25.8	169	28.3	222
Moray Firth	Scotland	25.2	157	27.9	212
S. Buchan	Scotland	26.2	175	28.3	222
S. Buchan	Netherlands	24.8	139	27.2	193
Yorkshire coast	Netherlands	25.8	147	27.8	193
Yorkshire coast	English acoustic survey	25.9	142	28.0	182
Division IVb (Nor.sector)	Norway	24.0	121	25.4	142

Data supplied by Working Group members.

This clearly shows that the average lengths and weights of both 2- and 3-ring fish in the Norwegian fishery were considerably less than those in the fisheries of the western North Sea, and the eastern 3-ring fish were generally smaller than most of the 2-ring observations from the west.

This very preliminary analysis of the immediately available data shows that consideration of maturity stage distributions should feature more prominently in assessments to determine the proportion of partial recruitment for use in VPA.

2.9 Projection of Catch and Stock Size for 1987 and 1988

2.9.1 Divisions IVa and IVb combined

The input data for the prediction of catch, stock size and spawning stock in 1987 and 1988 for Divisions IVa and IVb combined are given in Table 2.9.1. The stock size as 3-ringers and older fish in 1986 was taken from the outputs of the combined VPA for this area. Owing to big changes both in stock size and the fishery in this area over the last few years, the exploitation pattern from 1985 was applied in the prediction. Recruitment of the 1983 year class in 1986 was based on the IYFS index for the total North Sea reduced by the Downs component (see Section 2.3.4). By applying the F and natural mortality given in the VPA outputs for 1-ringers for the total North Sea in 1985, the 2-ringers in 1986 were estimated at 5,430 millions. Similarly, the IYFS index obtained for the 1-ringers in 1986 was projected using the same F as in 1985 to give an estimate of 2-ringers in 1987 for Divisions IVa and IVb (5,700 millions).

The input of recruitment of 2-ringers in 1988 was the average of 2-ringers for the period 1981-85 given by the VPA for this area.

The catch in 1986 was set to the TAC agreed between EEC and Norway: 500,000 tonnes. The weights at age in the catch in the prediction are the same as observed in 1985 (Section 2.8).

The results from the projection are given below ('000 tonnes) and are based on 2-ringers and older fish. The TAC in 1986 and catches for the former years are much higher than the catches generated using $F_{0.1}$ in 1987. The $F_{0.1}$ catch in 1987 will be 50% lower than the TAC in 1986. The effect of different levels of F in 1987 on the catch in 1987 and on the biomass in 1988 is shown in Figure 2.9.1.

1986				1987					1988	
Stock biomass (1 Jan)	SSB at spawn.	$\bar{F}_{(2-6)}$	Catch	Management option	$\bar{F}_{(2-6)}$	Stock biomass (1 Jan)	SSB at spawn.	Catch	Stock biomass (1 Jan)	SSB at spawn.
1,765	1,137	0.37	500	$F_{0.1}$ = 0.14		2,094	1,596	244	2,326	1,889
				0.8 x F_{85}=0.30			1,431	503	2,038	1,467
				F_{85} = 0.38			1,361	608	1,922	1,310
				F_{max} = 0.44			1,311	682	1,839	1,203

2.9.2 <u>Divisions IVc - VIId</u>

The input data used in the stock projections are summarised in Table 2.9.2. The recruitment used for 2-ringers in 1986 was 600 x 10^6 (1983 year class) based on a 10% proportion of the total North Sea recruitment for this year class derived from the IYFS. This is a higher value than that used in the 1985 projection (200 x 10^6) since it was considered that a 10% split for Downs herring was more realistic in relation to the relative distributions of spawning stock biomasses in the North Sea (see Section 2.3.4).

Recruitment in 1987 was estimated at 800 x 10^6 (1984 year class) on the basis of the regression between VPA 2-ringers and the English 0-group survey abundance indices.

Recruitment in 1988 was taken as the mean of the above two values, which incidentally was also similar to the 1981-85 mean for 2-ringers shown in the VPA output. The selected exploitation pattern was averaged (and slightly smoothed) over the years 1980-83.

The following management option projections were carried out:

<u>1986</u>:

(1) Catch of 70,000 tonnes (EEC agreed TAC)

(2) Catch of 6,000 tonnes (already taken in first quarter) with no further catch

1987

Each of the 1986 catch options using:

(1) $F_{0.1}$ ($\bar{F}_{(2-6)} = 0.14$)

(2) $\bar{F}_{87} = 0.5\ \bar{F}_{86}$ (assuming the TAC option in 1986)

(3) $\bar{F}_{87} = \bar{F}_{86}$

(4) $\bar{F}_{87} = \bar{F}_{85}$

The results of the projections are presented in Table 2.9.3. If it is assumed that the 70,000-tonne TAC will be taken in 1986, then exploitation in 1987 at the ACFM-recommended level of $F_{0.1}$ would reduce the catch to 22,000 tonnes but result in an increased SSB. If fishing mortality in 1987 is maintained at F = 0.58 (1986 TAC option), a catch of 76,000 tonnes results but the SSB shows little increase.

Long-term and short-term yields with consequent changes in spawning stock biomass are presented in Figures 2.7.5C and 2.7.5D for the assumption that the TAC will be taken in 1986.

2.9.3 Sub-area IV and Division VIId (Total North Sea)

The catch of juvenile herring (0- and 1-ringers) in 1985 was about 70,000 tonnes of which approximately 62,000 tonnes were taken in Division IVb. In order to evaluate the likely impact of different levels of fishing mortality on 1-ringers on TAC options, predictions were made for the total North Sea. Separate predictions including 1-ringers for the two separable management areas (Divisions IVa + IVb and IVc + VIId) are not possible because the catch in numbers and fishing mortality on 1-ringers cannot be estimated for the separate stocks.

The following alternative assumptions of F on 1-ringers were used:

a) $F_{(1-ri)}$ in 1986 and 1987 is half that on 1-ringers in 1985, i.e., 0.5 x 0.17 = 0.085;

b) $F_{(1-ri)}$ in 1986 and 1987 is equal to that in 1985, i.e., $F_{(1-ri)} = 0.17$;

c) $F_{(1-ri)}$ in 1986 and 1987 is equal to the F on 2-ringers in the respective years.

For each of the first two alternative assumptions, the catch in weight of 1-ringers in 1986 was subtracted from the TAC of 570,000 tonnes to give a TAC constraint in a prediction starting with recruitment as 2-ringers. For each of the management options in 1987, the recruitment of 2-ringers was calculated using the F on 1-ringers in 1986 and the number of survivors was used as input. The number of 1-ring recruits for 1987 and 1988 was determined as the mean number over the period 1981-85 from VPA. The numbers of 1-ring and 2-ring fish for 1 January 1986 are estimated from the IYFS survey (Sections 2.3.4 and 2.3.5).

In the third alternative assumption, the predictions were run starting with recruitment as 1-ringers.

The input catches in number and assumed recruitment levels are given in Table 2.9.4.

Catch and stock projection based on these inputs are given in Table 2.9.5.

2.10 Management Considerations

2.10.1 Adult fisheries

From the discussion on the state of the stocks in various parts of the North Sea (Section 2.7), it appears that the present level of exploitation is quite different in the southern, central and northern areas. This difference in exploitation level is a strong argument for maintaining the two existing management units: Divisions IVa + IVb, and Divisions IVc + VIId.

In last year's report, concern was expressed that fishing mortality in the southern stock (Divisions IVc + VIId) could already be far above $F_{0.1}$. This suspicion was confirmed by this year's assessment; it is now estimated that F on 3-ringers and older has fluctuated between 0.80 and 1.50 in recent years. A partial explanation for this could be the prolonged exposure of this stock to fisheries throughout the year. It is probably exploited not only during autumn and winter in the southern North Sea and Channel, but also during spring and summer in the central and northern North Sea.

Management measures should aim at reducing F on the southern stock. It should be realised that a substantial proportion of the Downs catch is taken in Divisions IVa,b. In former years, the Working Group has suggested that up to 20% of the Downs TAC could be transferred from Divisions IVc + VIId to Divisions IVa,b.

The Working Group now suggests that ACFM formulates its advice differently by reducing any catch option for this area by 20% to allow for fish that will be taken in more northern areas.

In view of the many uncertainties regarding the southern stock, together with the present alarmingly-high exploitation level, the Working Group suggests that a final decision concerning the TAC for 1987 is postponed until early 1987. At that time, new information about the development of the stock in 1986 will be available, together with a first estimate of the 1983 year class.

Finally, it is recommended that strict enforcement of TAC's should be applied in the fishery in the southern North Sea and Channel. Because the trawl fishery on the spawning grounds is capable of taking large quantities of herring in a very short time, special provisions should be taken to ensure that the national TAC's are not overshot.

In Division IVb, there are currently closures of the spawning areas at spawning time. No further discussion on this subject took place at the Working Group meeting.

2.10.2 Juvenile fisheries

The management of the juvenile fisheries has been discussed in detail in earlier reports and no new biological material on this subject is available. The results from VPA (Section 2.7) show that the present "sprat box" in the eastern North Sea has been quite effective in reducing F on 0-group herring in the two most recent years and, therefore, this regulation should be maintained.

2.11 Requests from the ad hoc Multispecies Working Group

2.11.1 Geographical distribution of the catches

Data on geographical distribution of the catches in 1985 were available from Denmark (human consumption), Federal Republic of Germany, the Netherlands, Norway (catches for reduction), UK (England), UK (Scotland), France and unallocated catches. The data were in most cases derived from logbooks or market sampling programmes with a satisfactory coverage. The catches by the Netherlands were distributed on ICES rectangles using the geographical distribution of the random biological samples. For all countries, the geographical data were scaled to the national catches in each month. In the case of Denmark, the catches were scaled to the total catch of herring for human consumption.

Figures 2.11.1 to 2.11.12 show the total catch of the six countries by ICES rectangles for each month in 1985.

The data available represent countries taking approximately 95% of the total catch of adult herring and the quantities indicated on the figures are, therefore, close to the total international catch of adult herring in 1985.

The *ad hoc* Multispecies Working Group has asked for information on the quarterly geographical distribution of herring in the North Sea. The catch by area and time can, however, not be used as a direct measure of the abundance. An important reason for this is the lack of agreement in management of the North Sea herring in 1985 between the EEC and Norway. Norwegian and EEC vessels were, therefore, only allowed to fish in their own economic zone (indicated on the figures). The fishing effort in the two zones could be markedly different and catches cannot, therefore, be assumed to be proportional to the biomass.

However, within the EEC and the Norwegian zones, respectively, the catches by ICES rectangle could be an indicator of stock size.

The preference for herring of a particular quality (for economic reasons) could, however, direct the effort to certain areas of the North Sea and the Working Group, therefore, stresses that the figures only give a rough indication of the biomass within the two economic zones.

2.11.2 Quarterly catches of North Sea herring

Discrepancies between the catch at-age-tables in reports of the Herring Working Group and the quarterly catch-at-age tables reported to the Multispecies Working Group were identified at last year's meeting. The quarterly data base was revised recently and a full data set was not yet worked up at the present meeting. The biological samples are rather scanty from the middle 1970's and this gives rise to relatively large SOP discrepancies when biological samples are applied in areas without samples. A detailed output of these calculations will be provided by the Danish Institute (N.A. Nielsen) and circulated to the contact persons in the relevant countries. When commented and checked, the data will be submitted to the Multispecies Working Group and discussed at the next meeting of this Working Group.

3 DIVISION IIIa HERRING

3.1 Stock Composition

A split between spring and autumn spawners has been made in the case of the IYFS for age groups 0-2 inclusive. The results are shown in Section 3.4 which deals with the recruitment.

In the case of the commercial landings, too few samples were available from the industrial fisheries in the second half of 1985 to permit an estimation of the two components amongst 0- and 1-group herring. In the case of the 2-group, very few autumn spawners appear to be present in the second half of the year, whereas about 25% of the catches of this year class in early 1985 may be assigned to what are probably North Sea herring.

3.2 The Fishery

3.2.1 Landings

Table 3.2.1 shows the landings by countries and by the Skagerrak and Kattegat, respectively, during 1976-85. When looking at its content, it should be kept in mind that Danish data for 1984 and Danish and Swedish data for 1985 are provided by Working Group members and have no official standing.

With this proviso, the total figure for 1985 is the highest on record and the 242,000 tonnes represents an increase of 18% from 1984. Almost the entire increase took place in the Skagerrak.

