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REPORT OF THE ATLANTO-SCANDIAN HERRING AND CAPELIN WORKING GROUP

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

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1 INTRODUCTION AND PARTICIPATION

1.1 Terms of Reference

The Atlanto-Scandian Herring and Capelin Working Group (Chairman Dr V.N. Shleinik) met at ICES Headquarters from 15-19 October 1990 (C.Res.1990/2:4:12) to:

a) assess the status of the Norwegian spring-spawning herring, Icelandic summer-spawning herring and capelin stocks in Sub-areas I, II, V and XIV and provide catch options within safe biological limits for the herring for 1991 and for the capelin for the winter 1990/1991 and summer-autumn 1991 seasons;

b) provide information on the spatial and temporal distribution of Norwegian spring-spawning herring.

1.2 Participants

J. Hamre	Norway
J. Jacobsen (from 18 October)	Faroe Islands
P. Kanneworff	Greenland
A. Krysov	USSR
I. Røttingen	Norway
V. Shleinik (Chairman)	USSR
G. Stefánsson	Iceland
S. Sveinbjörnsson	Iceland

2 THE ICELANDIC SUMMER - SPAWNING HERRING

2.1 Working Papers

Two working papers were presented: "The Icelandic summer-spawning herring" by S. Sveinbjörnsson and "Length distribution of catches for the Icelandic summer-spawning herring from 1983-1990" by S. Sveinbjörnsson.

2.2 The Fishery in 1989

The landings of the summer-spawning herring from 1970-1989 are given in Table 2.1. The 1989 landings amounted to about 101,000 t, including estimated unavoidable dumping of about 3,700 t. Apart from 916 t caught in January and 1,469 t caught in June, all the herring were caught in the purse-seine fishery in October-December.

The main fishing took place at southeast Iceland this year and a much smaller proportion of the catch was taken in the fjords at east Iceland than in recent years.

The text table below gives the landings and the TACs recommended during the last few years for this fishery ('000 t).

Year	Landings	TACs	Recommended TACs[1]
1984	50.3	50.0	50.0
1985	49.4	50.0	50.0
1986	65.5	65.0	65.0
1987	75.4	72.9	70.0
1988	92.8	90.0	100.0
1989	101.0[2]	90.0	-

[1]Recommended by ACFM.
[2]Inclusive 3,700 t discards.

2.3 Catch in Number and Weight at Age

The catches in numbers at age for the Icelandic summer spawners for the period 1970-1989 are given in Table 2.1. In the first years after the fishery was re-opened in 1975, the 1971 year class was most abundant. During the period 1983-1986, the fishery was dominated by the very strong 1979 year class. In 1987 and 1988, the fishery was based on a number of year classes ranging from 3- to 10-ring herring, although 4- and 5-ringers were most abundant in the catch in 1988. In the 1989 fishery, the 1983 year class predominated in the catch with the 1982 and 1984 year classes also abundant.

The 1983 year class appears to be the strongest year class recruited to the stock in the last 40 years.

2.4 Acoustic Surveys

The Icelandic summer-spawning herring stock has been monitored annually by acoustic surveys since 1973. In the autumn of 1989, it was not possible to investigate the distribution and abundance of immature herring in the fjords and bays of west and north Iceland. Investigations on the abundance of the mature component of the stock did not begin in 1989 until 10 December when the east coast fjords and the coastal areas off southeast Iceland were surveyed. Very little herring was located in the east coast fjords, and the concentrations in the area off southeast Iceland were much lower in abundance than expected. Another survey in January 1990 gave similar results, and it was concluded that only part of the stock had been located in the surveys.

During a capelin survey in February 1990, a research vessel located a large herring overwintering school at southeast Iceland on which a successful acoustic biomass estimate was made (Table 2.4).

2.5 Stock Assessment

Results of the February 1990 biomass estimate and the abundance estimate of immature herring obtained in November/December 1988, together with the catch in numbers by age, were used to calculate an exploitation pattern for the 1989 season. The results are given in Table 2.4. It is clear that the fishery was strongly directed towards the very large 1983 year class which was concentrated to a large extent off the southeast coast of Iceland during the fishing season. Using this exploitation pattern, a series of VPA runs was made using a range of terminal Fs. The best one to one relation using 13 acoustic estimates from 1974-1989 (excluding 1976, 1982 and 1986 for which no estimates are available) and virtual population analysis was obtained with an input of $F = 0.29$ on the older herring (see Appendix for fitting method). According to this assessment, the spawning stock has increased from about 260,000 t in 1984 to 430,000 t in 1987.

It is estimated that in 1990 the spawning stock was 510,000 t, which is about 19% higher than obtained in the 1989 assessment.

As explained in the Appendix, the Group agreed that an average F, weighted by stock in numbers, gives an appropriate measure of the exploitation of the stock. For this purpose, an average of age groups 4-14 has been used. It is noted that all measures of average F levels are hard to interpret, since the fishery has a tendency to concentrate on large year classes (e.g., the 1979 year class, which enters as 3-ringers in 1983).

For input F on the oldest age groups, however, an average reflecting the fishing intensity on the oldest age groups is required. For this, an unweighted average over ages 6-13 has been used.

The results of the VPA are given in Tables 2.5 and 2.6, and Figures 2.1A and 2.1B.

2.6 Catch and Stock Projections

The initial stock-in-number data for projections are derived from Table 2.6. Weight at age in the catch is obtained by using the relation:

$$W_{i+1} - W_i = -0.2404\ W_i + 91.88\ (g)$$

where W_i and W_{i+1} are the mean weight of the same year class in year i and i+1, respectively, for the starting years 1980-1988. This relation was used to calculate the weight at age in the catch in 1990 for 2- to 8-ringed herring. For 1-ringed herring, the mean weight from 1985-1988 was used and for older herring the mean weight from 1985-1988.

The long-term (1970-1990) average recruitment has been about 400 million. Recruitment has been better in the 1980s than in the 1970s. Simple smoothing of the recruitment time series indicates that the current level may be over 600 million. The average recruitment in the 1980s was 584 million. A constant recruitment level of 600 million has been used in the projections. This corresponds to a steady state of some 500,000 t of spawning stock biomass.

When choosing a selection pattern for stock projection, the candidates Fp and a scaled version of F^2_{89} (Table 2.4) were considered, as well as the average F over the years 1983-1986 (Table 2.5). The three resulting patterns are given in Table 2.7. The fishing pattern based on the average mortalities in the 1983-1986 period has been used in the predictions. This should be adequate for long-term prediction but can of course not fully accommodate inevitable variability in the next few years. Some testing has revealed, however, that the short-term predictions are quite robust to changes in the lower tail of the pattern (in particular to decreasing the selection of 2-3 ringers, which seems to reflect the current situation). This, along with the use of weights deduced from the regression, should make both the long-term and short-term forecasts quite reliable.

A summary of input data for the predictions is given in Table 2.8. The target fishing mortality has been $F_{0.1}$, which is now estimated as 0.202 (since the predicted pattern is flat on the 4+ group, the value is the same whether a weighted or unweighted average is used).

During the period 1983-1986, the fishing mortality varied from 0.204 to 0.323 (average, weighted by stock in numbers, 4-14 rings). It was on average 0.24, which is close to the target of 0.20.

Projections of spawning stock biomass and catches ('000 t) based on input data shown in Table 2.8 for a range of values of Fs are given in the text table below:

1990		1991			1992
Catch	F_{4+}	SSB at 1 July	F_{4+}	Catch	SSB at 1 July
90	0.19	510	0.17	80	510
			0.19	90	505
			0.21	100	495

More detailed predictions are given in Table 2.9 and Figures 2.1D and 2.2.

Continued fishing at $F_{0.1}$ would yield just below 95,000 t in 1990 and just above 95,000 t in 1991.

2.7 Management Considerations

Based on this assessment it is estimated that the spawning stock in 1990 was 510,000 t, which is about 19% higher than what was expected according to the 1989 assessment. It is shown in the present projection of spawning stock and catches that fishing at $F_{0.1}$ would lead to a catch of 95,000 t in 1990 and a spawning stock of 503,000 t in 1991. This is about 19% larger catch than had been predicted in the 1989 assessment. A TAC for the 1990 season has been set at 90,000 t, resulting in a fishing mortality of F = 0.19. This would leave a spawning stock of 510,000 t in 1991 (the same spawning stock size as in 1990) and fishing would be close to the target level of fishing mortality for this stock which is $F_{0.1}$ = 0.20. Assuming a catch of 90,000 t in 1990, fishing at $F_{0.1}$ in 1991 would yield a catch of 95,000 t.

Advice on the TAC for 1991 should, however, be deferred until after the acoustic survey in November-December 1990.

3 NORWEGIAN SPRING-SPAWNING HERRING

3.1 Working Papers

The following working papers were presented: "Soviet investigations and fishery of Atlanto-Scandian herring in the Norwegian Sea in 1990" by A.I. Krysov and F.I. Seliverstova; "Atlanto-Scandian herring survey in the open Norwegian Sea in June-July 1990" by A.I. Krysov; "Norwegian data on Norwegian spring-spawning herring for the period October 1989 - October 1990", by J. Hamre and I. Røttingen.

3.2 The Fisheries

The Norwegian fishery in 1989 started in January, and 12,500 t were caught in the over-wintering areas in the fjords of northern Norway. From approximately 10 February to mid-March, the main fishing area was the spawning area off Møre, where the Norwegian catch amounted to 18,000 t. The catches of herring in late spring and summer were small, but after the herring had migrated into the over-wintering areas in northern Norway in the autumn, some 35,000 t were caught.

These catches consisted mainly of the 1983 year class. In addition, some 7,500 t dominated by the 1987 year class were caught in the Møre area in the autumn. This year class has had a very rapid growth (mean length of 29.5 cm in November 1989), and the bulk of this cohort spawned in the winter of 1990. The USSR fishery in 1989 started off Møre in the second half of February and terminated in the area south of Lofoten in late March. The 1983 year class also dominated in the USSR catches. The recorded Norwegian and USSR catches were 78,707 and 15,123 t, respectively.

The same main features have prevailed in the fishery in 1990. The Norwegian catch by 1 July 1990 was 34,660 t, and the USSR catch was 11,807. In 1990, as in 1989, the catches consisted mainly of the 1983 year class.

3.3 Catch Statistics

The total annual catches of Norwegian spring spawning herring during the period 1972-1990 in terms of weight and numbers are presented in Tables 3.1, 3.2, and 3.3. The estimated unreported catches have been converted to catch in numbers using Norwegian data on catch at age in the adult fisheries.

3.4 Recruitment

The nursery area of the herring are the Norwegian fjords and coastal areas, and, in some years, the southern part of the Barents Sea. The recruitment has, therefore, been assessed in two components, one coastal and one from the Barents Sea.

3.4.1 Acoustic 0-group estimates in Norwegian coastal areas

An acoustic survey of 0-group herring distributed in the coastal areas of Norway has been conducted in November-December each year since 1975. The results are presented in Table 3.4. In 1987, the Working Group recommended the target strength (TS) = 20.0 log L - 71.9 to be used for acoustic abundance estimations of this stock. Prior to 1987, the same target strength as applied to capelin abundance estimates was also used for herring. In Table 3.4, estimates for the years 1975-1986 have been recalculated using the new target strength.

3.4.2 The 0-group index in the Barents Sea

Indices of 0-group Norwegian spring-spawning herring have been estimated for the period 1965-1990 based on data from the international 0-group surveys in the Barents Sea (Toresen, 1985, Anon.,1990) (Table 3.5).

3.4.3 Acoustic 0-group estimates in the Barents Sea

The acoustic estimates of 0-group herring in the Barents Sea for the last seven years are shown in the text table below:

Year class	Estimated number (billions)	Time of survey
1983	17.9	Nov 1983
1984	3.8	Nov 1984
1985	2.7	Nov 1985
1986	-	Sep 1986
1987	-	Sep 1987
1988	4.9	Nov 1988
1989	4.4	Jun 1990

The Barents Sea components of the 1984 and 1985 year classes are depleted, most probably due to predation by cod (Mehl, 1987). However, since 1987-1988, the cod stock in the Barents Sea has been at a low level, and this may result in a decreased natural mortality for the immature herring in the Barents Sea. This may eventualy be confirmed (or invalidated) in 1992 with knowledge of the recruiting strength of the 1988 year class. In the present stock prognosis the same natural mortality has been applied as previously for immature herring.

3.5 The Adult Stock

As in 1989, the stock is assessed as one unit, and based on acoustic stock estimates.

3.5.1 Acoustic estimates

The assessment is based on acoustic stock measurements carried out during the spawning period. The survey was carried out from 12 February to 15 March 1990 and covered the spawning grounds off Møre and further north. The stock estimate in number (million individuals, TS = 20 logL -71.9) by year class is shown in the text table below. The estimate is compared with last year's stock prognosis for 1 January 1990 (Anon., 1990). Taking into account that the catch in 1989 may have been somewhat higher than used in the prognosis, and that some 90 million herring were caught in 1990 prior to the survey, there is a quite good agreement between the acoustic estimate and the prognosis.

Year class	Prognosis (1 Jan) (WG 1989)	Acoustic estimate (1 March 1990)
1987	36	187
1986	51	-
1985	321	345
1984	119	112
1983	4554	4489
1982+	153	146
Total	5234	5092

The 1990 estimate applies to the areas from Møre and further north. However, for the first time in 30 years, the Norwegian spring-spawning herring reappeared on the traditional spawning grounds off Karmøy (approximately 59°15'N) in 1989 (Røttingen, 1989) and again in 1990. The amount of spawning herring at Karmøy in 1990 (1 March) is estimated to some 30,000 t, but this amount has not been added to the estimate off Møre (obtained between 17 February and 12 March) because the component which spawned at Karmøy in March may have passed through the spawning areas off Møre in the two last weeks of February, and thus been included in the survey off Møre. Recaptures of tagged herring at Karmøy in 1990 show that the herring were tagged on the coast north of 62^{0}N and had similar length and age distributions to the herring which spawned at Møre.

3.5.2 The state of the stock and VPA

The input data in the VPA are the following:

Total catch:	Table 3.1 (Column "Total catch as used by the WG")
Catch in number pr year:	Table3.3
Weight at age in the stock:	Table 3.6
Proportion of maturity:	Table 3.8
Natural mortality:	0.13 (age 3 and older)

The terminal F of the older age groups (1983 and older year classes) chosen was the one which minimized the squared residuals between VPA estimates of the stock, and those of the series of acoustic stock estimates for the year classes 1983 and older in 1988 (the year when the 1983 year class recruited to the spawning stock),1989, and 1990. The result is shown in Figure 3.1. The curve shows a minimum at approximately F = 0.066.

The acoustic estimates (in million individuals) of the year classes younger than 1983 are shown in the text table below:

Year class	1988	Year 1989	1990
1984	146	103	112
1985	225	373	345
Sum	371	476	457

These data indicate that these year classes may not be fully recruited until 1990. The catch from these year classes in 1989 amounted to approximately 10 million individuals, indicating an F of approximately 0.02, a value which has been used in the VPA. It should be noted that considerable uncertainty is involved in determining the proportions of year classes other than the 1983 year class, due to the dominance of the year class, both in the catches and the acoustic survey. For example, catches of the 1985 year class are estimated to 3.6 million individuals or 0.9% of the total catch in numbers. If a random sample of, e.g. 1,500 scales is used for age determination, then the standard deviation of the proportion of the 1985 year class will be about .25%. Thus, the 95% confidence interval for the proportion becomes roughly (.4%, 1.4%) or 1.5 - 5.3 million caught. The consequence of this is that it is quite difficult to obtain reliable acoustic estimates (or fishing mortalities) for individual year classes other than the 1983 year class.

The results of the VPA are given in Tables 3.9 and 3.10 and Figures 3.3A and B.

Figure 3.2 shows a plot of the logarithm of abundance (1983 and older) from the acoustic surveys against year. The slope of the line gives a Z of 0.20. This is in good agrement with F = 0.066 and a natural mortality of 0.13, indicating that the applied target strength gives a correct level of the absolute biomass estimate.

3.6 Catch and Stock Prognosis

The input data (Table 3.11) refer to the stock size on 1 January 1990. The estimate of the 1989 year class as 1-year-old was taken from the 0-group acoustic estimate (refers to 1 November 1989) in Norwegian coastal waters and the 1 group acoustic estimate (refers to 1 June 1990) from the Barents Sea. The 0-group estimate was reduced by an annual natural mortality of 0.9 for two months, and the 1-group estimate was increased by the estimated decrease in this population from 1 January to 1 June 1990 (i.e., annual natural mortality of 0.9 applied for five months). The number of 2-year-olds (1988 year class) was derived from the prognosis made last year (no new total estimate exists for this year class). For the year classes 1986 and older, the VPA estimates were used. As mentioned earlier, the 1987 year class has had a rapid growth, and it is thought that the entire year class was present on the spawning grounds in 1990 as 3-year-olds.

The biomass prognosis (in weight) will of course strongly depend on the future growth pattern of the dominant 1983 year class. The growth of this year class is reduced compared with other year classes since the rebuilding period started in the early 1970s (Toresen, 1990). The Working Group in 1989 estimated a future individual growth pattern for the 1983 year class (Anon., 1990). The same growth pattern is applied in this year's prognosis for ages 7 and older.

However, the year classes younger than 1983 seem to have a higher growth rate. For example, the 1989 year class in the Barents Sea in September 1990 (I-Group) had a mean weight of 38.7 g. The corresponding weight of the 1983 year class in the Barents Sea in September 1984 was 20 g. The weights at age in the catch and the stock chosen for the prognosis are the mean values for the period 1984-1990 (excluding the values for the 1983 year class).

3.7 Results of Prognosis

Table 3.12 gives the effects of different levels of fishing mortality in 1991 on catch, stock biomass, and spawning stock biomass. The spawning stock biomass will decrease in the short term whether any fishing takes place or not.

A long-term prediction for the next 5 years is illustrated in Figure 3.4. The recruitment for the years 1990 and onwards is assumed to be the same as for the 1988 year class, because the index for 0-group herring in the Barents Sea in 1990 is almost the same as the corresponding index for 1988 (Anon., 1990a).

3.8 Management Considerations

The Working Group notes with satisfaction that certain measures have been enforced to reduce the problems concerning the additional mortality in the fishery on this stock. In 1989, a Norwegian national ban on purse seining during daytime (when large and dense schools occur) was put into force. Further, 10,000 t of the Norwegian part of the TAC was not allocated to the fishery but reserved to account for additional mortality in the fishery.

The Norwegian spring-spawning herring is a depleted stock (Category 1) according to the criteria used by ACFM (Anon., 1989a). The preferred level of the stock, 2.5 million t, will not be reached in the near future, even without any fishing. The Working Group recommends that the utmost caution be taken in the exploitation of the stock in the coming year.

3.9 Information on the Spatial and Temporal Distribution of Norwegian Spring-Spawning Herring

The account below gives information to supplement that provided by the Atlanto-Scandian Herring and Capelin Working Group in 1989 (Doc. C.M.1990/Assess:5).

The herring presently spawns along the Norwegian coast from Stadt and northwards towards the Lofoten area. In 1990, as in 1989, the same herring also spawned at Karmøy (approximately 59°N). No information has been obtained in 1990 on changes in larval distribution.

The adult herring at present have their feeding areas west of the Lofoten-Vesterålen area, mainly within 200 nautical miles off the coast. In July 1988 and in June-July 1990 herring were observed, mostly as scattered schools, in the Norwegian Sea between 63°-71°N, 5°W-5°E.