The distribution of the landings by quarters is shown below:

First quarter	16%
Second quarter	11%
Third quarter	51%
Fourth quarter	22%

As in earlier years, an important proportion of the landings was taken in the small-meshed trawl fishery which, together with small herring sorted from human consumption catches, was used for meal and oil. This amount is estimated at about 130,000 tonnes, while 120,000 tonnes were used for human consumption.

3.2.2 Catch in numbers at age

The species composition in the Danish industrial landings is based on a rather large number of samples collected by the fishery inspectors. The biological data base is, however, far from being satisfactory, and the same is the case for the Swedish industrial landings, being mainly young herring rejected for human consumption.

Table 3.2.2 shows, by quarters, the number caught at age for those parts of the total landings where a data base is available, i.e.,

1) All landings for human consumption.

2) All industrial landings in the first half of 1985.

3) Industrial landings from the southern Kattegat (south of 56°30'N) in the second half of 1985.

These landings comprise about 151,000 tonnes or 62% of the total. They also comprise the major part, by far, of the 2-group which is the youngest age group of direct importance to an assessment of the Division IIIa herring. The number of 0- and 1-groups which dominate the unsampled landings of industrial herring in the third and fourth quarters (about 90,000 tonnes) cannot be estimated and are consequently not included in Table 3.2.2.

The catches of 2-group in the two first quarters are an overestimate of the spring-spawned component. From data on 1-group late in 1984 and on 2-group in the IYFS, it appears that the content of autumn spawners is close to 25%. Having extracted these from Table 3.2.2, the following input figures for an eventual VPA are arrived at:

Winter rings	Catch no. (millions)
2	537.5
3	347.9
4	107.7
5	20.5
6	7.0
7	0.8
8+	0.2

The underestimate of 2-group in the second half of 1985, due to lack of sampling of the industrial landings in the Skagerrak and the northern Kattegat, is probably negligible. The few samples at hand do not contain any 2-group and the average for the years 1981-83 suggests that 2-group in the second half of the year amounts to less than 50 million specimens, i.e., less than 10% of the number stated in Table 3.2.2.

3.3 Biomass Estimates from Acoustic Survey

Three acoustic surveys of herring biomass were carried out in 1985. In July-August, a small part of the shallow waters in the western Skagerrak were surveyed by R/V "Dana" and in August-September, Division IIIa and Sub-divisions 22-24 in the western Baltic were surveyed by R/V "Argos" and R/V "Dana". A third survey by R/V "Eldjarn",covering Division IIIa and the North Sea, was made in November.

The integration was carried out using 38 kHz echosounders and a Simrad QD integrator ("Dana") and a NORD-10 computer system ("Argos" and "Eldjarn"), respectively. All systems were calibrated on standard copper spheres. An intercalibration of the system on board R/V "Argos" and R/V "Dana", carried out in 1984, resulted in a good regression with insignificant differences, and the integrator output was pooled together in the August-September survey.

In the two first surveys, a depth stratification was used, whereas in the November survey, statistical rectangles were used as strata. The area shallower than 20 m was sparsely covered in the two latest surveys and the estimates are applicable to the area deeper than 20 m.

The results of the August-September survey are based on 4,100 nautical miles of integrations and the species composition in 59 pelagic hauls. In the November survey, integration was carried out over 1,155 nautical miles, and a total of 21 pelagic hauls were made.

Recorded echo levels were split on species according to the composition in the catches. The following length-dependent TS regressions were used:

Herring and sprat:

TS_{ind} = 21.7 log L - 75.5 dB
(Halldorsson and Reynisson, 1983).

Gadoids:

TS_{ind} = 21.8 log L - 72.7 dB
(Anon., 1984b).

For mackerel, spurdogs and other species without a swimbladder, a TS 6 dB below that of herring was used. The TS regressions applied are consistent with those used in previous years. The number of herring was allocated to age according to the age composition in the trawl samples.

The estimates of the herring stocks in Division IIIa in August-September for the period 1979-85 are given in Table 3.3.1. It should be noted that the estimates from 1979-83 are not raised to the area used in 1984-85. The estimates of the herring stocks in Sub-divisions 22-24 are given in Table 3.3.2. The November-December estimates in 1982, 1983 and 1985 are given in Table 3.3.3.

A striking feature in the 1985 stock estimates is the very high number of 0-ringers both in August and September and, especially, in November. The July-August estimate of 3.05×10^9 fish could be compared with the estimate of 3.15×10^9 fish in the same area some weeks later. Usually, the 0-group is distributed in shallow waters and consequently not adequately covered by the August-September survey. This year, the 0-group was distributed over the whole area, including the deeper parts, and not concentrated in the Kattegat and in shallow waters in Skagerrak, as seen in earlier years. The higher estimate of the 0-group in November could be interpreted as an offshore migration to deeper waters in the autumn which are better covered by the surveys.

Even if the November estimate of 9.3×10^9 fish does not include shallow waters where part of the 0-group fish still occurred, the estimate could, however, be too high. The estimate in November is likely to be influenced by inefficient trawling in the upper water layers during this survey. The difference in age distribution between the estimate and the commercial catches at that time corroborates the suspicion of a low trawling efficiency as seen from the percentage age compositions in the text table below:

Source	0	1	2	3	4	5
Acoustic estimate						
November	90.9	9.0	0.1	-	-	-
Commercial catches 4th quarter						
Skagerrak	22.0	26.3	36.6	11.1	3.2	0.8
Kattegat	73.2	11.7	8.4	4.9	1.4	0.3

Even if there is some doubt about the very high estimate of the 0-group, the strength of that year class is confirmed by the IYFS index in February 1986 (see Section 3.4) and the catches of 0-group in 1985 (Table 3.2.2).

In contrast, the estimate in August-September of older herring (≥3-group) was very low: 85 million fish compared to 918 million in 1984 and 485 million in 1983. The low estimate of older herring is not corroborated by information from the catches or by the trend in the IYFS survey (see Section 3.4).

The scarcity of old herring in the estimate is likely to be influenced by the timing of the survey in relation to the migration pattern and the behaviour of the adult herring. The surveys have started earlier, and the 1985 survey started on 14 August compared to 22 August in 1984.

Normally, the older and larger herring are found and fished in the western part of the Skagerrak during August. The shoals are then moving eastward and remain for a period in the eastern part of the Skagerrak along the Swedish coast before passing into the archipelago and southwards to Kattegat and to the overwintering areas in the Sound and the southwestern Baltic.

In August 1985, according to information from the fishing fleet, large herring were observed in small, dense shoals in the surface layers throughout the day and night in the western part of the Skagerrak. This behaviour has been observed in earlier years to be common in June-July. The shoals were difficult to catch even with pair trawls, and the catches at the time of the survey were dominated by the 2- and 1-group herring. This behaviour pattern strongly indicates that the adult herring could not be integrated or fishedby the research vessel, even if the adult herring were present in the area surveyed.

The fishing pattern which has prevailed for a long period indicates that the old herring are concentrated or start to aggregate in fishable shoals in the western part of the Skagerrak. Thus, it could not be excluded that a part of the adult stock had penetrated into the eastern part of Division IVa during the time of the survey.

The adult herring showed up in the catches after the survey in September. Comparing the proportion by weight of old (large) herring in the acoustic estimates with the proportion of large herring in the Swedish herring fisheries corroborates that the older herring were not adequately covered by the survey. The proportion of larger herring is compared in the text table below:

Year	Proportion of large herring in Swedish catches		Proportion of ≥3 ringed herring in acoustic surveys (0-gr. excluded)
	September	October	August
1984	0.25	0.16	0.30
1985	0.30	0.21	0.06

It could be concluded that the present estimate derived from the acoustic survey in August-September underestimates the adult stock in Division IIIa and indicates a very strong 0-group abundance in that division.

3.4 Recruitment

3.4.1 Abundance of 1-group herring

The 1986 Young Fish Survey in February was carried out in spite of extensive ice cover east of 10°E and a total of 40 trawl hauls were made in 15 rectangles. The highest catches of 1-group herring were obtained in the Kattegat and the eastern part of the Skagerrak, whereas lower catches were made in the western part. The total index for 1986 calculated as an area-weighted arithmetic mean is 21,499 which is about 270% higher than the very high index of 1985 and the highest ever recorded in the area.

During the 1986 survey, a new GOV trawl, thicker wire and larger trawl doors were used. The trawl hauls were made according to the description of the standard GOV trawl. The new larger trawl doors are very close to the size recommended and the new arrangement reduced the opening from about 6.5 m to 5.5-6.0 meters. Measurements of the door spread indicate that the new set had an increased swept area. It is, therefore, possible that the fishing power could be somewhat higher with the new trawl set. A comparable increase in catch rates was not observed in other species.

An attempt to split the 1-group herring into spring- and autumn-spawned components was carried out using the same method used in previous years (Anon., 1984c). The indices for the period 1980-86 are given in the text table below and the mean length and the proportions of the components are shown in Table 3.4.1.

Year	Index		
	Total	Spring spawners	Autumn spawners
1980	2,311	1,607	704
1981	3,246	966	2,250
1982	2,560	1,408	1,152
1983	5,419	1,522	3,897
1984	6,035	2,793[1]	3,242[1]
1985	7,994	3,947[1]	4,047[1]
1986	21,489	5,554[1]	15,935[1]

[1] Tentative.

The split of the 1-group herring in 1986 gave as the best fit to the observed length frequency distribution components with mean lengths of 11.5-14.9 cm. The components have mean lengths within the range of spring spawners observed in previous years (Table 3.4.1), and autumn-spawned components with a mean length of 16 cm or more were not found. The mean vertebral count of the components does not, however, support that all were indigenous spring spawners. The mean VS count and number of each component are shown in the text table below:

Mean length (cm)	Mean VS	Number
11.5	56.08	6,154
11.8	56.10	4,906
13.1	56.18	79,291
13.3	56.20	67,746
14.0	56.28	320,930
14.4	56.28	195,713
14.9	56.31	81,349

The result of the split is basically dependent on a difference in growth between the spring-spawned component born approximately six months later than the autumn-spawned components. The outcome of the analysis of the 1986 data, as well as of the 1985 data, strongly indicates that the North Sea component had a reduced growth. The reduced mean length of the North Sea components is also observed in the North Sea area for these year classes (see Section 2.3).

From available VS counts, the 1984 year class in the central and northern components in the North Sea has VS values in the range 56.35-56.57. The VS counts of the components indicate that the autumn- and spring-spawned components have not been separated completely. A tentative split was carried out allocating components with VS counts below 56.28 to the spring spawners. The VS counts indicate that the tentative split has overestimated the spring-spawning component in 1985 and possibly underestimated it in 1986.

3.4.2 Abundance of 2-group and 3-group herring in the IYFS

Abundance indices of 2-group and 3-group herring in the Young Fish Survey have been calculated and, in the case of the 2-group herring, separated by the same methods used in the analysis of 1-group herring. The 3-group herring in the IYFS are all spring spawners and a split has not been needed.

The indices are shown in the text table below:

Year	2-group herring			3-group herring
	Total	Spring spawners	Autumn spawners	Spring spawners
1980	387	307	80	147
1981	4,531	4,270	261	315
1981[1]	1,393	1,318	75	-
1982	549	445	104	183
1983	1,063	946	117	184
1984	1,947	1,419	528	344
1985	2,473	1,867	606	1,392
1986	2,738	1,562	1,176	1,737

[1] Excluding one large haul.

All indices indicate an increased abundance of older fish in the area.

The high 2-group index in the 1981 survey is very dependent on a very large catch in one haul in the largest stratum (<35-m depth). There are no obvious reasons to exclude the catch in that haul in the analyses except the large contribution to the index. The very high index is not supported by other information of that year class (e.g., 1-group index catches, acoustic estimates) and the comparison is based on the lower value where the large catch has been excluded.

The separation of the 2-group has proved to give components that could be allocated to spring- and autumn-spawned herring with good confidence over the whole series. The result of the split in 1985 and 1986 is shown in the text table below:

Year	Spring-spawned herring		Autumn-spawned herring	
	Mean length	VS	Mean length	VS
1985	18.6	<56.0	24.2	56.51
	18.7	<56.0	-	-
	20.5	56.02	-	-
	20.7	56.04	-	-
1986	18.6	55.90	23.5	56.32
	18.7	55.83	25.0	56.44
	20.6	56.06	25.8	56.46

The two sets of indices of the same year class could be compared to test if the IYFS could be used to estimate the abundance of 2-group. The regressions of 1-group index on 2-group index for spring- and autumn-spawned herring have the following values:

Spring-spawned herring: $Y = 0.322X + 602.8$
$r = 0.72$, $df = 4$, $t = 2.08$

Autumn-spawned herring: $Y = 0.256X - 219.3$
$r = 0.84$, $df = 4$, $t = 3.1$

Both regressions are significant and the regressions are shown in Figure 3.4.1.