In late August-early September the herring congregate close to the coast in the Lofoten-Vesterålen area. From there they gradually migrate to the wintering areas in the inner part of the fjords in this area. A USSR survey in December 1989 and January 1990 on the traditional over-wintering areas east of Iceland and north of Faroes recorded no herring.

In the middle of January the herring start the spawning migration from the over-wintering areas to the spawning grounds on the Norwegian coast. A survey conducted in January-February 1990 showed that the migration routes were close to the shore, no herring were recorded on the outer coastal banks during the migration.

A distribution pattern in the period 1987-1990 has been summarized in Figure 3.5.

4 BARENTS SEA CAPELIN

4.1 Working Papers

The following working papers were presented: "Barents Sea Capelin" by H. Gjøsæter, J. Hamre, and B. Bogstad, "Soviet investigations of Capelin in spring 1990" by N. Ushakov and "Report from the joint Norwegian/USSR acoustic survey of the pelagic fish in the Barents Sea in September-October 1990".

4.2 Regulation of the Barents Sea Capelin Fishery

Since 1979, the Barents Sea capelin fishery has been regulated by a bilateral fishery management agreement between the USSR and Norway. A TAC has been set separately for the winter fishery and for the autumn fishery. The fishery was closed from 1 May to 15 August until 1984. During the period 1984-1986, the fishery was closed from 1 May to 1 September. Since May 1986, there has been no fishing.

4.3 Catch Statistics

The international catch by country in the years 1965-1990 is given in Table 4.1.

4.4 Stock Size Estimates

4.4.1 Larval and 0-group surveys

Larval surveys based on Gulf III plankton samples have been conducted in June each year since 1981. The calculated numbers by year are shown in Table 4.2. From 1981 to 1985, the index was almost constant, in the range 8.2-9.9. In 1986, no larvae were caught in the Norwegian larval survey, although some spawning is known to have taken place in the Varangerfjord area. In 1987 and 1988 the index was only 0.3, and in 1989 it was 7.3. This year's index of 13.0 is the highest on record.

During the international 0-group survey in the Barents Sea in August 1990 (Anon., 1990a), 0-group capelin were observed over a much more limited area of the Barents Sea than in 1989, and the area of dense concentrations was much more limited (Figure 4.1). The abundance of 0-group capelin was, therefore, considered to be lower than that in the previous year, but much higher than the average for the year classes 1985 to 1988. On the whole, the larval and 0-group surveys confirm that the stock is rapidly recovering.

4.4.2 Acoustic stock estimates

The 1990 acoustic survey was carried out jointly by three Soviet and three Norwegian vessels during the period 8 September - 6 October. The same acoustic equipment has been used for the last two years, and it has been calibrated with equipment used earlier.The distribution of capelin is shown in Figure 4.2. Table 4.3 gives the estimate as numbers by age and length, and the biomass at age. The results are summarized in the text table below (the estimates of the same age groups in 1989 are shown in parentheses).

Year class		Number (billions)		Mean weight (g)		Biomass ('000 tonnes)	
1989	(1988)	700.0	(177.8)	3.8	(3.4)	2,663.5	(608.3)
1988	(1987)	177.4	(18.5)	15.3	(12.4)	2,718.4	(229.8)
1987	(1986)	16.6	(1.5)	27.1	(22.8)	448.9	(33.8)
1986	(1985)	1.5	(0.0)	20.0	(21.0)	2.9	(0.3)

The estimate of the 1989 year class (1-group) is about 4 times higher than the 1-group estimate in 1989. The 1-group estimate indicates that the 1989 year class is above the average abundance of year classes observed prior to 1983. The mean weight of the 1-group is 3.8 g as compared to 3.4 g in 1989, and consequently the biomass of the 1989 year class is almost 4.4 times larger than the 1988 year class as one-year-old.

The number of fish in the 1988 year class (2-group) is more than 9 times the size of the 2-group measured in 1989. The biomass estimate is almost 12 times larger than that obtained for the 2-group in 1989, as the mean weights are very much higher (15.3 g this year against 12.4 g last year). This mean weight is the highest ever measured at age group 2.

The text table below shows the number of fish in various year classes, and their survival from age 1 to age 2.

Year class	1982	1983	1984	1985	1986	1987	1988
Age 1 (Numbers in billion)	515	145	35	7	37	20	178
Age 2 (Numbers in billion)	184	47	3	1	29	18	177
Total mortality %	64	68	90	80	33	8	0

The acoustic estimate of the one-year-old capelin has always been considered to be less reliable than those of the older age groups, and has in most years been considered to be an underestimate. Nevertheless, the decreasing figures in natural mortality among the youngest age groups since 1987 probably reflects a real trend, associated with declining stocks of predators in the area.

The 1987 year class is estimated at 16.6 billion individuals with mean weight of 27.1 g, giving a biomass estimate of 450 thousand tonnes. This is the highest mean weight measured for age group 2 since the measurements started in 1973. It is also higher than the highest mean weight measured for four-year-old capelin. The estimated mortality of about 10% from last autumn is unexpected, taking into account that as much as half of this year class was expected to take part in the spawning.

Estimates of stock in number and weight for the period 1973-1990 are shown in Table 4.4. From 1973 to 1985 stock numbers were back-calculated to August 1 from the survey data at October 1, and the amount fished in September was subtracted. In the back-calculation, natural mortalities estimated by the Working Group were used. These are: 1973-1978: 0.051 per month, 1978-1983: 0.072 per month, 1984: 0.080 per month, 1985: 0.150 per month. From 1986 there has been no fishing in autumn, and the numbers given are those observed during the survey (October 1).

From 1973 to 1985, the numbers of 1-year-old fish were considered to be highly unreliable, and the numbers of 1-year-olds given in the table were back-calculated from the number of two-year-olds the year after, applying the estimated natural mortalities. From 1986, the number of one-year-olds given in the text table are those observed during the survey.

The fact that the estimated number of both 2- and 3-year-old fish this year is higher than expected from last year's survey, indicates that this year's estimate may be an overestimate for these age groups. The number of 3-year-olds is, however, only about 2% of the total stock in number, and under these circumstances, biased sampling, or pure chance alone may affect the estimate of this component of the stock. When the mean weight is so high, only small errors in the number estimated will lead to large errors in the estimated biomass. The same arguments may to some extent also be used on the estimate of the 1988 year class. Extra caution should, therefore, be shown to avoid overexploitation of the spawning stock caused by an overestimate of the maturing stock.

4.5 Management Considerations

4.5.1 Target spawning stock

A management aim for the Barents Sea capelin has been to preserve an adequate spawning stock. In the 1970s and early 1980s, the TAC recommendations were aimed at maintaining a spawning stock of about 500,000 t (see for example Anon., 1982). A paper by Hamre and Tjelmeland (1982) gave an optimal spawning stock of about 400,000 t. It is, however, uncertain whether the stock/recruitment relations from the 1970s are valid after the changes in the Barents Sea ecosystem in the middle of the 1980s, when the juvenile herring reappeared in the region.

The stock/recruitment relationship in the 1970s and early 1980s was closely related to a Beverton/Holt recruitment curve, but in 1984-1985, recruitment failed completely (Figure 4.3). This is probably related to the reappearance of the herring which had been absent from the Barents Sea since the 1960s (Hamre, 1988). This stock interaction may be decisive for the capelin survival as 0-group fish and should be taken into account in future stock prognoses. It is noted that the 1989 year class of herring in the Barents Sea is of considerable strength (180,000 t) and is expected to remain in the Barents Sea in the spring and summer of 1991. The prospects for capelin recruitment in relation to spawning stock in 1991 may, therefore, be rather poor, and this implies that a target stock for spawners in 1991 should be set at a relatively high level.

4.5.2 Natural mortality and predation

The natural mortality of non-spawners has been calculated on the basis of abundance estimates for year classes one year and the corresponding estimate of the abundance next year using age groups 2 and 3. The average of these measurements gave an M of 0.051 per month for the period 1973-1978 and a value of 0.072 for the period 1979-1983. These estimates were used in an earlier assessment for projecting the maturing stock from 1 October when the stock is surveyed until 1 April next year when the capelin spawns (Anon., 1985). It is assumed that most of the natural mortality during that period is due to cod predation.

A model of gastric evacuation (dos Santos, 1990) has been used to estimate the consumption of mature capelin (i.e., over 14 cm) by cod (of ages 2+). The model was fitted using cod in experimental tanks, where the cod were fed a controlled variety of prey during different seasons and at varying temperatures.

To obtain an estimate of consumption by cod in the Barents Sea in the winter and spring 1991, it is assumed that capelin will be a major source of food for cod (due to its abundance). The year 1985 is used as a baseline, since in that year the proportion of capelin in cod stomachs was the highest observed in the period 1984-1990 (Bogstad and Mehl, 1990).

The evacuation rate model allows computation of consumption by cod in the winter and spring of 1985 ($C_{a,85}$), by cod age group (a) based on the stomach samples. Consumption by cod age group in 1991 ($C_{a,91}$) is computed based on the cod biomass at age in 1985 ($B_{a,85}$) and in 1991 ($B'_{a,91}$):

$$C_{a,91} = C_{a,85} \frac{B_{a,91}}{B_{a,85}}$$

In this formula, the 1990 VPA stock estimates of cod have been used.

Adding these values gives an estimated total consumption of capelin in the winter and spring of 1991 of 720,000 t by cod. (For further explanation see the working paper by Gjøsæter et al.)