The spring-spawned herring index of 2-group herring could also be tested against the catches of the same year class in Division IIIa the same year as the IYFS. The regression of 2-group spring spawners on the catches in 1980-84 gave the following values:

$$Y = 0.486X + 76.6$$
$$r = 0.97,\quad df = 3,\quad t = 7.45$$

The regression is significant as shown in Figure 3.4.2.

3.5 State of the Stocks and Management Considerations

3.5.1 General remarks

Tagging experiments (Jönsson and Biester, 1979) have shown that spring spawners from the Rügen area (western Baltic) migrate to Division IIIa outside the spawning season. In an earlier report (Anon., 1983b), the Working Group pointed to the highly significant correlation between 2-group estimates in Division IIIa and western Baltic-Belt Seas, respectively, and between catches of 3-group fish in the western Baltic and catches of 2-group fish in Division IIIa one year earlier. The Working Group suggested the feasibility of a joint assessment and the Working Group on Pelagic Species in the Baltic did a trial run at its meeting later in 1983.

In later reports, both working groups have expanded on the possibility and, indeed, need for a joint assessment. At the present meeting, an overlap in time allowed members from the two working groups to discuss the problems involved and to agree on a feasible strategy. This is discussed in more detail in Section 3.5.3.

3.5.2 Management of sprat/young herring fisheries

The total catch of 0- and 1-group herring in Division IIIa in 1985 amounted to more than 100,000 tonnes. According to present views concerning the stock composition of juvenile herring in this area, it is assumed that most of the juveniles caught were potential recruits to the North Sea stocks.

Last year, the Working Group commented upon the ineffectiveness of existing conservation measures aimed at reducing the catch of juvenile herring. It was suggested that a combined quota for sprat and juvenile herring might be a more feasible method of controlling the sprat/herring fishery. This would leave room for the existence of a small-meshed clupeoid fishery, which in former years used to concentrate on sprat, but which presently is forced to take mainly juvenile herring owing to the drastically changed species composition in the area.

This problem was further considered in October 1985 by the *ad hoc* Study Group on Management Measures for the Small-Meshed Fishery in Division IIIa (Anon., 1986c), which came to the same conclusion. Contrary to the situation in the North Sea, it is not possible in Division IIIa to delimit a specific sub-area that contains most of the juvenile herring and that could be closed for small-meshed fisheries. The only way to restrict catches of juvenile herring in Division IIIa, apart from completely stopping all small-meshed fisheries, is a combined TAC for the catch of small clupeoids.

The level of this combined TAC will be a compromise between the objective to reduce catches of juvenile herring as far as possible (in order to maximise catches of adult herring) and the socio-economic objective of avoiding too drastic a disruption in one sector of the fishery. For 1986, an agreement has been reached between management parties in this area to set a combined sprat/juvenile herring TAC at 80,000 tonnes. If this TAC is adhered to, it will be a first and major step towards reducing the catches of juvenile herring in this area.

3.5.3 Adult herring in Division IIIa

On the present assumption that the major part of the adult herring present in Division IIIa belongs to spawning communities in the Baltic-Belt Seas, prognoses in the form of catch options should be based on a combined VPA using catches of 2-group and older from both areas. The two working groups involved agreed to a combined VPA being run by the Baltic Pelagic Working Group and tuned to a combination of 2-group estimates from IYFS and 1-group estimates from the German Democratic Republic young fish survey. It should then be possible to produce options for different levels of F in the two management areas as well as for the stock *in toto*.

With the present timing of the two working groups, the assessment and management advice have to be dealt with by the Working Group on Assessment of Pelagic Stocks in the Baltic including data for Division IIIa catches provided by the present Working Group.

4 CELTIC SEA AND DIVISION VIIj HERRING

4.1 Introduction

The herring fisheries in the Celtic Sea and Division VIIj are considered to exploit the same stock. The assessments of the stock and the management of the fisheries have been combined since 1982.

4.2 The Fishery in 1985/86

4.2.1 Catch data

The total catches from the combined areas both by year and by season (1 April - 31 March) are given in Tables 4.2.1 and 4.2.2. The only countries fishing in the area during 1985/86 were France and Ireland, with by far the greatest proportion of the total catch being taken by Ireland. The total provisional catch taken during 1985/86 was 16,200 tonnes, which was about 3,500 tonnes lower than the 1984/85 catch. The catch in 1985 was 16,000 tonnes compared with a TAC recommended by ACFM for this area of 13,000 tonnes, the figure adopted by the management body for 1985. There has been no change in recent years in the seasonal distribution of the fishery; approximately 80% of the total catch is taken during the October to January period by boats fishing the spawning concentrations.

As in recent years, catches throughout the winter fishery were largely restricted by lack of markets and the Irish fleet fished under small nightly quotas. The fishery was closed for a short period during November and December because the overall quota had been exceeded. Large concentrations of herring were reported on the spawning grounds, particularly during the December/January period.

4.2.2 Catches in numbers at age

The total seasonal catches in number data are shown in Table 4.2.3. These are based completely on Irish data, the French catches in 1985 having been raised to numbers at age using Irish samples for the appropriate period. The age distributions are dominated by the 1980, 1981 and 1982 year classes which were exceptionally strong and are largely responsible for the recovery of the stock. The 1983 year class contributed about 14% of the total catch.

4.3 Larval Surveys

Larval surveys have not been carried out in this area during 1985/86, thus bringing to an end a series which began in 1979. It was, therefore, not possible to obtain an independent index of stock sizes or to determine the trends of the different spawning components within the overall stock. The 1984/85 larval surveys had indicated that the winter-spawning component had recovered at a more rapid rate than the autumn-spawning component. It is unlikely that these surveys will be resumed during 1986/87.

4.4 Estimates of Fishing Mortality and VPA

Because of the different trends exhibited in the 1984/85 larval surveys, separate assessments were attempted by the 1985 Working Groups for both autumn- and winter-spawning components. These assessments were based on a number of dubious assumptions concerning the splitting of the catches-in-number data for each component. However, both assessments resulted in spawning stock sizes of the two components which were approximately equal resulting in an overall spawning stock in the area in 1985/86 of about 100,000 tonnes. It was decided not to carry out separate assessments for the 1985/86 season, because of the absence of larval surveys and the doubts expressed about the separation of the catches in previous years into the different components. An examination of the percentage age compositions in the autumn and winter catches showed a much more uniform distribution of 2-winter-ring fish than that observed during 1981-84. (The proportion of 2-winter-ring fish had been considerably higher in the catches of the winter spawners than in the catches of the autumn spawners during the 1981-84 period, suggesting a much higher recruitment to the winter-spawning component.) The catches taken during the autumn and winter periods during 1985/86 were about equal. Therefore, on the assumption of a more uniform recruitment to both components during the year and the fact that both components were estimated at about the same level during 1984/85, it is likely that they will still be at about the same relative proportion during 1985/86.

For the most recent year, there are no independent data on the size of the two components. It was, therefore, decided to carry out one assessment for the stock, in line with those carried out prior to 1985. ACFM considered that a total catch of 22,000 tonnes during 1985/86 would produce an overall F on both components of about 0.18, resulting in a spawning stock in 1985/86 of about 110,000 tonnes. This was about the same level as the highest recorded over the historic time series. The 1985/86 catches were in fact less than those predicted by ACFM and the total spawning stock might, therefore, be more than 110,000 tonnes. However, as this was considered unlikely, it was decided to assume a level of F in 1985/86 which would generate a spawning stock of about 100,000 tonnes. A value of F = 0.17 produced a spawning stock of the required level and thus was considered a realistic value of F for 1985/86.

Results from VPA

The results from the VPA (Tables 4.4.1 and 4.4.2) using an input F = 0.17 in 1985/86 show that the spawning stock has increased each year since 1980 due to a number of good year classes. The value of M on 1-winter-ring fish was increased from 0.1 to 0.8 throughout the VPA. The spawning stock in 1985 is estimated to be 100,000 tonnes. The values of F have fallen each year since 1981, when they were at a high level (F = 0.92) on the 2- to 7-winter-ring fish. Some high values of F are indicated in the older fish each year since 1980. It is difficult to know whether this is because of poor sampling of some of the catches or because of a high fishing rate on some of the weaker year classes, e.g., those of 1977 and 1978. However, as has been pointed out by previous Working Groups (Anon., 1983b) there are no periods in this fishery when the F values can be considered as low. Recruitment since 1975 has been at two very different levels. From 1975 to 1980, the average value was 118 million fish, but since 1980, there has been a dramatic increase and the average from 1981 to 1984 is 522 million fish.

4.5 Recruitment for Stock Prediction

As has been shown above, there have been very different levels of recruitment in recent years. The 1983 Working Group used the young herring surveys carried out in the Irish Sea as an indication of recruitment to the Celtic Sea stock. Although the index from the young fish surveys, shown in Section 7 on the Irish Sea assessment, indicates that the 1984 year class is another strong one, it has not been possible to show a sufficiently good relationship between those indices and the number of 1-winter-ring fish from the VPA for predictive purposes. The 1985 Working Group, using M = 0.1 on 1-winter-ring fish, estimated recruitment to the winter spawners as 100 million fish based entirely on the catches of 1-winter-ringers in 1983-85 and the F values in those years. The value for the autumn-spawning component, again with M = 0.1 on 1 winter-ring fish, was taken as 77 million fish which was based on the geometric mean for the last ten years. It was decided that a geometric mean value of recruitment for the 1975-84 period would be the most realistic value to use for predictive purposes. This was calculated to be 214 million fish. This is a rather low level considering the recent strong year classes which have entered the fishery since 1981 and the size of the present spawning stock. However, because of the rapid changes that have taken place in both stock and recruitment, it is considered prudent to use a conservative value.

4.6 Weight at Age

The mean weights at age for the stock in this area are shown in Table 4.6.1. As the fishery takes place during the spawning period, the mean weights at age in the spawning stock are considered to be the same as those in the catches. The mean weights for 1985/86 have been used to update the data for VPA, but the data used for predictions are based on the average of the 1983-85 period.

The mean weights used in the VPA for 1985/86 are based on Irish data for the main fishery and are slightly different from those used by the 1984/85 Working Group. The overall difference, however, is less than 3%.

4.7 Stock Predictions and Management Considerations

The stock calculated at 1 April 1986 has been used to predict future catches and stock sizes. Recruitment has been assumed to be constant in 1986-88 and the input data for predictions are shown in Table 4.6.1. The agreed TAC for 1986 is 14,000 tonnes. However, the TAC has always been exceeded in this fishery. The Working Group considered that, as the difference between the TAC and the 1985/86 catches was not large, it would be justifiable to carry out only one catch option for 1986. The catch assumed to be taken in 1986 was, therefore, 16,000 tonnes. The spawning stock calculated for 1986 is about 111,000 tonnes which is about the highest level recorded, and it is apparent that this level of spawning stock has been obtained by a series of very good recruiting year classes. The recruitment level used in the predictions is barely sufficient to maintain this spawning stock even at very low levels of F. Fishing at $F_{0.1} = 0.16$ in 1986 will yield catches of about 17,000 tonnes.

Stock projections are given in Table 4.7.1 and in Figure 4.7.1.

4.8 Safe Biological Limits and Long-term Potential

Following the re-opening of the Celtic Sea fishery in 1982, the 1983 Working Group examined the development of the stock in the area since 1958 in order to define a desired stock level to which the stock should be rebuilt. At that meeting, the Working Group considered the problem in detail, in particular the stock-recruitment relationship and the yield/biomass ratio. The stock-recruitment relationship has been re-examined because of the additional data available. It is clear that there is no obvious relationship between stock ands recruitment, except that there appeared to be a period in the mid-1970's when recruitment and stock sizes were both low.

It is clear that several good year classes (e.g., those of 1979, 1980, 1981 and 1982) were all produced when the spawning stock was below 40,000 tonnes. From 1958 to 1972, when stocks were at a fairly high level averaging 80,000 tonnes, the average recruitment was 272 million. From 1973 to 1978, when the stock was collapsing and reduced to a low level (31,000 tonnes), the average recruitment was 118 million. However, from 1979 to 1982, when the stock was still at a very low level, very good recruitment was produced and averaged 522 million.

The questions posed by ACFM in relation to stock and recruitment could be answered as follows:

1) The available evidence indicates that recruitment was very low in the 1970's when spawning stocks were also low. Low stocks can, however, produce good recruitment.

2) The spawning stock is currently believed to be at a high level, comparable with the highest levels recorded during the historic series from 1958-85.