4.5.3 TAC options for the winter fishery 1991

As in previous years, it was assumed that all capelin above 14.0 cm will mature and spawn in 1991 (Table 4.3). In order to compensate for a possible overestimate of the 3-year-olds due to biased sampling, the age group was scaled down by 0.5 which corresponds to about 200,000 t, the resulting stock biomass of 2.4 million t was taken as the maturing stock at 1 October 1990. A natural mortality of 0.072 per month, equal to the natural mortality estimated for the period

1979-1983, was chosen (Anon., 1988, Table 3.4) and the following corresponding values of catch, spawning stock biomass, and natural mortality (in '000 t) were obtained using the model introduced in 1982 (Anon., 1982):

Catch	1,034	1,136	1,224	1,300
Spawning biomass	624	538	463	398
Natural mortality	742	726	713	702

The catches are equally distributed in January, February, and March, and no additional growth from October to March has been assumed.

These catch options provide an amount of capelin available for predators, (i.e., the natural mortality) of 700,000-750,000 t which coincides with the estimated food requirement of cod in the winter and spring of 1991. This is the primary justification for using the M-value calculated for the period 1979-1983. Taking into account the possible effect of herring on the capelin recruitment in 1991, and the uncertainties in the data base, the Working Group recommends that the lowest catch option should be considered.

4.5.4 TAC options for autumn 1991

The initial stock for the autumn-winter fishery 1991/1992 is the surviving stock component from the 1988 year class, and the contribution from the 1989 year class. It is assumed that the rest of the 1988 year class will mature and spawn in the spring of 1992, contributing about 1 million t. How much of the 1989 year class matures in 1991-1992 depends mainly on the growth rate of this age group, and this is impossible to predict. The Working Group has, therefore, not projected the stock a year ahead to assess the state of the maturing stock in the autumn of 1991. It is, however, observed that the stock abundance in number is approaching the level observed in the 1970s (Table 4.4) when the long-term yield was estimated at 1.3-1.6 million t depending on the growth and natural mortality (Anon., 1985). A total of 1.3 million t could, therefore, be considered as a preliminary 1991-1992 autumn-winter TAC.

The Working Group has previously recommended setting the autumn TAC at a lower level than the winter TAC, in order to prevent an overexploitation of the immature stock during autumn if the TAC calculation is based on too optimistic a stock prognosis. This was the case in the years 1982-1984, and contributed to the collapse of the stock in 1986, and this may also be the present situation for the Icelandic capelin.

Another important factor which favours a winter harvesting strategy is the role of the capelin as food for the fish-eating species. This has been quantified by converting the M-value of the capelin model to biomass output as illustrated in Figure 4.4. The Figure shows that by managing an exclusive autumn fishery with MSY strategy, some 2.0 million t of capelin remain as food for other stocks, whereas the M-output increases to some 2.5 million t when the catch is taken during winter only. This means that the loss in the MSY of some 50,000 t by fishing during winter only is compensated by a considerable gain in the M-output of some 500,000 t. In the context of a multispecies management strategy, priority should thus be given to the capelin fishery in the winter and spring.

5 CAPELIN IN THE ICELAND-GREENLAND-JAN MAYEN AREA

5.1 Working Papers presented

The following working papers and documents were presented:

- "Capelin in the Icelandic-Greenland-Jan Mayen Area" by S. Sveinbjörnsson.
- "Report on an Acoustic Survey of the Capelin Stock in the Iceland-Greenland-Jan Mayen Area in January 1990" by S. Sveinbjörnsson.
- "Report on an Icelandic Survey of 1-group Capelin in the Iceland-Greenland-Jan Mayen Area in August-September 1990" by S. Sveinbjörnsson.
- "Icelandic Capelin Catch Statistic for 1978-1990" by S. Sveinbjörnsson.
- "Length Distribution of Catches for the Icelandic Capelin for 1979-1988" by S. Sveinbjörnsson.

5.2 Catch Regulations

As this is a very short-lived species, the fishery depends to a very large extent upon the recruiting year class, the size of which is difficult to assess accurately until after recruitment to the fishable stock.

The fishery on the Iceland-Greenland-Jan Mayen stock of capelin has, therefore, been regulated by preliminary catch quotas set prior to each fishing season (July-March) based on the results of the surveys of the abundance of immature 1-group capelin carried out in August in the preceding year.

Final catch quotas for each season have then been set in accordance with the results of acoustic surveys of abundance of the maturing fishable stock carried out in autumn (October-November) and/or winter (January-February) in that season.

5.3 The Catch in the 1989/1990 Season

The total annual catch of capelin in the Iceland-East Greenland-Jan Mayen area since 1964 is shown in Table 5.1.

As all attempts to assess the 1989/1990 fishable stock of the capelin failed partially or completely, it was decided that the TAC for the 1989/1990 season should not exceed the preliminary TAC of 900,000 t set previously. The total catch amounted to 799,000 t, and the recommended TAC was, therefore, not reached.

Based on an acoustic biomass estimate in January 1990, carried out under unfavourable weather conditions, the residual spawning stock biomass was estimated to have been 115,000 t.

5.4 The Preliminary TAC for the 1990/1991 Fishery

In August 1989, an estimate of the abundance of 1-group capelin of the 1988 year class was obtained. All other attempts to obtain a reliable estimate of the abundance of immature capelin of either the 1988 or 1987 year classes in the autumn of 1989 and winter of 1990, failed.

The abundance of 1-group capelin has been estimated annually in August since 1982. The resulting estimates can be compared to estimates of the same year classes, obtained by back-calculating their abundance as 3- and 4-group spawners to the same point in time (1 August as 1-group) taking account of the catch and the mortality rate (M). Six such pairs of estimates are available, excluding the 1987 year class which is not fully recruited to the adult stock and may be underestimated due to trawl selection favouring the larger fish. The data are given in Table 5.2 and the relation between the two data sets in Figure 5.1.

Using the relationship in Figure 5.1, the August 1989 survey results correspond to 96 x 10^9 2-group capelin on 1 August 1990 when account has been taken of the mortality rate (M = 0.035/month). A TAC for the 1990/1991 season was then calculated making the following assumptions:

1) The fishery will depend on maturing capelin only.

2) About 70% of the capelin belonging to the 1988 years class and all the remainder of the 1987 year class will mature and spawn in 1991.

3) The 1990/1991 fishable stock and, therefore, the 1991 spawning stock, will consist of the 1988 and 1987 year classes in the ratio 80/20, this being close to the average for the 1981-1990 period when excluding the abnormal 1986/1987 season (Table 5.3).

4) The mean weight in the fishable stock will be 17.4 and 24.6 g for the 1988 and 1987 year classes, respectively (mean weights of 2- and 3-year olds in the fall in the 1980-1988 period (Table 5.4).

5) The mean weight in the 1991 spawning stock will be 19.4 and 26.3 g for the same year classes (Table 5.4).

6) The natural mortality rate will be M = 0.035/month (Table 5.5).

7) There will be 400,000 t left to spawn in 1991.

Calculations based on these assumptions gave a TAC of 973,000 t spread evenly over the period (ACFM, May 1990).

In view of the short time series and uncertainties related to the regression, the Working Group recommended a precautionary TAC of 600,000 t for the July-November 1990 fishery. ACFM in May 1990 recommended a precautionary TAC of 500,000 t for the same period. An administrative agreement on a TAC of 600,000 t for that period was reached at a meeting between Iceland, Norway and Greenland in spring 1990.

5.5 Final TAC for the 1990/1991 Fishery

In the Icelandic acoustic survey in August 1990, aimed at estimating the biomass of 1-group capelin, the estimated numbers of 2-group fish (year class 1988) were only 1/3 of the correponding estimate in the previous year (year class 1987). The estimate of the 1-group in August has been steadily decreasing in the last three years. This observed decrease in recruitment cannot be explained in terms of overfishing of the spawning stock as the target spawning stock of 400,000 t was believed to have been reached in that period. Taking a possible recruitment failure into consideration and the fact that the fishable stock of the 1990/1991 season has not yet been located (despite considerable effort), the preliminary TAC of 600,000 t set for the autumn fishery in 1990 may be considered too high. This may also have been the case as regards the preliminary TAC for the 1989/1990 fishing season when the target spawning stock was probably not reached.

In previous years TAC advice has been based on leaving a spawning stock biomass of 400,000 t and the Working Group believes that the SSB should under no circumstances be reduced below that level.

Icelandic surveys of the 1990/1991 fishable stock are planned for October-November 1990. After the completion of those surveys, the preliminary TAC should be reconsidered and adjusted to provide the target SSB of 400,000 t.

5.6 TAC for the Summer/Autumn 1991 Season

The fishable stock in the 1991/1992 season will consist of the 1989 year class and that part of the 1988 year class which does not mature and spawn in 1991. The abundance estimate (in numbers) of the 1989 year class was only 36×10^9 capelin. Most of the distribution area appeared to be covered but surveying conditions were unsatisfactory in part of the area. The results of the abundance estimates in 1982-1990 are given in Table 5.2 together with the back-calculated estimates of the corresponding year classes. The relative density distribution of the 1-group in 1990 is given in Figure 5.2.

Using the results given in Table 5.2 and in Figure 5.1 and a natural mortality rate of M = 0.035/month, the August 1990 survey results correspond to 69×10^9 2-group capelin on 1 August 1991. A TAC for the 1991/1992 season may then be calculated using the same assumptions as listed in Section 5.4 (Table 5.6). Calculations based on these assumptions give a TAC of 580,000 t for the 1991/1992 season, spread evenly over the period.

It is noted, however, that considerable additional data may become available after the completion of acoustic surveys of the stock that are planned for October/November 1990 and January/February 1991. Advice on TAC for the 1991 summer and autumn season should, therefore, be delayed until spring 1991.

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Table 2.1 Catch in numbers, millions and total catch in weight, '000 tonnes. Icelandic summer spawners. Age in years is number of rings + 1.