3) The spawning stock has shown a rapid increase since recruitment recovered in 1981 (the 1979-81 year classes were all produced when the stock was still at a low level).

The examination of the yield/biomass ratio carried out by the 1983 Working Group over the different periods of stock sizes and changing stock composition indicated that the catch levels have been maintained so long as they do not constantly exceed 20% of the spawning stock biomass. When, however, catches consistently exceeded 30% of the biomass, the stock collapsed. At the present high level of stock and recruitment, the yield/biomass ratio would, therefore, suggest that catches of 20-25,000 tonnes could be maintained.

The present yield-per-recruit curve would indicate that, if average recruitment of 214 million fish (i.e., the level used in the short-term predictions) were maintained, then the long-term yield of $F_{0.1}$ would correspond to 13,000 tonnes.

Apart from the above considerations, a number of estimates of maximum sustainable yield have been made for the stock in this area. It must be emphasized that all these assume stable conditions in which constant recruitment is produced. Burd and Bracken (1965) considered that for long-term exploitation of the fishery, the maximum economic yield would be catches of 12-15,000 tonnes per annum. Molloy (1969) concluded that when the stock was at a high level because of a series of very good recruitments, the maximum sustainable yield would be around 22,000 tonnes. Corten (1972), suggested that the management objective should be to limit catches to about 22,000 tonnes, provided recruitment remained high, but pointed out that the optimum level of exploitation might be considerably below this level. These conclusions would seem to agree with those made as a result of the examination of the yield/biomass ratio. However, since it is not possible to define a lower level of stock size below which the stocks should not be allowed to drop, the Working Group considers that a safe biological limit for this stock should be defined in terms of fishing mortality rate and not stock size.

It is important to stress that sufficient investigations be maintained on this stock to enable annual estimates of mortality to be calculated and also to detect changes in recruitment levels as early as possible. This is particularly important because of the collapse that occurred in the stock in the mid-1970's when a decrease in recruitment was not detected until the stock had declined to a very low level.

5 WEST OF SCOTLAND HERRING

5.1 Division VIa North

5.1.1 The fishery

The catches reported by each country for this area are given in Table 5.1.1. There have been some small changes to the preliminary total catch for 1984 given in last year's report. The preliminary total catch reported for 1985 is 44,933 tonnes. This is about 40% below the 1984 level of 75,154 tonnes and substantially less than the agreed TAC of 56,500 tonnes. This shortfall is almost entirely due to the 9,500-tonne reduction in catch by the Scottish fleet and to the absence of unallocated catches which represented 22% of the total in 1984.

In the 1985 Working Group report, it was stated that since the reopening of the fishery in this area in 1981, there had been a significant change in the seasonal and geographical distribution of the fishery. Since 1982, Scottish catches, which in all years had represented more than 50% of the total, had been mainly taken on offshore grounds during the summer. Prior to the closure in 1978, this fishery had been carried out in the winter on inshore grounds in the Minch. In 1985, however, fishing reverted to the pre-closure pattern. Scottish catches represent 62% of the total and of this only 7% was taken between April and September. Taking the total international catch, 40% was taken in the first three months of the year entirely by Scottish boats and, of this, approximately half originated from the Minch.

The change in the fishing pattern between 1984 and 1985 had significant implications for the catch of 1-ringed fish which was almost 16 times greater than in the previous year (see Section 5.1.2) and also for the mean weight at age in the catch (see Section 5.1.6).

5.1.2 Catch in numbers at age

The estimated numbers at age caught in Division VIa North in each of the years 1970 - 85 are given in Table 5.1.2. For 1985, age composition data were available from the Federal Republic of Germany, the Netherlands, Norway and Scotland. The Faroese and small French catches were converted to numbers at age using data from the Norwegian fishery which operated in a similar manner to the Faroese. The practice used in the 1985 Working Group of applying the Scottish purse seine age composition data to Faroese catches was not considered appropriate in this case because of the increased fishing activity in the Minch.

In previous years, catches of 1-ringed herring in the Moray Firth have been included in the catch-in-numbers data in Division VIa North on the basis that these fish recruit primarily to the west coast stock. In 1985, no catches of Moray Firth juveniles were recorded.

As in 1984, the 1981 year class represented a high proportion of the catch (48% by numbers), again indicating that this is a strong year class. The catch of 1-group fish was substantially higher in 1985 than in the previous year. However, this should not necessarily be interpreted as being indicative of a good 1983 year class since the change in the fishing pattern, described in Section 5.1.1, concentrated effort in the inshore areas where younger age groups predominate in the population.

5.1.3 Larval surveys

As in 1984, larval surveys were carried out in Division VIa North by the Federal Republic of Germany and Scotland, and excellent coverage in time and space was achieved.

Two outputs from the surveys were available to the Working Group: first, the abundance index (LAI) calculated as described in the 1985 report of the Herring Larval Working Group (HLWG), previous values of which were given by Saville and Rankine (1985); secondly, the larval production estimate (LPE) calculated as described in the 1986 report of the HLWG. This production estimate was converted into an estimate of the spawning stock biomass using the mean fecundity/kg values given in the 1986 HLWG report. In this estimate, no attempt is made to account for egg mortality.

The calculation of the LPE uses a mortality rate (Z/mm) to convert length distributions into production of 6-mm larvae over time. The HLWG calculated values of Z for each year and the mean of the time series was 0.42 for Division VIa North. A value of 0.4 was, therefore, used for all years in the calculation of the LPE. The use of Z = 0.4, as opposed to 0.42, results in approximately a 12% reduction in the LPE throughout the time series 1973-85, which was considered to be well within the likely precision of the method.

5.1.4 Acoustic survey

An acoustic survey of Division VIa North was carried out by a Scottish vessel during November 1985. The survey was a repeat of one carried out in 1983 (Heath, 1984) but covering a larger area.

Integration of signals from a 38 KHz sounder was carried out using an Aberdeen Echo-integrator, and fish echotraces were sampled whenever possible using a Jackson mid-water trawl fitted with a 20-mm codend.

Target strengths for herring were estimated for sub-areas of the survey. Sub-areas were assigned on the basis of the distribution and length composition of catches. For this purpose, length frequency data from a demersal trawl survey using a GOV trawl carried out in December 1985 were included in the analysis. The mean target strength per fish was calculated using the relationship:

$$\text{TS/fish} = 20 \log L - 71.2 \text{ dB} \quad (L = \text{length in cm})$$

Observations within each sub-area were then averaged giving equal weighting to each haul to produce an area mean TS/fish. Similarly, the mean weight per fish was calculated from a weight/length relationship based on 331 observations of individual weights and lengths collected during the acoustic survey in November.

Age and length data collected during the acoustic and demersal trawling surveys were not significantly different. Data from these two surveys were, therefore, combined to produce a single age/length key for each sub-area of the survey. Using these keys, the numbers and biomasses of each year class were calculated for each sub-area and for the whole of Division VIa North.

Age/maturity keys constructed from the trawl catch data indicated 80% by number recruitment of 2-ringed fish to the spawning stock in Division VIa North. Only 3% of the 3-ringers were immature. The mean weight of immature 2-ringers was 0.106 kg, whilst mature fish of this age had a mean weight of 0.123 kg. These data were used to estimate the spawning stock biomass from the survey data as 3-ringer and older biomass plus 82% by weight of 2-ringer biomass.

The results indicated a total population during the survey of 297,000 tonnes with 216,000 tonnes being mature fish. Adding on the commercial catch of 2-ringers and older from September, October and half of November (9,000 tonnes) gives an estimated spawning stock at 1 September of 225,000 tonnes.

The survey in 1983 only covered that part of Division VIa North to the north of 57°30'N, so that a direct comparison of these results with the 1985 survey is not possible. However, 98% by numbers of the juvenile fish (0- and 1-ringers) in the 1985 survey were in the northern part of the region so that a direct comparison of the abundance of 1-ringers was possible. The results indicate that the 1983 year class was very much more strongly represented than the 1981 year class had been in 1983.

<u>Numbers of 1-ringers north of 57°30'N</u>

Survey year	Year class	Number (millions)
1983	1981	28.1
1985	1983	1,016.4

These results conflict markedly with the results of the Scottish demersal trawl surveys carried out in the first quarters of 1984 and 1986 (see Section 5.1.5)

5.1.5 <u>Recruitment</u>

At previous Working Group meetings, data on the catch rates of 2-ringers during Scottish bottom trawl surveys carried out during the first quarter of each year were used to estimate the number of recruits. The survey results were taken as indications rather than as precise estimates, since a convincing relationship with VPA results could not be established.

These surveys have covered the whole of Division VIa North but only data from hauls off the north coast of Scotland and in the North Minch were used for this analysis, for two reasons:

i) 2-ringed herring have been almost entirely restricted to catches in these two areas.

ii) In 1984, the survey was restricted to this area, on account of mechanical difficulties with the research vessel.

Abundance indices of 2-ringers were calculated for the years 1981-86 according to the following procedure:

i) Catch rates of 2-ringers were normalised to a tow duration of 1 hour. (All tows were normally of 1-hour duration.)

ii) Mean catch per tow was calculated as the arithmetic mean of catch rates for all valid hauls in each of the sub-areas.

iii) Mean catch rates for the sub-areas were combined as an unweighted mean to give the recruitment index.

The results, along with the number of hauls used to estimate the index in each year, are shown in Table 5.1.3.

First, it should be noted that these results are based on only a small number of hauls in each year. Secondly, the results are clearly in conflict with the estimated sizes of the year classes sampled as 1-ringers two months earlier during the acoustic surveys. An indication of the source of this discrepancy is in the distribution of the recruiting age groups in the two types of survey. In the acoustic surveys, 90% of the 1-ringers in Division VIa North were found in the Minch in both 1983 and 1985. In the trawling surveys, the proportion of the 2-ringer index derived from hauls in the Minch was greater than 95% in all years except 1984 when this proportion was only 25%.

The index for this year class (1981) stands out as being an order of magnitude higher than any other in the series. Whilst it is clear from the catch-in-number data as well as from the results of the VPA that the 1981 year class is very large, one should be cautious about using the trawl survey index as a quantitative measure since it is clearly influenced by the timing of the arrival of recruits from the North Sea and hence on the occurrence of 2-ringers off the north coast of Scotland.

The acoustic survey in November can only provide a minimum estimate of the abundance of the recruiting year class. However, the 1983 survey was clearly a gross underestimate of the 1981 year class which arrived in large numbers from the North Sea later than usual during the trawling survey causing this to be biassed upwards relative to other years.

Because of this effect, it was not considered helpful to use the trawl survey index as a measure of the size of recruiting year classes in Division VIa North.

For the purpose of projecting catches and stock sizes in 1987 and 1988, respectively, two options remain for estimating the likely recruitment of 2-ringers in 1986, 1987 and 1988. First, the 1973-

82 geometric mean of the number of 2-ringers from the VPA (320 millions) may be used for all prediction years. The selected time period contains no outstanding year classes and is to be considered as being conservative. Secondly, for estimating recruitment in 1986, the estimated numbers of the 1983 year class in the acoustic survey, after a suitable correction for catches taken between the survey and the end of the year, may be used as a minimum likely recruitment. Examination of the stock numbers for each age group during the acoustic survey and the VPA estimate for 1 January 1986 (Figure 5.1.1) indicate very close agreement for 3-ringers and older fish. For comparison, the expected number of 2-ringers based on 1985 catches of 1-ringers, having applied the same exploitation pattern as in previous years, is also shown in the figure. Clearly, the acoustic survey of the 1983 year class is a reasonable value to accept as a minimum likely recruitment, and after subtraction of the commercial catches of 11 millions taken during December, the value is 1,028 millions.

This estimate suggests that the abundance of the 1983 year class is almost as high as that of the 1981 year class (1,304 millions from VPA). Observations in neighbouring stocks tend to support this conclusion.

In view of the considerations above, the estimated recruitment of 2-ringers in 1986 was taken to be 1,028 millions for the purpose of catch projections. For 1987 and 1988, the 1973-82 mean was used.

5.1.6 Mean weight at age

The mean weights at age in the catch and in the stock for this population were revised at the 1985 Working Group meeting in order to adjust the data to the changed fishing pattern after the reopening of the fishery in this area (see Section 5.1.1).

Inspection of the data from the 1985 fishery clearly shows that these are substantially lower than the revised data from last year's assessment as a result of the change in the geographical distribution of the fishery in 1985 to that prevailing in the preclosure period. Therefore, the 1985 weight-at-age data were used after being smoothed by fitting a von Bertalanffy curve and are given in Table 5.1.4. The SOP for 1985 is almost identical to the reported catch in that year.