Rings	1970	1971	1972	1973	1974	1975	1976
1	2.003	8.774	0.147	0.001	0.001	1.518	0.614
2	22.344	13.071	0.322	0.159	3.760	2.049	9.848
3	33.965	5.439	0.131	0.678	0.832	31.975	3.908
4	4.500	13.688	0.163	0.104	0.993	6.493	34.144
5	2.734	3.040	0.264	0.017	0.092	7.905	7.009
6	4.419	1.563	0.047	0.013	0.046	0.863	5.481
7	1.145	3.276	0.028	0.006	0.002	0.442	1.045
8	0.531	0.748	0.024	0.006	0.001	0.345	0.438
9	0.604	0.250	0.013	0.003	0.001	0.114	0.296
10	0.195	0.103	0.009	0.003	0.001	0.004	0.134
11	0.103	0.120	0.003	0.001	0.001	0.001	0.092
12	0.076	0.001	0.001	0.001	0.001	0.001	0.001
13	0.061	0.001	0.003	0.001	0.001	0.001	0.001
14	0.051	0.001	0.001	0.001	0.001	0.001	0.001
Total	15.779	10.975	0.310	0.255	1.274	13.280	17.168

Rings	1977	1978	1979	1980	1981	1982	1983
1	0.705	2.634	0.929	3.147	2.283	0.454	1.470
2	18.853	22.551	15.098	14.347	4.629	19.187	22.422
3	24.152	50.995	47.561	20.761	16.771	28.109	151.198
4	10.404	13.846	69.735	60.728	12.126	38.280	30.181
5	46.357	8.738	16.451	65.329	36.871	16.623	21.525
6	6.735	39.492	8.003	11.541	41.917	38.308	8.637
7	5.421	7.253	26.040	9.285	7.299	43.770	14.017
8	1.395	6.354	3.050	19.442	4.863	6.813	13.666
9	0.524	1.616	1.869	1.796	13.416	6.633	3.715
10	0.362	0.926	0.494	1.464	1.032	10.457	2.373
11	0.027	0.400	0.439	0.698	0.884	2.354	3.424
12	0.128	0.017	0.032	0.001	0.760	0.594	0.552
13	0.001	0.025	0.054	0.110	0.101	0.075	0.100
14	0.001	0.051	0.006	0.079	0.062	0.211	0.003
Total	28.924	37.333	45.072	53.269	39.544	56.528	58.665

Rings	1984	1985	1986	1987	1988	1989
1	0.421	0.111	0.100	0.029	0.869	3.963
2	18.011	12.800	8.161	3.144	4.702	22.568
3	32.237	24.521	33.893	44.590	40.855	26.578
4	141.324	21.535	23.421	60.285	98.222	77.618
5	17.039	84.733	20.654	20.622	68.533	188.155
6	7.111	11.836	77.526	19.751	22.691	43.000
7	3.915	5.708	18.228	46.240	19.899	8.095
8	4.112	2.323	10.971	15.232	31.830	5.881
9	4.516	4.339	8.583	13.963	12.207	7.273
10	1.828	4.030	9.662	10.179	10.132	4.767
11	0.202	2.758	7.174	13.216	7.293	3.440
12	0.255	0.970	3.677	6.224	7.200	1.406
13	0.260	0.477	2.914	4.723	4.752	0.842
14	0.003	0.578	1.786	2.280	1.935	0.347
Total	50.293	49.092	65.413	75.439	91.760	100.733

Table 2.2 Mean weight at age in grammes, Icelandic summer spawners. Age in years is number of rings + 1.

Rings	1970	1971	1972	1973	1974	1975	1976
1	85.0	88.0	96.0	90.0	80.0	110.0	103.0
2	169.0	165.0	177.0	199.0	189.0	179.0	189.0
3	216.0	237.0	278.0	257.0	262.0	241.0	243.0
4	263.0	273.0	332.0	278.0	297.0	291.0	281.0
5	312.0	301.0	358.0	337.0	340.0	319.0	305.0
6	329.0	324.0	379.0	381.0	332.0	339.0	335.0
7	338.0	346.0	410.0	380.0	379.0	365.0	351.0
8	357.0	368.0	419.0	397.0	356.0	364.0	355.0
9	378.0	390.0	470.0	385.0	407.0	407.0	395.0
10	396.0	409.0	500.0	450.0	410.0	389.0	363.0
11	408.0	412.0	500.0	450.0	410.0	430.0	396.0
12	425.0	420.0	500.0	450.0	423.0	416.0	396.0
13	430.0	442.0	500.0	450.0	423.0	416.0	396.0
14	450.0	450.0	500.0	450.0	423.0	416.0	396.0

Rings	1977	1978	1979	1980	1981	1982	1983
1	84.0	73.0	75.3	68.9	60.8	65.0	59.3
2	157.0	128.0	145.3	115.3	140.9	141.0	131.7
3	217.0	196.0	182.4	202.0	190.5	186.1	179.7
4	261.0	247.0	230.9	232.5	245.5	217.3	218.1
5	285.0	295.0	284.7	268.9	268.6	273.7	259.9
6	313.0	314.0	315.7	316.7	297.6	293.3	308.6
7	326.0	339.0	333.7	351.6	329.8	323.0	328.7
8	347.0	359.0	350.4	360.4	355.7	353.8	356.5
9	364.0	360.0	366.7	379.9	368.3	384.6	370.2
10	362.0	376.0	368.3	382.9	405.4	388.7	406.9
11	358.0	380.0	370.6	392.7	381.5	400.4	436.6
12	355.0	425.0	350.0	390.0	400.0	393.5	458.6
13	400.0	425.0	350.0	390.0	400.0	390.3	429.9
14	420.0	425.0	450.0	390.0	400.0	419.5	471.5

Rings	1984	1985	1986	1987	1988	1989	1990
1	49.3	53.2	60.0	60.0	75.1	62.8	62.1
2	131.4	146.0	139.7	167.5	157.1	130.5	139.6
3	188.6	219.0	200.4	200.3	221.1	206.4	191.0
4	216.8	265.8	251.6	239.8	238.6	245.9	248.7
5	244.9	285.3	282.2	277.7	271.0	261.0	278.7
6	276.9	314.6	297.9	303.7	298.0	290.5	290.1
7	314.6	334.6	320.1	325.3	318.9	331.3	312.5
8	321.7	365.0	334.4	338.8	333.6	337.7	343.5
9	350.7	388.2	372.7	355.8	354.0	352.4	367.7
10	333.8	400.5	379.6	377.6	351.5	368.6	377.3
11	361.9	453.0	393.9	400.2	371.4	388.6	404.6
12	446.3	468.9	407.8	403.6	390.4	380.1	417.7
13	417.4	432.8	404.8	424.1	408.5	434.1	417.5
14	392.3	446.7	438.9	429.6	436.6	409.2	438.0

Table 2.3 Proportion of mature Icelandic summer spawners in each age group. Based on samples taken in September-December by purse-seine.

Rings	1970	1971	1972	1973	1974	1975	1976
1	0.00	0.01	0.00	0.00	0.00	0.00	0.00
2	0.22	0.38	0.29	0.64	0.14	0.27	0.13
3	0.89	0.98	1.00	0.99	0.94	0.97	0.90
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Rings	1977	1978	1979	1980	1981	1982	1983
1	0.00	0.00	0.00	0.00	0.00	0.02	0.00
2	0.02	0.04	0.07	0.05	0.03	0.05	0.00
3	0.87	0.78	0.65	0.92	0.65	0.85	0.64
4	1.00	1.00	0.98	1.00	0.99	1.00	1.00
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Rings	1984	1985	1986	1987	1988	1989	1990
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.01	0.00	0.03	0.01	0.05	0.06	0.04
3	0.82	0.90	0.89	0.87	0.90	0.93	0.90
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00

<u>Table 2.4</u> Stock abundance and catches by age groups (millions) and fishing mortality rates for the Icelandic summer spawners. F' is the F in 1989 calculated from the February 1990 survey. F_p is the fishing pattern in 1989 calculated from the February 1990 survey. F^1_{89} is the fishing mortality in 1989 according to the method introduced in the 1986 Report of the Herring Assessment Working Group for the Area South of 62^{0}N. F^2_{89} is modified to F^1_{89} to fit younger herring to the Nov-Dec 1988 survey.

Rings 1989	Acoustic survey estimate February 1990	Catch 1989	F'	F_p	F^1_{89}	F^2_{89}
0	8.2					
1	244.3	3.9	0.015	0.06	0.017	0.010
2	782.3	22.6	0.029	0.12	0.035	0.024
3	227.9	26.6	0.110	0.44	0.128	0.126
4	384.9	77.6	0.170	0.68	0.197	0.197
5	683.4	188.2	0.230	0.92	0.267	0.267
6	232.5	43.0	0.250	1.00	0.290	0.290
7	-	8.1	0.250	1.00	0.290	0.290
8	-	5.9	0.250	1.00	0.290	0.290
9	-	7.3	0.250	1.00	0.290	0.290
10	22.0	4.8	0.250	1.00	0.290	0.290
11	-	3.4	0.250	1.00	0.290	0.290
12	-	1.4	0.250	1.00	0.290	0.290
13	-	0.8	0.250	1.00	0.290	0.290
14	-	0.3	0.250	1.00	0.290	0.290

Table 2.5 Icelandic summer spawners.
Fishing mortalities (M=0.1).