The mean weights in the stock are used as in last year's assessment.

5.1.7 Spawning stock biomass and fishing mortality in 1985

Considering first the LAI (Table 5.1.5), regression of the converged (1973-81) values of spawning stock biomass (SSB) from a VPA using a fishing mortality of 0.21 on ages 2-7 in 1985 against the index provides a significant relationship. Using this relationship, the SSB estimated from the 1985 index is 339,000 tonnes.

Taking the LPE of SSB simply as an index in the first instance, a similar exercise to that described above also produces a significant relationship (Table 5.1.5) which indicates an SSB in 1985 of 274,000 tonnes. In this case, it is important to notice that the constant term of this relationship is very small and that the coefficient is close to 1.0 (see Figure 5.1.2). This suggests that the absolute value of SSB of 266,000 tonnes given by the LPE may not be unrealistic.

The difference between the LAI and the LPE estimates of SSB is approximately 25% of the LPE value. No indication of likely confidence limits is available so it is not known if this difference is significant . However, the superior theoretical basis of the LPE suggests that more credence should be given to this value. This view is supported by the results of the acoustic survey (Section 5.1.4) which gives an SSB estimate closer to the LPE value.

A series of VPA's was run for the years 1973 to 1985 with F values for 1985 ranging from 0.15 to 0.30. The SSB estimates obtained from the different runs were then regressed against the SSB estimates from LPE's. The results are summarised in Figure 5.1.3 and are as follows:

i) The correlation coefficients are highest within the range of F from 0.18 to 0.21.

ii) The slope of the regression line reaches the level of 1.0 required by the underlying theory if F = 0.20.

iii) The sum of the residuals for the years 1983-85 is reduced towards zero with increasing fishing mortality. However, if the SSB estimate from LPE of 266,000 tonnes is considered to be the minimum target level, any F higher than 0.22 is ruled out on this basis.

The residuals for 1985 only are reduced to zero between fishing mortalities of 0.21 and 0.22.

iv) The SSB estimates decrease with increasing F and the target level of 266,000 tonnes is exceeded at a fishing mortality of 0.21.

On these grounds, a fishing mortality of 0.21 in 1985 was accepted as the best estimate.

The VPA gives an SSB estimate of 283,000 tonnes for 1985 which is close to the mean of the three fishery-independent estimates of 278,000 tonnes.

5.1.8 Results of the assessment

As a consequence of the high year-to-year variability in the catch of 1-ringers which does not necessarily reflect year-class strength, converged VPA estimates of this age group cannot be used to predict recruitment in catch projections. Calculations of 1-ringer population size are, therefore, of little significance in the VPA of this stock and are, therefore, not included in the analysis.

The results of the assessment are given in Tables 5.1.6 and 5.1.7 and are shown in Figure 5.1.4. They are in good agreement with those obtained at the previous Working Group meeting both in terms of SSB and fishing mortality. Also, the trend in the development of the SSB from larval production estimates is reasonably well reflected.

The spawning stock biomasses in the VPA (Table 5.1.7) show that there was a rapid recovery of the stock once the fishery was closed in mid-1978. This recovery was, however, halted with the reopening of the fishery in 1981.

The increase of the spawning stock biomass in 1984 and 1985 is due to the recruitment to the spawning stock of the good 1981 year class. A further increase is expected in 1986 when the good 1983 year class recruits to the spawning stock. The intervening 1982 year class is of about average size.

Only two years after the reopening of the fishery, fishing mortality increased to the relatively high level of 0.50 followed by a continous decrease. The 1985 value of 0.21 is the lowest in this series but still about 50% above the $F_{0.1}$ level of 0.141.

The reduction of F from 1983 to 1984 and 1985 is consistent with the reduction in effort since 1984 due to diversion of fishing activity of Scottish vessels to the Shetland area resulting in a lower catch in Division VIa North.

5.1.9 Projection

The results of the assessment were used to project yields in 1987 and stock biomasses for adult (2+) herring at the beginning of 1988 as well as at spawning time (spawning stock biomass) for different levels of fishing mortality in 1987. Estimates of spawning stock biomass in 1988 have been made by applying 2/3 of both the natural and fishing mortality of the previous year in 1988. The 1-ringers have not been included in the projection since they do not contribute significantly to the total catch.

The projections are made on the assumption that the agreed TAC for 1986 of 51,850 tonnes will be taken.

The parameters used are given in Table 5.1.8 and the results are shown in Figure 5.1.4. Selected management options are given in the text table below:

1986					1987				1988	
Stock biom, (2+)[1]	SSB[2]	$\bar{F}_{(2-7)}$	Catch (2+)[3]	Management option	Stock biom, (2+)[1]	SSB[2]	$\bar{F}_{(2-7)}$	Catch (2+)	Stock biom, (2+)[1]	SSB[2]
458	376	0.194	51.9	$F_{0.1}$=2/3 x F_{85}	442	376	0.141	38	432	367
				F_{87} = F_{85}		359	0.21	55	406	330

Weights in '000 tonnes.
[1]Stock biomass calculated at 1 January.
[2]SSB calculated at spawning time, i.e., 1 September.
[3]The assumed catch in 1986 corresponds to the agreed TAC of 51,850 tonnes.

It is clear from the projections that, if the main aim is to at least maintain the spawning stock biomass at the present relatively high level to reduce the risk of recruitment failure, the exploitation rate will have to be reduced to at least the $F_{0.1}$ level and maintained there.

Continued fishing at the present level of exploitation would reduce the size of the spawning stock by about 10% at the 1988 spawning season.

5.1.10 Long-term potential yield

Total annual catches from the west of Scotland herring stock are documented from 1930 onwards. The data were presented by Saville and Bailey (1980), and these authors performed a VPA back to 1957 to examine the changes in fishing mortalities and stock sizes over this period.

From 1930 to 1965, catches were stable with a mean value of approximately 52,000 tonnes with a standard deviation of 14,000 tonnes. From 1968-71, catches increased by a factor of more than 2, reaching a peak of more than 200,000 tonnes in 1973. However, during the same period, mean F on ages 2-7 increased from the stable level between 0.20 and 0.35 for the period 1957-70, to over 0.8 in 1974. The estimated spawning stock size over the same period rose from the stable pre-1965 level of approximately 200,000 tonnes to about 600,000 tonnes in 1972.

Following the peak catches and fishing mortalities in the early 1970's which corresponded with the introduction of purse seine fishing in the area, catches declined very rapidly to only 22,000 tonnes in the first half of 1978, coincident with an all-time minimum spawning stock of 70,000 tonnes. At this point the fishery was closed.

Stock size recovered rapidly during the closure and fishing commenced again in 1981. Catches since 1981 have been relatively stable although fishing mortality was relatively high (0.5) in the period immediately following reopening.

The establishment of a summer fishery in the Shetland area following the recovery of the North Sea herring stocks has reduced fishing pressure on the west of Scotland stock, and catches and fishing mortality rates are now similar to those observed in the stable period up to 1965.

Examination of the catch- and stock-in-number data shows that the massive increase in catches in the early 1970's was sustained almost entirely by a single exceptional year class (1969) which was the biggest on record. The estimated number of this year class joining the stock as 2-ringers in 1972 was 3,000 millions. Recruitment of this age group in the stable period prior to 1965 was generally in the range of 300-600 millions. On this basis, and considering the Y/R value at the $F_{0.1}$ level, the long-term yield from the west of Scotland herring is within the range of 45,000 to 60,000 tonnes which corresponds to the average catch in the stable period.

5.1.11 Safe biological limits

No convincing stock and recruitment relationship can be established for the Division VIa North herring stock, so considerations of this type cannot be used to to identify a safe biological limit in terms of spawning stock biomass.

Inspection of the historic fishing mortality data of the stable period prior to 1965 indicates that an F not exceeding 0.35 did not drive the stock to collapse. Therefore, that level might indicate the upper value which should not be exceeded in the management of the stock. This does not mean that this level should constantly be used as a target. A fishing mortality in the order of $F_{0.1}$ is preferable and would reduce the risk of approaching or even exceeding the safe biological limit.

However, management of the stock on the basis of a mortality rate criterion contains an element of risk after a period of above-average recruitment due to inertia in the ability of fleets to substantially reduce effort when, as must inevitably happen, recruitment returns to levels more typical for the stock. This typical level may be regarded as a primary biological characteristic of the environment occupied by the stock. In view of this, a safe exploitation limit might be regarded as the annual catch which the stock is able to sustain during periods of typical recruitment (see Section 5.1.10). Authorisation of catches in excess of this during periods of consistently higher recruitment must contain a high risk factor even though they may be safe in the immediate term with respect to fishing mortality.

5.1.12 Research and data requirements

Catch and biological data for this stock are generally of a high quality and are well documented. This is a situation which must be maintained.

With regard to the fishery-independent estimates of spawning stock size, the larval surveys appear to be providing a good record of trends in stock size and should be continued. In this context, it is most important that new fecundity data be collected from this stock, as the existing data are almost 15 years old and must be supplemented with observations from the Shetland area.

The acoustic survey covering the whole of Division VIa North for the first time in 1985 has been used by this Working Group to provide an estimate of stock size and recruitment. For these reasons, this survey should be continued.

5.2 Clyde Herring

5.2.1 The fishery

The reported landings from the Firth of Clyde in Scottish ports in 1985 were 3,001 tonnes (Table 5.2.1). A further 22 tonnes was landed at Irish Sea ports. Boxes of herring sampled weighed rather more than the nominal weight.

In 1985, sampling for discarding was carried out on a number of vessels in each month of the fishery. The estimated proportion of the catch discarded over the entire season was 28% by weight. The total catch in the Clyde in 1985 including discards is estimated to be approximately 4,800 tonnes. The landings in this fishery are used entirely for human consumption.

Catch in numbers at age in 1985 was estimated from samples of landings (corrected for the percentage that boxes were overweight) and discards. The age composition in the landings and discards in each month is given in Table 5.2.2. Three- and 4-ringers were the most abundant age groups, while 2- and particularly 1-ringers were poorly represented in the catches.

5.2.2 Fishing mortality and population size

Because accurate discard data are available for only two years, the number of 1-ringers caught prior to 1984 cannot be estimated. For this reason, a VPA was carried out on 2-ringers and older.

A trial run indicated that in the period 1982-84, the value of F on 2-ringers was approximately twice that on the older age goups. This exploitation pattern was subsequently used in all further calculations. To estimate an input value of F, the number of days absence from port by all vessels taking part in the fishery (pair trawlers) was examined for the years 1974-85. These effort data are given in Table 5.2.3. As explained in the previous year's report, there is no correlation between F and effort in the years for which the estimates of F are not greatly affected by the input value (i.e., 1974-80). If one assumes that there is a linear relationship between F and the number of days fishing, however, then a value of input F in 1985 can be chosen which gives the best fit to a linear relationship. The correlation coefficients and intercepts on the F-axis are given in the text table below for a range of values of input F.

Input F in 1985 weighted F_{3-9}	Correlation coefficient (r)	Intercept F-axis
0.05	0.72	-0.19
0.10	0.74	-0.12
0.20	0.71	+0.01
0.30	0.63	+0.11

The value of weighted F_{3-9} in 1985 that best fits the series of effort data is thus between 0.1 and 0.2. A VPA based on an input F of 0.15 is given in Tables 5.2.4 - 5.2.6.

For the years 1982-85, an SOP check indicated a major discrepancy. New weight-at-age data based on sampling of both catches and discards in 1985 demonstrated that the values used in previous years do not apply to present catches. The new values given in Table 5.2.7 have, therefore, been used in the years 1982-85 and in subsequent catch predictions. For calculations of spawning stock biomass, the 1985 values of weight at age for the month of September have been used. On the basis of the most recent few years, the proportion of mortality in the period before spawning is taken to be 0.9 for F and 0.67 for M.

Using the new weights at age and exploitation pattern, $F_{0.1}$ is calculated to be 0.27 on the reference age group (2-ringers), associated with F = 0.135 on 3-ringers and older.

The results of the VPA given in Tables 5.2.5 and 5.2.6 indicate that F has been relatively stable in this fishery since 1980 when TAC's were introduced.

From 1970-85, the estimated number of 2-ringer recruits varied between 8.2 and 59.6 million, with median and geometric mean values of 19.35 and 21.9 million, respectively. A value of 19.35 million at 1 January has been used in the projections for both 1986 and 1987.