Rings	1970	1971	1972	1973	1974	1975	1976
1	0.064	0.140	0.002	0.000	0.000	0.008	0.001
2	0.965	0.647	0.006	0.002	0.010	0.018	0.059
3	1.026	0.577	0.010	0.014	0.012	0.104	0.039
4	0.655	1.577	0.026	0.009	0.024	0.108	0.138
5	0.779	1.165	0.086	0.003	0.009	0.237	0.146
6	0.754	1.355	0.039	0.005	0.009	0.097	0.230
7	0.856	2.427	0.059	0.006	0.001	0.104	0.147
8	1.019	3.261	0.089	0.014	0.001	0.174	0.128
9	1.688	2.437	0.674	0.013	0.003	0.139	0.199
10	0.765	1.772	0.546	0.282	0.005	0.012	0.216
11	1.591	1.502	0.173	0.094	0.128	0.005	0.367
12	2.426	0.043	0.033	0.072	0.115	0.164	0.006
13	3.800	0.165	0.159	0.038	0.086	0.145	0.219
14	1.612	1.620	0.222	0.066	0.044	0.105	0.189
W.Av 4-14	0.784	1.655	0.050	0.007	0.019	0.149	0.147
U.Av 4-10	0.931	1.999	0.217	0.048	0.007	0.125	0.172

Rings	1977	1978	1979	1980	1981	1982	1983
1	0.002	0.014	0.004	0.012	0.003	0.002	0.007
2	0.040	0.061	0.092	0.064	0.020	0.025	0.109
3	0.180	0.131	0.160	0.158	0.089	0.143	0.248
4	0.124	0.134	0.237	0.280	0.117	0.266	0.202
5	0.251	0.130	0.208	0.324	0.244	0.209	0.210
6	0.182	0.313	0.152	0.197	0.316	0.382	0.143
7	0.331	0.271	0.312	0.235	0.165	0.559	0.209
8	0.266	0.707	0.157	0.360	0.167	0.205	0.299
9	0.198	0.492	0.408	0.117	0.400	0.320	0.147
10	0.354	0.558	0.242	0.572	0.082	0.551	0.161
11	0.055	0.727	0.497	0.557	0.723	0.243	0.310
12	1.133	0.040	0.100	0.002	2.178	1.524	0.074
13	0.006	0.610	0.156	0.506	0.200	1.932	1.109
14	0.316	0.465	0.253	0.318	0.529	0.714	0.307
W.Av 4-14	0.217	0.240	0.236	0.290	0.240	0.346	0.204
U.Av 4-10	0.244	0.372	0.245	0.298	0.213	0.356	0.196

Rings	1984	1985	1986	1987	1988	1989	1983-1986
1	0.001	0.000	0.000	0.000	0.001	0.010	0.002
2	0.101	0.028	0.006	0.005	0.019	0.024	0.061
3	0.202	0.173	0.085	0.040	0.082	0.126	0.177
4	0.343	0.181	0.223	0.192	0.105	0.197	0.237
5	0.150	0.316	0.236	0.278	0.310	0.267	0.228
6	0.089	0.133	0.471	0.330	0.493	0.290	0.209
7	0.080	0.086	0.276	0.504	0.570	0.290	0.163
8	0.078	0.056	0.213	0.348	0.690	0.290	0.162
9	0.137	0.100	0.270	0.406	0.459	0.290	0.164
10	0.090	0.156	0.298	0.521	0.513	0.290	0.176
11	0.017	0.172	0.402	0.741	0.778	0.290	0.225
12	0.030	0.093	0.322	0.642	1.077	0.290	0.130
13	0.041	0.066	0.391	0.772	1.409	0.290	0.402
14	0.070	0.108	0.330	0.533	0.748	0.290	0.204
W.Av 4-14	0.236	0.206	0.323	0.326	0.228	0.252	
U.Av 4-10	0.138	0.147	0.284	0.369	0.449	0.273	

Table 2.6 Icelandic summer spawners.
VPA stock size in numbers (millions) and spawning stock biomass in tonnes at 1 July.

Rings	1970	1971	1972	1973	1974	1975	1976
1	33.784	70.427	91.546	420.060	134.240	200.940	556.090
2	37.637	28.666	55.392	82.694	380.085	121.464	180.374
3	55.178	12.977	13.576	49.815	74.674	340.340	107.958
4	9.786	17.902	6.595	12.159	44.430	66.777	277.576
5	5.274	4.599	3.346	5.813	10.903	39.258	54.254
6	8.712	2.190	1.298	2.776	5.244	9.778	28.020
7	2.077	3.707	0.511	1.130	2.500	4.701	8.028
8	0.866	0.799	0.296	0.436	1.017	2.260	3.834
9	0.768	0.283	0.028	0.245	0.389	0.919	1.717
10	0.381	0.128	0.022	0.013	0.219	0.351	0.723
11	0.134	0.160	0.020	0.012	0.009	0.197	0.314
12	0.086	0.025	0.032	0.015	0.010	0.007	0.178
13	0.064	0.007	0.021	0.028	0.013	0.008	0.005
14	0.066	0.001	0.005	0.016	0.025	0.010	0.006
Spawning biomass	19684	13007	10363	28854	46292	117804	130597

Rings	1977	1978	1979	1980	1981	1982	1983
1	439.897	201.960	270.971	278.844	907.057	251.980	219.861
2	502.587	397.365	180.237	244.301	249.317	818.568	227.569
3	153.850	436.840	338.119	148.740	207.418	221.191	722.431
4	93.969	116.279	346.834	260.780	114.871	171.745	173.446
5	218.733	75.145	92.063	247.652	178.356	92.421	119.084
6	42.435	153.932	59.694	67.687	162.135	126.396	67.848
7	20.152	32.002	101.831	46.414	50.290	106.954	78.059
8	6.271	13.094	22.076	67.445	33.186	38.574	55.350
9	3.053	4.351	5.842	17.079	42.596	25.410	28.436
10	1.273	2.265	2.407	3.514	13.748	25.828	16.702
11	0.527	0.809	1.173	1.709	1.795	11.459	13.473
12	0.196	0.451	0.354	0.646	0.886	0.788	8.134
13	0.160	0.057	0.392	0.290	0.583	0.091	0.155
14	0.004	0.144	0.028	0.304	0.158	0.432	0.012
Spawning biomass	134516	177495	200627	216241	191960	203154	233243

Rings	1984	1985	1986	1987	1988	1989	1990
1	546.538	1462.807	670.319	293.746	1086.193	440.091	600.000
2	197.541	494.128	1323.497	606.435	265.765	982.002	394.443
3	184.613	161.631	434.938	1189.790	545.736	236.004	867.098
4	510.215	136.444	122.968	361.344	1034.183	454.982	188.300
5	128.292	327.668	103.014	89.038	269.728	842.457	338.004
6	87.321	99.902	216.131	73.611	61.002	179.064	583.779
7	53.189	72.255	79.154	122.136	47.878	33.710	121.237
8	57.326	44.407	59.956	54.329	66.730	24.490	22.824
9	37.121	47.963	37.974	43.837	34.718	30.287	16.581
10	22.202	29.300	39.277	26.217	26.434	19.851	20.506
11	12.859	18.352	22.684	26.375	14.086	14.325	13.440
12	8.943	11.443	13.987	13.727	11.375	5.855	9.699
13	6.836	7.850	9.433	9.169	6.534	3.506	3.964
14	0.046	5.938	6.649	5.773	3.835	1.445	2.374
Spawning biomass	249360	269680	288548	426213	496338	457898	

Table 2.7 Comparison of fishing patterns.

Rings	Fp	S89	S83-86
1	0.06	0.03	0.01
2	0.12	0.08	0.29
3	0.44	0.43	0.84
4	0.68	0.68	1.00
5	0.92	0.92	1.00
6+	1.00	1.00	1.00

Fp = pattern based on February 1990 survey and catches 1989.

S89 = adjusted pattern to incorporate measurements of juveniles in Nov-Dec 1988 survey.

S83-86 = average over the years 1983-1986, from the table of fishing mortalities (scaling by average of 4-13).

Table 2.8

List of input variables for the ICES prediction program.

ICELANDIC SUMMER SPAWNERS.
The reference F is the mean F for the age group range from 4 to 10

The number of recruits per year is as follows:

Year	Recruitment
1990	600.0
1991	600.0
1992	600.0

Proportion of F (fishing mortality) effective before spawning: .0000
Proportion of M (natural mortality) effective before spawning: .5000

Data are printed in the following units:

Number of fish:	millions
Weight by age group in the catch:	gram
Weight by age group in the stock:	gram
Stock biomass:	tonnes
Catch weight:	tonnes

age	stock size	fishing pattern	natural mortality	maturity ogive	weight in the catch	weight in the stock
1	600.0	.01	.10	.00	62.075	62.075
2	375.0	.29	.10	.05	139.588	139.588
3	883.0	.84	.10	.90	191.013	191.013
4	188.0	1.00	.10	1.00	248.666	248.666
5	338.0	1.00	.10	1.00	279.430	279.430
6	583.0	1.00	.10	1.00	290.141	290.141
7	121.0	1.00	.10	1.00	312.549	312.549
8	23.0	1.00	.10	1.00	343.540	343.540
9	17.0	1.00	.10	1.00	367.675	367.675
10	21.0	1.00	.10	1.00	377.300	377.300
11	13.0	1.00	.10	1.00	404.625	404.625
12	10.0	1.00	.10	1.00	417.675	417.675
13	4.0	1.00	.10	1.00	417.550	417.550
14	2.0	1.00	.10	1.00	437.950	437.950

Table 2.9

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

ICELANDIC SUMMER SPAWNERS.

Year 1990					Year 1991					Year 1992	
factor	ref. F	stock biomass	sp.stock biomass	catch	factor	ref. F	stock biomass	sp.stock biomass	catch	stock biomass	sp.stock biomass
.2	.19	640	510	90	.2	.16	649	508	78	665	520
					.2	.17		508	81	661	517
					.2	.17		508	82	660	516
					.2	.18		508	86	656	511
					.2	.19		508	91	651	507
					.2	.20		508	95	646	503
					.2	.20		508	96	645	502
					.2	.21		508	100	642	498
					.2	.22		508	104	637	494
					.3	.25		508	117	623	480
					.3	.27		508	126	614	472

The data unit of the biomass and the catch is 1000 tonnes.
The spawning stock biomass is given for the time of spawning.
The spawning stock biomass for 1992 has been calculated with the same fishing mortality as for 1991.
The reference F is the mean F for the age group range from 4 to 10

Table 3.1 Catches of Norwegian spring-spawning herring (tonnes) since 1972 as used by the Working Group.