5.2.3 Management considerations

The estimated stock in numbers at age at 1 January 1986 is given in Table 5.2.6. In 1986, the agreed TAC is 3,100 tonnes excluding discards. To estimate the likely level of discarding in 1986, the estimated values of F at age in 1984 and 1985 from the VPA were allocated to landings and discards. The resulting estimates are given in Table 5.2.8. The validity of using the estimated proportions of F in landings and discards in making projections receives some support from the fact that the overall rate of discarding decreased from 40% in 1984 to 28% in 1985. This was associated with a decrease in the proportion of 1- and 2-ringers in the catches in 1985 (see Tables 5.2.2 and 5.2.4).

Using the division of F into that attributable to landings and discards in Table 5.2.8 and the weight at age in landings and discards in Table 5.2.7, values of F in 1986 were calculated that would produce landings at the level of the TAC (3,100 tonnes). These are given in Table 5.2.9. This indicated values of F_2=0.25

and F_3=0.125 in 1986. The predicted stock in number at 1 January 1987 is also given in Table 5.2.9.

Catch and stock projections were made using a range of values of F and are given in the text table below:

1985	1986				1987				
Spawn. stock biom.	F_2	Land-ings	Dis-cards	Spawn. stock biom.	Management option	F_2	Land-ings	Dis-cards	Spawn. stock biom.
28,100	0.25	3,150	550	27,000	$F_{0.1}$	0.27	3,210	580	25,300
					$F_{87} = F_{85}$	0.30	3,540	640	25,000

5.2.4 Long-term potential

Since the Clyde herring population forms a component of a stock or stocks that spawn outside the Clyde, it is neither possible nor appropriate to define a safe biological limit to the size of the population. The Clyde population, however, contributes to the spawning potential of adjacent stocks and it is, therefore, appropriate to manage it at the same level of fishing mortality rate as is advised for other herring stocks.

From the end of the last century until the late 1960's, the mean catch in the Clyde was around 14,000 tonnes per annum, after which catches decreased. A high proportion of the catches in the earlier period were composed of local spring spawners. Recent larval and acoustic surveys of the spawning area, however, indicate that the indigenous stock is still at a low level, and commercial catches are predominantly of autumn spawners. Since these are the result of recruitment from other stocks, it is unlikely that the historic level of catches will be reached unless and until recruitment to the local spring-spawning stock recovers. The cause of the continued low level of recruitment is not known, but it is clearly appropriate to continue the closure of the fishery during the spawning season, January-March. The distribution of this stock at other times of the year is not well well understood, but there was some earlier evidence of a seasonal emigration from the Clyde into other parts of Division VIa.

6 HERRING IN DIVISIONS VIa (SOUTH) AND VIIb,c

6.1 The Fishery

6.1.1 Catch data

The catches by each country fishing in this area from 1976-84 and the preliminary catches for 1985 are given in Table 6.1.1. The preliminary catch for 1985 decreased to about 23,300 tonnes, compared with 27,400 tonnes in 1984. No revisions have been made to the 1984 data. The main catches from this area are taken by Ireland. The proportion of unallocated catches taken in 1985 was 52%.

The TAC recommended by ACFM for 1985 was 14,000 tonnes and this figure was adopted by the EC. In 1985, the main catches by the Irish fleet were taken off the northwest coast of Ireland in the second quarter, while the main catches by the Dutch fleet were taken during the third and fourth quarters. A higher proportion of the catch (27%) was taken in the fourth quarter than in 1984. Shoals were reported by the Irish fleet to be difficult to locate during the year, although this may have been because of the smaller number of boats participating in the fishery.

Small quantities of herring were reduced to fishmeal during the year, but no figures were available at the time of this meeting.

6.1.2 Catches in numbers at age

The catches in numbers at age from this fishery are shown in Table 6.1.2. No changes have been made to the 1984 data. The 1985 figures are based on Irish and Dutch sampling data. The predominant age class present was that from 1981 and this contributed about 50% of the catches in Division VIa South and about 35% of the catches in Division VIIb. This year class also contributed about 50% of the catches made in both areas in 1984 which was the highest percentage contribution by any year class since 1970. The 1982 year class (2-winter-ring fish in 1985) appears to be considerably weaker and contributed only 8% to the catches in Division VIa South and about 18% to the catches in Division VIIb.

6.2 Larval Surveys

Larval surveys have been carried out in this area for a number of years by Scotland and Ireland. The Scottish surveys which have been carried out since 1972 have not always covered the southern part of Division VIa South and in some years have not extended over the entire spawning season. The Irish surveys which cover the main spawning areas in both Divisions VIa South and VIIb have, however, only been carried out since 1981. The Herring Larval Working Group has suggested a new standard area for Divisions VIa South and VIIb and surveys in future years will be concentrated in this area. Previous working groups have used a regression using the larval index in Division VIa South alone to predict the spawning stock biomass in the whole of Divisions VIa South and VIIb. This regression has a very high intercept, and

Saville and Rankine (1985) have pointed out that the original regression used at the previous working group meetings was based on miscalculated larval indices. However, a new regression based on recalculated larval indices for Division VIa South and the SSB from the 1984 VPA also has a very high intercept ($y = 0.126x + 79.625$) and does not appear to be suitable for the combined area. The larval surveys in Division VIa South have, therefore, not been used for the assessment in the combined areas.

It is not yet possible to use the larval indices calculated from the Irish surveys carried out in the new standard area in Divisions VIa and VIIb and the spawning stock biomasses from VPA's to obtain a regression. The Irish surveys have only been carried out since 1981 and convergence occurs in VPA's about 1980. An examination of larval production, estimated by the 1986 Herring Larval Working Group, and the larval indices for the new standard area indicates a declining spawning stock since 1981 (Table 6.2.3). An examination of the ratios of both indices from the 1981-83 period compared with the 1984-85 period would suggest that the spawning stock might have been halved. There is some indication, however, that the Irish surveys in 1985 may have missed some of the earlier spawning which took place during September, because over 20% of the samples examined from Division VIIb had spawned during that month. Previous surveys have indicated that the spawning always starts earlier in Division VIa South than in Division VIIb.

6.3 Fishing Mortality Rate and Stock Size

The only method available to determine the value of F in 1985 was to compare the estimated spawning stocks since 1981 produced from VPA's with different values of input F, and the spawning stocks as indicated by the larval surveys. Accordingly, VPA's were run with input F in 1985 = 0.3, 0.4, 0.5 and 0.6. The spawning stocks estimated as a result of the different input F values and the abundances of spawning stocks obtained from the larval surveys are shown in Figure 6.3.1.

It is difficult to determine which trend in spawning stock is closest to that observed in the larval abundances. The recruitment of the strong 1981 year class has produced an increase in the spawning stocks in 1985 estimated by VPA's which was not apparent in the larval surveys for that year. However, input F's in 1985 of 0.5 and 0.6 produce spawning stock sizes in that year which are considerably lower than any calculated over the historic time series. These would seem to be unrealistically low levels considering the recruitment in 1984 of the exceptionally strong 1981 year class and the reduced fishing level in 1985. The input value F = 0.4 produced a spawning stock in 1985 of 63,000 tonnes, which is also lower than any recorded. However the decrease in spawning stocks since 1980, calculated with this input F value,was considered to resemble more closely the likely trend in larval abundances if the 1985 surveys had covered the entire spawning season.

6.4 Results from VPA's

The results from a VPA using an input F in 1985 = 0.40 are shown in Tables 6.3.1-6.3.2 and in Figure 6.3.2. The value of M on 1-winter-ring fish has been set at 0.8 and on adults at 0.1 throughout the VPA's. There has been a period of rather stable F values in the stock from 1975 to 1983 when the mean F was about 0.30. The F increased in 1983 to 0.50 when catches suddenly increased to over 33,000 tonnes and decreased in 1984 to about 0.34. Recruitment during this period has been fairly constant, fluctuating between 275 and 430 million fish with the exception of the 1976, 1977 and 1981 year classes which averaged about 630 million fish. Preliminary evidence of the 1982 year class, based solely on the numbers taken in catches during 1984 and 1985 seems to suggest that this year class may be the weakest one to enter the fishery for some time, while the catch data would also suggest that the latest year class (1983) may be more abundant. As discussed earlier, the spawning stock has decreased from 1984 to 1985 and, if the input F value in 1985 of 0.4 is correct, then the spawning stock at present is the lowest recorded.

6.5 Recruitment

There are no fishery-independent methods of estimating recruitment to this stock. At previous meetings, the Working Group used for prediction purposes the geometric mean of the number of 1-winter-ring fish present in the stock over a period when the stock was in a more or less stable condition. Using the same procedure now, but including the additional and weak 1982 year class, results in a recruitment figure of 366 million fish which is used in the stock prognosis.

6.6 Mean Weight at Age

The mean weights at age in the catch are based on data from the Dutch and Irish fisheries. There has been a considerable drop (25%) in the average weight of the 1-winter-ring fish, while the mean weight of the older age groups also decreased by about 8%. The mean weights of the stock also showed similar decreases compared with the values used in 1985. The mean weight of 1-winter-ring fish in the stock decreased by 17% while there was an average decrease of about 8% in the older fish. The 1985 mean weights were used to update the VPA, but the average values calculated by the 1984 Working Group for both stock and catch were considered more appropriate to use in the stock predictions. Mean weights are shown in the prediction input table (Table 6.6.1).

6.7 Stock Predictions and Management Considerations

Using the stock at 1 January 1986 calculated from VPA and an assumed level of recruitment of 366 million fish the spawning stock has been projected forward using two catch levels for 1986. The catch levels assume a) that the 1986 TAC of 17,000 tonnes will be adhered to and b) that catches in 1986 will be about the same level as those of 1985, i.e., about 23,000 tonnes. The input data are shown in Table 6.6.1 and the results are shown in Tables 6.6.2a and 6.6.2b.

If the 1986 catch is 17,000 tonnes, then the F generated will be 0.27 and the spawning stock in 1986 will be 70,000 tonnes. If the fishery in 1987 is conducted at $F_{0.1}$ = 0.15, then the catch will be 11,000 tonnes and the spawning stock will increase to about 82,000 tonnes. If the fishery is conducted at the same level as that of 1985 (F = 0.4), the catches will be 25,000 tonnes and the spawning stock will remain at about 69,000 tonnes.

On the other hand, if the 1986 catch is assumed to be at the more realistic level of 23,000 tonnes, then the F generated will be 0.39 and the spawning stock in 1986 will be 65,000 tonnes. If the fishery in 1987 is conducted at $F_{0.1}$ = 0.15, then the catch will be 10,000 tonnes and the spawning stock will increase to 75,000 tonnes. If the fishery is conducted at the same level as that of 1985 (F = 0.4) then the catches will be maintained at 23,000 tonnes, but the spawning stock will decrease to 63,000 tonnes.

ACFM has pointed out that in recent years the average fishing mortality on this stock has been twice as high as that considered advisable for the management of herring stocks in general. The spawning stock has remained fairly constant in the area up to 1984, but the results of the present assessment would indicate that the spawning stock has now dropped to a hithertofore unrecorded low level. This may be because of the long series of annual F values exceeding the $F_{0.1}$ level. There are no estimates of maximum sustainable yield from this area. The product of the yield per recruit at the $F_{0.1}$ level for 1986 and the assumed level of recruitment of 366 million fish would suggest a long-term yield of around 20,000 tonnes.

The Working Group would stress the need for careful monitoring of this stock in the immediate future in order to determine the extent of the recent decline in spawning stock.

6.8 Research and Data Requirements

The assessments in Divisions VIa South and VIIb are based solely on age compositions of the catch and larval surveys. In general, the data sampling of the catches is considered adequate. The larval surveys in both divisions have not yet been carried out for a sufficient number of years to enable the results to be used to predict stock sizes. It is necessary to examine the timing of the surveys to ensure that they are covering the main spawning season, particularly the spawning in the earlier part of the season. There is also a possible winter/spring spawning component in this area which has not been included in any assessment calculations. It has been pointed out in previous reports that this omission may lead to an underestimate of the total stock in the area. There are no methods available in this area to study the abundance of young herring and subsequently to predict recruitment. Young fish surveys are now undertaken in the area to study the abundance of mackerel and consideration should be given to extending these to cover the herring nursery areas.

7 IRISH SEA HERRING (DIVISION VIIa)

7.1 The Fishery in 1985

7.1.1 Total catch

The TAC recommended by ACFM for herring in Division VIIa for 1985 was 5,000 tonnes; this was subsequently adopted by the EC.

The reported catch from the North Irish Sea in 1985 was 9,187 tonnes, including 404 tonnes taken by selective fishing on the Mourne spawning ground (Table 7.1.1). In June, July and August, many small fish were sorted and discarded at sea; the weight of these fish (estimated at 1,731 tonnes) is not included in the totals quoted.

There was a small fishery in February, but most of the herring were caught in the summer fishery from June to September. A very small quantity of herring was caught in November. A fortnightly quota system was operated in the summer by the UK fleet reporting to a control vessel as in 1984, but there are no reliable data on effort by all vessels participating in the fishery.

Fishermen reported that herring were easy to find in the area south of the Mull of Galloway, and between the Isle of Man and Northern Ireland. Quotas were easily taken and the TAC was substantially exceeded. No landings were reported from the Manx spawning grounds east of the Isle of Man. There were inadequate data to split the catch into two components by stock, i.e., Manx herring and Mourne herring. Estimates of stock composition made by means of vertebral count of samples and location of catches made by the Northern Irish fleet indicated that herring age less than 5 rings were predominantly of Mourne origin in June and July. In August and September, when most of the catch was taken, there appeared to be a mixture of stocks in varying proportions.

7.1.2 Catch in numbers at age

The catch in numbers at each age group for the years 1975 to 1985 is given in Table 7.1.2. This has been estimated from data derived from samples of catches landed in the Republic of Ireland, Northern Ireland and the Isle of Man, and the quantities of herring landed. Numbers of herring discarded in 1985 were estimated from data derived from counts and samples taken in surveys at sea made between 19 June and 11 September. A total of 22 hauls made by commercial fishing vessels was examined. Discards in 1985 were not included in the catch in number at age (Table 7.1.2) because there are no similar data for years earlier than 1985, though discarding has been practised on an increasing scale since 1980. Discard data for 1985 are given in Table 7.1.3. It is estimated that 82% by number of the 1-ring fish caught were discarded and dumped at sea, 30% of the 2-ring fish and 6% of the 3-ring fish. The dominant age group in the landed catch was 3-rings.

7.2 Estimation of Fishing Mortality Rate

7.2.1 Estimate by projection

There are no data independent of the fishery from which stock size and fishing mortality can be estimated. In earlier years, the Working Group has used effort data from a portion of the fleet to select an input F for VPA. In 1985, available effort data were unrepresentative of the whole fishery, so there is no objective method of estimating fishing mortality in 1985.

Projections from the VPA made by the Working Group in March 1985 indicate that the catch in 1985 would have generated F_{85} on ages 2-8 of about 0.3. An exploitation pattern derived from an average over the years 1980-83 was assumed, with full exploitation of herring 2-rings and older and exploitation of 1-ring fish 0.15 of that for fully-recruited age groups. This refers to the landed catches which did not include discards. The period 1980-83 was chosen because the pattern of fishing was reasonably stable and the ratios $F_{age\ 1}/F_{2+}$ were relatively insensitive to VPA input F. The exploitation pattern is the same as that used by the Working Group in 1985.

7.2.2 Short-cut method to determine total biomass in 1985 and yield in 1986

Shepherd (1984) proposed a '*status quo*' method of catch estimation for use in fishery management. His 'worst case' estimate of the *status quo* catch (Y_{sq}) was:

$$Y_{sq} = (1 - \tilde{F}_n)\ Y_n + \tilde{F}_n\ \bar{Y} \quad \text{(Shepherd's equation 6)}$$

where $\tilde{F}_n$ is the catch/exploited biomass ratio in year n, Y is the yield in year n and Y is the mean yield over the range of years over which the *status quo* may reasonably be assumed to have been maintained. The 'worst case' is one in which there is no means of 'tuning' the estimates, e.g., by use of data from larval surveys or by some objective estimate of stock size. The limited data for the North Irish Sea herring implies that only a worst case estimate is applicable.

$\tilde{F}_n$ cannot be estimated without some measure of absolute stock size, and Shepherd suggested that if no estimate were available, then $\tilde{F}_n$ could be guessed and either one value or a range of values employed. If $\tilde{F}$ has remained reasonably constant over a recent period of years, one could use a regression of Y_{n+1} on Y_n to estimate an average value of F ($\bar{F}$).

The only period of apparent stability in the North Irish Sea herring fishery was from 1981 to 1984 inclusive (see Table 7.1.1). Declared yield in those years is given below:

Year	1981	1982	1983	1984	Mean 1981-84
Catch (tonnes)	4,377	4,855	3,933	4,066	4,308

In this case, the regression method cannot be applied because only 3 scattered points are available.

Trial VPA's with a range of input F_{85} were run and were beginning to converge for the year 1981. The stock biomass estimated could be used to obtain either a mean value for F or a range of values, as shown below:

Input F_{85}	0.2	0.3	0.4	0.5	0.6	Mean
Estimated total biomass 1981	28,403	24,198	22,105	20,856	20,029	
$\tilde{F}$	0.15	0.18	0.20	0.21	0.22	0.19

The mean value of $\tilde{F}$ for 1981 may be used as an approximation to $\tilde{F}_n$ for 1984 if in fact the conditions necessary for the use of the <u>status quo</u> method held over the period 1981-84. We may then estimate

$$Y_{sq} = (1 - 0.19)\ 4{,}066 + 0.19\ (4{,}308) = 4{,}112;$$

Then from Shepherd's equation 5

$$Y_{n+1} = \frac{\tilde{F}_{n+1}}{\tilde{F}_n}\ Y_{sq}$$

where year n = 1984.

$\tilde{F}_{n+1}$ may be estimated and hence biomass in 1985 since yield in 1985 is known = 9,187 tonnes.

$$\tilde{F}_{n+1} = \frac{9{,}187 \times 0.19}{4{,}112} = 0.42$$

Then biomass in 1985 = $\frac{9{,}187}{0.42}$ = 21,874 tonnes

and the yield in 1986 for a yield/biomass ratio of 0.2 would be 1,958 tonnes (from equation 5) and, for Y/B = 0.3, 2,937 tonnes.

The value of $\tilde{F}_n$ has relatively little influence on the estimate of Y_{sq} (Shepherd, 1984); a value of $\tilde{F}_n$ = 0.15 gives Y_{sq} = 4,102 and $\tilde{F}_n$= 0.22 gives Y_{sq} = 4,119.

The assumptions of stability of stock size and recruitment over the period considered are highly critical. If these were not met over the period 1981 to 1984, the estimates given are unreliable. Furthermore, if the catch in weight data are unreliable as a result of heavy discarding at sea, the results will be distorted.

The estimated Y/B ratio of 0.42 corresponds roughly with a VPA estimate with input F_{85} = 0.67. This could perhaps be taken as a maximum estimate of F_{85}, since the biomass at 1 January 1985 was expected to be higher than the average for 1981-84 and the Y/B ratio of 0.42 estimated as shown above is likely to be an overestimate, because the management strategy for the period 1981-84 with very modest catches at low F should have led to an increase in stock size by January 1985.

7.3 Recruitment

7.3.1 Estimates

One further problem remains: that of recruitment in 1986. One could use the Shepherd stock-recruit curve presented at the 1985 Working Group with the stock biomass estimated for the parent year 1984 from the VPA made in 1985. This gives an estimated recruitment of 125 x 10^6 1-ring fish, but it is, of course, highly dependent on the input F in 1985 for the estimate of SSB in the parent year 1984. A further point is that recent estimates of recruitment (1979-83) do not show a positive correlation with SSB. It was, therefore, decided to take as an estimate geometric mean recruitment from 1979-83 (taken from the VPA in the Working Group report 1985) which gives a value of 67.7 x 10^6 1-ring fish.

7.3.2 Young herring surveys

Young herring surveys have been carried out each spring in the Irish Sea since 1980. The surveys have been conducted in the North Western Irish Sea, which is considered to be an important nursery area. The adult stocks to which these juveniles recruit is not yet known precisely, but it appears that some will recruit to both the Celtic Sea and Mourne stocks. Sufficient investigations, however, have not been carried out to determine the relative proportions of the different components in the catches. The overall index (catches in numbers of 1-ring fish per hour) is shown below:

Year	1980	1981	1982	1983	1984	1985	1986
Index	121	725	1,078	474	409	723	951

Although these indices have not been used to predict recruitment to any adult stocks, there would seem to be no evidence of any decline in the abundance of young fish in the area.

No information is available on the abundance and distribution of young fish in the northeastern Irish Sea, where there are also nursery areas for North Irish Sea herring.

7.4 Mean Weight and Maturity at Age

Mean weights at age calculated from aged samples of herring are given in the text table below. The weights in 1985 were appreciably smaller than those for 1984 and earlier years. The mean weights given in the table were used in VPA's to calculate biomass at 1 January and at spawning time, which was assumed to be 1 October.

Mean weights in kg

	Age							
Year	1	2	3	4	5	6	7	8+
1985	0.087	0.125	0.157	0.186	0.202	0.209	0.222	0.258
1984	0.076	0.142	0.187	0.213	0.221	0.243	0.240	0.273
1976-83	0.074	0.155	0.195	0.219	0.232	0.251	0.258	0.278

Proportions of each age group likely to reach maturity, as indicated by gonad stages of sampled fish, were similar to those found in earlier years. The proportions used in estimates of spawning stock size in all years were the same as those used by the Working Group in 1985.

7.5 Management Considerations

7.5.1 Results of VPA's

Two widely different values for F_{85} have been estimated from data: F = 0.3 derived by projection from 1984 and F = 0.67 estimated by the *status quo* method. Neither can be considered reliable. VPA's were run with input F_{85} set at 0.3, 0.67 and the intermediate value 0.5, all with M on 1-ring = 0.8 and M on 2-rings and older = 0.1. The results are summarised in Table 7.5.1.

All the runs indicated a rising trend in SSB at spawning time between 1980 and 1984. The catch in 1985 was much greater than the TAC and it appears to have disturbed the trend. The VPA's suggest that recruitment has been falling since 1982. The figures are difficult to interpret because they are based on the catch landed rather than the real catch, but it remains a possibility that recruitment is declining.

If recruitment has been falling and SSB rising, the *status quo* procedure is unreliable. An estimate of F_{85} = 0.3 derived by projection from VPA in the Working Group report 1985 was, therefore, used in the VPA (Tables 7.5.2 and 7.5.3) and projections to examine trends in the stock.

7.5.2 State of the stocks

Long-term changes in the stocks of herring in the North Irish Sea are shown in Figure 7.5.1. The SSB declined sharply from 1972, then rose from 1980 to 1982 and probably 1983. The general trend of recruitment indicated by VPA's was downward.

The present state of the stocks is uncertain. SSB is unlikely to be as low as it was in 1980. There is a conflict of evidence on recent recruitment: the Young Fish Surveys in the northwest Irish Sea suggest that recruitment to the Mourne stock is unlikely to have declined in 1985; VPA's suggest that recruitment overall in the North Irish Sea did decline. The age distribution of the declared catch showed a shortage of 1- and 2-ring fish in 1985. A possible explanation is that Manx stock recruits have declined while Mourne recruitment was reasonably stable over the last three years. Figure 7.5.2 illustrates data derived from VPA on separate stocks made in 1985.

It is likely that F_{85} was higher than $F_{0.1}$ (= 0.15).

Projections made from VPA with input F_{85} = 0.3 are given in Tables 7.5.5 and 7.5.6, with input data shown in Table 7.5.4, and illustrated in Figure 7.5.3. The weights at age used are means for the years 1981 to 1985 because weights at age are very dependent on timing and location of the catches in the Irish Sea; these have varied from year to year and the stock composition also changes.

The projections assume that the catch in 1986 = 6,300 tonnes (1986 TAC) and, alternatively, that the catch in 1986 = 9,000 tonnes (1985 catch). Estimates of catch in 1987 at $F_{0.1}$ from the two projections are 4,200 tonnes and 4,000 tonnes, respectively.

7.5.3 Spawning and nursery area closures

The 1985 Working Group, at the request of ACFM, reviewed spawning area and nursery area closures which had been applied for several years, and possible modifications were discussed.

The Working Group now suggests that the spawning area and nursery area closures applied by the EC to the 1985 fishery in the North Irish Sea should continue.

7.6 Research and Data Requirements

The Working Group suggests that data on discards should be collected regularly for inclusion in the catch-in-number table and VPA when a sufficiently long series is available.

Efforts should be made to assign the catch to the Manx stock and the Mourne stock as in years prior to 1985. This would be facilitated by accurate reporting of the location of catches.

Estimates of stock size and fishing mortality independent of the fishery are highly desirable; failing this, effort data would be useful.

8 ICELANDIC SPRING- AND SUMMER-SPAWNING HERRING

8.1 The Fishery

8.1.1 The fishery in 1985

No signs of recovery of the Icelandic spring-spawning herring were observed, and the fishery in 1985 was entirely (99.6%) based on Icelandic summer-spawning herring.