Year	A	B[1]	C	D	Total	Total catch as used by the Working Group
1972	-	9,895	3,266[2]	-	13,161	13,161
1973	139	6,602	276	-	7,017	7,017
1974	906	6,093	620	-	7,619	7,619
1975	53	3,372	288	-	3,713	13,713
1976	-	247	189	-	436	10,436
1977	374	11,834	498	-	12,706	22,706
1978	484	9,151	189	-	9,824	19,824
1979	691	1,866	307	-	2,864	12,864
1980	878	7,634	65	-	8,557	18,577
1981	844	7,814	78	-	8,736	13,736
1982	983	10,447	225	-	11,655	16,655
1983	3,857	13,290	907	-	18,054	23,054
1984	18,730	29,463	339	-	48,532	53,532
1985	29,363	37,187	197	4,300	71,047	169,872[3]
1986	71,122[4]	55,507	156	-	126,785	225,256[3]
1987	62,910	49,798	181	-	112,899	127,306[3]
1988	78,592	46,582	127	-	125,301	135,301
1989	52,003	41,770	57	-	93,830	103,830
1990[5]	46,467					

A = catches of adult herring in winter
B = mixed herring fishery in autumn
C = by-catches of 0- and 1-group herring in the sprat fishery
D = USSR-Norway by-catch in the capelin fishery (2-group)

[1] Includes also by-catches of adult herring in other fisheries.
[2] In 1972, there was also a directed herring 0-group fishery.
[3] Includes mortality caused by fishing operations in addition to unreported catches.
[4] Includes 26,000 tonnes of immature herring (1983 year class) fished by USSR in the Barents Sea.
[5] Preliminary catch pr 1 July 1990.

Table 3.2 Total catch (as used by the Working Group) of Norwegian spring-spawning herring (tonnes) since 1972.

Year	Norway	USSR	Total
1972	13,161	-	13,161
1973	7,017	-	7,017
1974	7,619	-	7,619
1975	13,713	-	13,713
1976	10,436	-	10,436
1977	22,706	-	22,706
1978	19,824	-	19,824
1979	12,864	-	12,864
1980	18,577	-	18,577
1981	13,736	-	13,736
1982	16,655	-	16,655
1983	23,054	-	23,054
1984	53,532	-	53,532
1985	167,272	2,600	169,872
1986	199,256	26,000	225,256
1987	108,417	18,889	127,306
1988	115,076	20,225	135,301
1989	88,707	15,123	103,830
1990	34,660[1]	11,807	

[1] Preliminary up to 1 July.

Table 3.3 Catch in numbers ('000) of Norwegian spring spawners. Unreported catches are included for age 3 and older herring. The catches in 1985, 1986 and 1987 are adjusted for by the effects of discards and the breaking of gear, as reported by the Working Group in 1988.

Age	1974	1975	1976	1977	1978	1979	1980	1981
0	65,900	30,600	20,100	43,000	20,100	32,600	6,900	8,300
1	7,800	3,600	2,400	6,200	2,400	3,800	800	1,100
2	3,900	1,800	1,200	3,100	1,200	1,900	400	11,900
3	100	3,268	23,248	22,103	3,019	6,352	6,407	4,166
4	241	132	5,436	23,595	12,164	1,866	5,814	4,591
5	24,505	910	-	336	20,315	6,865	2,278	8,596
6	257	30,667	-	-	870	11,216	8,165	2,200
7	196	5	13,086	419	-	326	15,838	4,512
8	-	2	-	10,766	620	-	441	8,280
9	-	-	-	-	5,027	-	8	345
10	-	-	-	-	-	2,534	-	103
11	-	-	-	-	-	-	2,688	114
12	-	-	-	-	-	-	-	964
13	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-

Age	1982	1983	1984	1985	1986	1987	1988	1989
0	22,600	127,000	33,857	28,571	13,805	13,846	15,488	7,120
1	1,100	4,679	1,700	13,149	1,381	6,327	2,787	1,927
2	200	1,675	2,489	207,224[1]	3,091	35,770	9,112	25,203
3	13,817	3,183	4,483	21,500	539,785[2]	19,776	62,923	2,890
4	7,892	21,191	5,388	15,500	17,594	501,393	25,059	3,623
5	4,507	9,521	61,543	16,500	14,500	18,672	550,367	5,650
6	6,258	6,181	18,202	130,000	15,500	3,502	9,452	324,290
7	1,960	6,823	12,638	59,000	105,500	7,058	3,679	3,469
8	5,075	1,293	15,608	55,000	75,000	28,000	5,964	800
9	6,047	4,598	7,215	63,000	42,000	12,000	14,583	679
10	121	7,329	16,338	10,000	77,000	9,500	8,872	3,297
11	37	143	6,478	31,000	19,469	4,500	2,818	1,375
12	37	40	-	50,000	66,000	7,834	3,356	679
13	121	143	-	-	80,000	6,500	2,682	321
14	-	862	-	-	-	7,000	1,565	258
15	-	-	1,652	-	-	453	542	-
16	-	-	-	2,638	2,469	-	-	-

[1] 197,244 are from the oceanic component.
[2] 481,481 are from the oceanic component.

Table 3.4 Norwegian spring-spawners. Acoustic abundance (TS= 20 log L - 71.9) of 0-group herring in Norwegian coastal waters in 1975-1989 (numbers in millions).

Year	Area			Total
	62^0N-65^0N	65^0N-68^0N	North of $68^0$30'	
1975	164	346	28	538
1976	208	1,305	375	1,888
1977	35	153	19	207
1978	151	256	196	603
1979	455	1,130	144	1,729
1980	6	2	109	117
1981	132	1	1	134
1982	32	286	1,151	1,469
1983	162	2,276	4,432	6,866
1984	2	234	465	701
1985	221	177	104	502
1986	5	72	127	204
1987	327	26	57	410
1988	14	552	708	1,274
1989	575	263	2,052	2,890

Table 3.5 Abundance indices for 0-group herring in the Barents Sea, 1973-1990 (Anon., 1990).

Year	Log index	Year	Log index
1973	0.05	1982	0.00
1974	0.01	1983	1.77
1975	0.00	1984	0.34
1976	0.00	1985	0.23
1977	0.01	1986	0.00
1978	0.02	1987	0.00
1979	0.09	1988	0.30
1980	0.00	1989	0.58
1981	0.00	1990	0.31

Table 3.6 Average weight (gm) in stock (1 January), Norwegian spring spawners, 1978-1990.

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
3	180	178	175	170	170	155	140	148	54	90	96	154	219
4	294	232	283	224	204	249	204	234	206	143	143	175	198
5	326	359	347	336	303	304	295	265	265	241	200	209	258
6	371	385	402	378	355	368	338	312	289	279	250	252	288
7	409	420	421	387	383	404	376	346	339	299	300	305	309
8	461	444	465	408	395	424	395	370	368	316	333	367	428
9	476	505	465	397	413	437	407	395	391	342	343	377	370
10	520	520	520	520	453	436	413	397	382	343	352	359	403
11	543	551	534	543	468	493	422	425	388	362	400	395	387
12	500	500	500	512	512	480	459	434	383	370	358	375	386
13	500	500	500	512	500	470	449	443	403	378	360	406	401
14	500	500	500	512	500	500	427	452	403	381	385	436	480
15	500	500	500	512	500	500	437	463	450	388	400	417	480
16	500	500	500	512	500	500	437	480	470	390	400	417	480

Table 3.7 Average weight (gm) in catch, Norwegian spring spawners, 1977-1989.

Age	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
3	294	232	283	224	204	249	204	233	226	54	121	149	189
4	326	359	347	336	303	304	250	281	292	244	169	186	265
5	371	385	402	378	355	368	317	348	311	288	248	234	261
6	409	420	421	387	383	404	356	371	357	306	287	291	283
7	461	444	465	408	395	424	386	408	380	345	306	320	307
8	476	505	465	397	413	437	401	428	402	367	321	367	310
9	520	520	520	520	453	436	410	442	419	390	342	368	392
10	543	551	534	543	468	493	418	434	432	394	346	382	423
11	500	500	500	512	512	480	441	456	440	393	362	372	365
12	500	500	500	512	500	470	455	469	458	392	371	383	415
13	500	500	500	512	500	500	438	460	460	409	379	398	421
14	500	500	500	512	500	500	432	460	465	434	380	440	439
15	500	500	500	512	500	500	432	445	470	450	390	440	442
16	500	500	500	512	500	500	432	445	470	454	400	440	442

Table 3.8 VIRTUAL POPULATION ANALYSIS

NORWEGIAN SPRING SPAWNING HERRING

PROPORTIONS OF MATURITY

UNIT:

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
3	.620	.060	.100	.000	.500	.500	.500	.500	.730	.130	.100	.250
4	.890	.130	.250	.100	.900	.900	1.000	.900	.890	.900	.620	.500
5	.950	.310	.600	.250	1.000	1.000	1.000	1.000	1.000	1.000	.950	.970
6	1.000	.170	.900	.600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	1.000	1.000	1.000	.900	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	1981	1982	1983	1984	1985	1986	1987	1988	1989
3	.300	.100	.100	.100	.100	.100	.100	.100	.100
4	.500	.480	.500	.500	.500	.200	.300	.300	.300
5	.900	.700	.690	.900	.900	.900	.900	.900	.900
6	1.000	1.000	.710	.950	1.000	1.000	1.000	1.000	1.000
7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 3.9 VIRTUAL POPULATION ANALYSIS