The landings of summer-spawning herring from 1969-85 are given in Table 8.1.1. The 1985 landings amounted to nearly 50,000 tonnes. Of these, about 45,000 tonnes were taken by purse seiners, 4,000 tonnes in drift nets and about 100 tonnes by set nets. The main fishery started on 29 September and finished by 15 December. Practically all catches were used for human consumption. The text table below gives the landings, the TAC's set and the TAC's recommended during the last few years for this fishery ('000 tonnes):

Year	Landings	TAC's	Recommended TAC's
1982	56.5	50.0	50.0
1983	58.7	52.5	50.0
1984	50.3	50.0	50.0
1985	49.1	50.0	50.0

8.1.2 Catch in number, weight at age and age distribution

The catches in numbers at age for the Icelandic summer spawners for the period 1969-85 are given in Table 8.1.1. From 1975-77, the catches were dominated by the 1971 year class. During the period 1979-82, the year classes from 1974 and 1975 predominated in the catches, but in 1983, the strong year class from 1979 dominated in the catch. In 1984 and 1985, this year class is still the most abundant one and in 1985, it made up almost 50% of the total catch by number. The weights at age for each year are given in Table 8.1.2. In 1985, the weight at age is high, and is on average 24.5 g or 8% higher for each year class than the average weight at age for the period 1982-84. The maturity at age is given in Table 8.1.3.

8.2 Acoustic Surveys

The Icelandic summer-spawning herring stock has been monitored by acoustic surveys annually since 1973. These surveys have been carried out in December or January after the fishery is closed.

In November and December 1985 and in January 1986, two surveys were carried out for this purpose. The survey in November and December was aimed at the 0- and 1-ringed herring in fjords and shallow waters off west and north Iceland. In this survey, the 0- and 1-ringers (1984 and 1983 year classes) were estimated to count 311.3 and 604.9 million individuals, respectively. The 0-ringers were mainly distributed in two fjords on the north-northwest coast of Iceland, but the 1-ringers were mainly found in two fjords at the north coast of Iceland. In addition, an estimate of 305.6 million individuals from the 1983 year class was obtained at the southeast coast in January 1986. No herring, juveniles or adults, were located off the south or southwest coast of Iceland in December 1985 or January 1986. The survey in January 1986 was aimed at the adult component of the stock. During this survey, the adult herring were distributed in almost all the east Iceland fjords. About 50% of the total estimate was, however, obtained in one fjord. Based on target-strength values used previously for this herring (Halldórsson and Reynisson, 1983) as well as the mean weight of the herring in the catches, it was estimated that about 350,000 tonnes of herring were located in the fjords off east Iceland. The total stock estimate was about 380,000 tonnes. As shown in Table 8.2.1, the 1979 year class is dominating in the adult stock. It is also shown that the abundance of the 1983 year class is very high and can be compared to that of the 1979 year class. If the 1983 year class turns out to be as strong as indicated by this estimate, the recruitment in 1987 will be good. The estimate of the 1984 year class of 311.5 million individuals indicates that the strength of this year class is about the average.

8.3 Virtual Population Analysis

The acoustic estimates, which have been obtained immediately after the fishing season, have been used together with catch-in-number figures to calculate terminal F's to run a VPA. In previous calculations, only stock size estimates from the most recent acoustic survey have been considered. However, in this assessment, it was decided to consider all available acoustic estimates when estimating the terminal F's. This implies that year-to-year fluctuations in the assessment will be less than in assessments based on the most recent survey in each year only.

Including the survey carried out in January 1986, ten separate acoustic estimates are available from 1974. In this assessment, all these acoustic estimates have been utilised when estimating the fishing mortality rate in 1985. A detailed description of this method is presented in a separate working paper by Halldórsson. In addition, the survey results from January 1986 were used to estimate the exploitation pattern for the 1985 fishing season.

In Table 8.2.1, it is shown that the calculated average fishing mortality rate in 1985 is 0.16 for 3-to 6-ringed herring, but 0.13 for 7-to 14-ringed herring. Thus the fishery in 1985 was probably more concentrated on the strong 1979 year class and the younger age groups rather than on the less abundant older fish. From 1975-84, the F's on 3-ringers have ranged between 28 and 100% of the mean F on fully-recruited year classes. In 1985 as in 1984, it is believed that the fishery was more concentrated on the younger age groups than on older and less abundant ones. Therefore, it is suggested that the 3-ringers in 1985 are considered as fully recruited to the fishery and should consequently be grouped with the 4-to 6-ringed herring. Since the acoustic estimate of the 2- ringers in 1985 is uncertain, the F for this year class (1982) is calculated to give 400 million individuals as 1-ringers in 1984, a figure which is close to the long-term average. The proportion of the F for 2-ringers of the fully-recruited year classes in 1985 is very close to the average for the period 1975-84. This results in an F which is slightly lower than the F derived directly from the acoustic estimate obtained in January 1986. The fishing mortality rate for the 1-ringers in 1985 (1983 year class) is calculated from the acoustic estimates obtained in 1985 and 1986.

In Table 8.3.1 comparisons are given of the acoustic estimates for herring from the 1980 year class and older fish obtained in the period 1983-86. The comparison is given in terms of fishing mortality rates in 1985 obtained from the three different acoustic surveys and the catch taken in between. It can be seen that the acoustic estimate obtained in January 1985 is an underestimate compared to the estimates obtained in 1983 and 1986. This was also mentioned in last year's report (Anon., 1985) when the results from the acoustic surveys, carried out in 1983 and 1985, were compared. In Table 8.3.1, it can also be seen that the fishing mortality rate in 1985 estimated by the new method is close to the average fishing mortality rate estimated from the three previously mentioned surveys.

Using the catch-at-age data given in Table 8.1.1 and the 1985 F values given in the last column of Table 8.2.1, a VPA was run using a natural mortality rate of 0.1 on all age groups. Fishing mortality at age, stock in numbers at age and spawning stock biomass on 1 July are given in Tables 8.3.2 and 8.3.3, respectively. This year's assessment is similar to last year's assessment in that fishing mortalities in the period from 1978 to 1983 are higher than in the assessment made prior to 1983. However, the present difference is less compared to last year's assessment, since the 1985 assessment was entirely based on the low acoustic estimate obtained in January 1985. Due to the strong recruitment to the stock in 1983, the fishing mortalities have decreased and were below the $F_{0.1}$ level in 1984 and 1985.

According to this assessment, the spawning stock biomass increased from about 11,000 tonnes in 1972 to about 200,000 tonnes in 1980. Some decline occurred in 1981 and 1982, but owing to the strong 1979 year class, the spawning stock increased again in 1983, and it is estimated that the spawning stock will reach about 330,000 tonnes in 1986.

8.4 Management Considerations

8.4.1 Catch and stock projections

Catches have been calculated over a range of F's for 1986 using the parameters given in Table 8.4.1. The stock in numbers data are derived from Table 8.3.3, apart from the 1-ringers which are assumed to be 400 millions. This age group is practically absent from the catch and has no effect on the results of the predictions. Weight at age in the catch are obtained by using the relation:

$$W_{i+1} - W_i = 0.186W_i + 80.415 \text{ (g)}$$

where W_i and W_{i+1} is the mean weight of the same year class in year i and i+1, respectively, for the period 1976-85. This relation is used to calculate the weight at age in the catch in 1986 for 1-to 8-ringed herring. For the older herring, the mean weight at age from 1983-85 is used. It is assumed that the fishing pattern will be similar to that observed prior to 1984.

Projections of spawning stock biomass and catches ('000 tonnes) for for a range of values of F's are given in the text table below and in Figure 8.4.2.

1985		1986			1987	
Catch	F_{4+}	SSB on 1 July	F_{4+}		Catch	SSB on 1 July
50	0.155	328	F_{85}	0.16	48	419
			$F_{0.1}$	0.22	65	401
				0.30	85	380

During the period 1980-83, the fishing mortality rate in the adult component has been about 0.3. This is well in excess of the $F_{0.1}$ level, which has been advised by ACFM and which corresponds to F = 0.22. In 1984 and 1985, the fishing mortality rates were below this level, and the spawning stock increased due to the strong 1979 year class. The Working Group points out that exploitating this stock at the $F_{0.1}$ level in 1986 would result in a catch of 65,000 tonnes. The projection indicates that exploitation at the $F_{0.1}$ level in 1987 would result in a preliminary TAC of 70,000 tonnes. Any projection for 1987 should, however, be revised when new data become available late in 1986 or early in 1987.

8.4.2 Long-term potential

For the Icelandic summer spawners, information about catch, spawning stock size, fishing mortalities and recruitment is available back to 1947. This information is given in Tables 8.1.1, 8.3.2 and 8.3.3 and in Jakobsson (1980). In Figure 8.4.1, catches and fishing mortalities from 1947 to 1985 are shown.

In 1947 and 1948, the catches were relatively high, about 50-60,000 tonnes. Then the catches decreased and from 1949-60, they ranged from 10-35,000 tonnes. In 1961, the catch increased and obtained a maximum in 1963 of 130,000 tonnes. Until 1965, the catches remained at a high level, but in 1966, the catches went downwards, and this decrease in the fishery continued to 1972 when the purse seine fishery was prohibited. The fishery started again in 1975 and has increased to a level of about 50,000 tonnes in the last few years. The fishing mortalities from 1947-85 are also given in Figure 8.4.1. Except for the high F's in 1947 and 1948, the fishing mortalities were low (0.1-0.2) up to 1960. From 1960-63, there was a sharp increase in the fishing mortality from 0.2 to 0.7. In 1965 and 1967, the F values were about 1.2 and 1.5, respectively, and from 1968 to 1970, the F's were about 0.7-0.9. When the herring fishery started again in 1975, the strategy for the exploitation was to keep the fishing mortality at the $F_{0.1}$ level, which is 0.22 for this stock. This has also, in general, been observed for the period 1975-85. Using this level for exploitation, the spawning stock biomass has increased in 1986 to the same level it had in 1961, which is the highest since 1947. During the recovery of the stock, the catch has increased to 50,000 tonnes in 1980 and has for the last 5 years been at that level. The recent history of the stock indicates that one of the main advantages obtained by exploiting stocks such as the Icelandic herring with low fishing mortality rates is that the fluctuations in the fishery would be expected to be less.

Based on the yield-per-recruit curve (Figure 8.4.2) and the average recruitment for this stock, which has been approximately 400 million individuals as 1-ringers, the long-term yield would be about 60,000 tonnes. From Figure 8.4.3, the average recruitment from 1947-83 was calculated to be 348 million individuals. In the period from 1975-83, the average recruitment is estimated to be 472 million individuals. From Figure 8.4.3, it is evident that the recruitment for the Icelandic summer-spawning herring has been more variable in the period since the mid-1960's than in the previous 20 years. These variations may reflect variations in the environment around Iceland, especially in the most recent years. Although there is no clear stock-recruitment relationship for this stock, it is observed that when the stock level is high, the recruitment has been higher compared to periods with low stock levels.

Any Y/R studies are based on a steady-state situation for the stock. During the high stock level in the early 1960's, there were three different herring stocks in the Icelandic waters. Today, the summer-spawning herring is the only herring stock in the area. Historic data for that period may not be a satisfactory guide to future yields.

8.5 Research and Data Requirements

The basis for the assessment of the Icelandic summer spawners is very dependent on the annual acoustic surveys and, therefore, they should continue. In order to improve the estimates of the recruitment, more regular acoustic estimates of the juvenile component would improve the basis for assessment.

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10 WORKING PAPERS

The following working papers were presented:

1. "Report from an acoustic herring survey in Skagerrak, Kattegat and the North Sea during Oct.-Nov. 1985" by A. Aglen.

2. "Report on a meeting to evaluate the microwire tagging experiment in the Orkney-Shetland area" by Anonymous.

3. "Irish Sea herring (Division VIIa)" by A. Bowers.

4. "A method for estimating terminal F's from a series of acoustic surveys" by O. Haldórsson.

5. "An acoustic survey for herring in Division VIa (N) during November 1985" by M. Heath.

6. "Preliminary report on: Acoustical survey in eastern North Sea and Skagerrak in July-August 1985" by E. Kirkegaard.

7. "Celtic Sea, VIIj herring" by J. Molloy.

8. "Shetland herring microtagging project 1983-1985" by J. Morrison.

9. "North Sea herring. On weight at age in the catches" by N. A. Nielsen.

10. "IYFS 1986 herring length frequency distribution" by N. A. Nielsen.