NORWEGIAN SPRING SPAWNING HERRING

FISHING MORTALITY COEFFICIENT UNIT: Year-1 NATURAL MORTALITY COEFFICIENT = .13

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
3	2.073	.559	.298	.075	.081	.001	.083	.032	.044	.023	.014	.021
4	.278	1.540	.149	1.369	.066	.010	.001	.180	.038	.028	.016	.040
5	.786	.320	.331	1.015	.988	.078	.043	.000	.014	.038	.019	.023
6	.618	.714	.298	2.101	1.807	1.408	.123	.000	.000	.042	.025	.026
7	.361	1.138	.510	1.403	2.445	1.415	.072	.066	.027	.000	.019	.041
8	.325	1.211	1.725	4.209	2.203	.045	.037	.017	.066	.046	.000	.029
9	.206	.692	3.018	2.463	.054	.054	.054	.022	.020	.037	.000	.000
10	.411	.228	.470	.065	.065	.065	.065	.065	.026	.023	.022	.000
11	.400	.600	.080	.080	.080	.080	.080	.080	.080	.030	.027	.027
12+	.400	.600	.080	.080	.080	.080	.080	.080	.080	.030	.027	.027
(4- 9)U	.429	.936	1.005	2.094	1.260	.502	.055	.047	.027	.032	.013	.027
(4- 9)W	.282	1.031	.444	1.657	.079	.076	.089	.058	.039	.033	.020	.034

	1981	1982	1983	1984	1985	1986	1987	1988	1989
3	.010	.020	.032	.061	.134	.060	.048	.263	.020
4	.018	.023	.036	.066	.282	.144	.067	.074	.020
5	.025	.020	.032	.130	.269	.425	.207	.091	.020
6	.026	.022	.032	.074	.400	.400	.158	.142	.066
7	.017	.027	.027	.080	.332	.600	.295	.229	.066
8	.026	.022	.021	.075	.526	.836	.288	.399	.066
9	.027	.022	.023	.145	.442	.914	.274	.221	.066
10	.002	.011	.031	.098	.198	1.455	.489	.308	.066
11	.013	.001	.015	.032	.252	1.080	.250	.240	.066
12+	.013	.001	.015	.032	.252	1.080	.250	.240	.066
(4- 9)U	.023	.023	.029	.095	.375	.553	.215	.193	.051
(4- 9)W	.022	.022	.031	.099	.394	.564	.074	.093	.062

Table 3.10 VIRTUAL POPULATION ANALYSIS

NORWEGIAN SPRING SPAWNING HERRING

STOCK SIZE IN NUMBERS UNIT: thousands

BIOMASS TOTALS UNIT: tonnes

ALL VALUES ARE GIVEN FOR 1 JANUARY

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
3	224851	15603	7515	518565	32746	112253	43488	798338.	551803	142160	499805	324276
4	3501	24848	7837	4900	422251	26519	98475	35129	679254	463847	122004	432929
5	17102	2328	4679	5928	1094	347196	23061	86347	25766	574364	395915	105384
6	10807	6846	1484	2951	1886	358	281944	19398	75820	22311	485332	341224
7	2452	5118	2945	967	317	272	77	218895	17032	66576	18777	415667
8	44767	1500	1440	1552	209	24	58	63	179965	14564	58459	16182
9	191688	28392	392	225	20	20	20	49	54	147953	12208	51332
10	113371	136927	12476	17	17	17	17	17	42	47	125211	10719
11	966	65989	95762	6846	14	14	14	14	14	36	40	107575
12+	9662	6106	77510	16478	2522	69	69	69	69	180	200	200
TOTAL NO	619167	293656	212040	558430	461076	486742	447222	1158317	1529820	1432037	1717950	1805489
SPS NO	532484	250083	197379	29731	402478	427963	425478	755636	1306115	1261974	1201969	1342656
TOT.BIOM	141643	88649	68190	36521	117307	145006	149641	291828	400710	461983	551495	622517
SPS BIOM	132936	80920	65668	9303	103587	134778	145705	217506	354391	426083	453564	517599

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
3	429301	744733	106459	81165	182215	9935722	446035	289068	155608	0
4	278747	373066	641012	90502	67075	139899	8219376	373153	195076	133933
5	365351	240469	320200	543034	74427	44428	106395	6748230	304217	167903
6	90404	312766	206935	272253	418782	49948	25496	75979	5410728	261842
7	291984	77324	268780	175923	222033	246521	29408	19115	57880	4447686
8	350171	252165	66063	229627	142653	139915	118779	19235	13348	47578
9	13797	299733	216674	56799	187031	74051	53252	78161	11329	10972
10	45067	11792	257533	185956	43130	105518	26075	35556	55010	9313
11	9411	39476	10241	219278	148004	31081	21636	14048	22942	45219
12+	79912	82154	74983	56055	251326	237022	104757	40607	21023	36139
TOTAL NO	1954146	2433678	2168879	1910591	1736676	11004104	9151208	7693152	6247162	
SPS NO	1477727	1497283	1593287	1724376	1531702	1945594	2985575	6496960	5940140	
TOT.BIOM	623156	705493	734215	657073	580703	898717	1368344	1501419	1548704	
SPS BIOM	528574	530116	587298	616995	546611	391608	506891	1307720	1496881	

Table 3.11

List of input variables for the ICES prediction program.

NORWEGIAN SPRING SPAWNING HERRING
The reference F is the mean F for the age group range from 4 to 9

The number of recruits per year is as follows:

Year	Recruitment
1990	7000.0
1991	7000.0
1992	7000.0

Data are printed in the following units:

Number of fish:	millions
Weight by age group in the catch:	kilogram
Weight by age group in the stock:	kilogram
Stock biomass:	thousand tonnes
Catch weight:	thousand tonnes

age	stock size	fishing pattern	natural mortality	maturity ogive	weight in the catch	weight in the stock
0	7000.0	.01	.90	.00	.008	.001
1	9135.0	.01	.90	.00	.035	.008
2	2161.0	.02	.90	.00	.118	.040
3	191.0	.02	.13	.10	.184	.141
4	134.0	.02	.13	.30	.254	.193
5	168.0	.02	.13	.90	.291	.255
6	262.0	.07	.13	1.00	.322	.293
7	4448.0	.07	.13	1.00	.344	.309
8	48.0	.07	.13	1.00	.293	.325
9	11.0	.07	.13	1.00	.341	.340
10	9.0	.07	.13	1.00	.351	.359
11	45.0	.07	.13	1.00	.394	.395
12+	36.0	.07	.13	1.00	.361	.375

Table 3.12

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

NORWEGIAN SPRING SPAWNING HERRING

Year 1990					Year 1991					Year 1992	
factor	ref. F	stock biomass	sp.stock biomass	catch	factor	ref. F	stock biomass	sp.stock biomass	catch	stock biomass	sp.stock biomass
.7	.04	1767	1554	82	.0	.00	1724	1411	0	1752	1380
					.1	.01			9	1743	1371
					.2	.01			19	1733	1362
					.4	.02			37	1714	1344
					.6	.03			55	1695	1327
					.8	.04			73	1677	1310
					1.0	.05			91	1659	1293
					1.2	.06			108	1641	1276
					1.4	.07			125	1623	1260
					1.6	.09			142	1605	1243
					1.8	.10			159	1588	1227
					2.0	.11			176	1571	1211

The data unit of the biomass and the catch is 1000 tonnes.
The spawning stock biomass is given for 1 January.
The reference F is the mean F for the age group range from 4 to 9

Table 4.1 International catch of Barents Sea Capelin ('000 tonnes) in the years 1965-1989 as used by the Working Group.

Year	Norway	USSR	Other	Total
1965	217	7	-	224
1966	380	9	-	389
1967	403	6	-	409
1968	522	15	-	537
1969	679	1	-	680
1970	1,301	13	-	1,314
1971	1,371	21	-	1,392
1972	1,556	37	-	1,593
1973	1,291	45	-	1,336
1974	987	162	-	1,149
1975	943	431	43	1,417
1976	1,949	596	-	2,545
1977	2,116	822	2	2,940
1978	1,122	747	25	1,894
1979	1,109	669	5	1,783
1980	999	641	9	1,649
1981	1,238	721	28	1,987
1982	1,158	596	5	1,759
1983	1,493	846	36	2,375
1984	811	628	42	1,481
1985	453	398	17	868
1986	72	51	-	123
1987	-	-	-	-
1988	-	-	-	-
1989	-	-	-	-
1990	-	-	-	-

Table 4.2 Larval index for Barents Sea Capelin.

Year	Index
1981	9.7
1982	9.9
1983	9.9
1984	8.2
1985	8.6
1986	-
1987	0.3
1988	0.3
1989	7.3
1990	-

Table 4.3 Acoustic estimate, autumn 1990, for Barents Sea Capelin.

Total length	Age 1	Age 2	Age 3	Age 4+	Total number (10E-7)	Biomass tonnes (10E-3)	Biomass (cum.)
7.0- 7.4	361				361	3.3	
7.5- 7.9	1182				1182	24.3	
8.0- 8.4	5105				5105	102.1	
8.5- 8.9	9085				9085	209.0	
9.0- 9.4	10222				10222	278.0	
9.5- 9.9	10241				10241	324.0	
10.0-10.4	10100				10100	383.8	
10.5-10.9	8105	16			8121	354.2	
11.0-11.4	6823	293			7115	365.1	
11.5-11.9	4280	654			4935	299.1	
12.0-12.4	2459	1046			3505	257.7	
12.5-12.9	1171	971			2142	183.8	
13.0-13.4	310	1585			1895	190.6	
13.5-13.9	347	1723			2070	238.6	
14.0-14.4	179	2050			2229	292.6	2620.1
14.5-14.9	15	1979	15		2009	300.7	2327.5
15.0-15.4	16	2276			2292	392.6	2026.8
15.5-15.9		1683	172		1855	365.1	1634.2
16.0-16.4		1751	218	15	1983	439.3	1269.1
16.5-16.9		1011	222		1233	302.1	829.8
17.0-17.4		433	467		900	250.3	527.7
17.5-17.9		176	321		497	155.8	277.4
18.0-18.4		100	174		274	95.9	121.6
18.5-18.9			61		61	23.0	25.7
19.0-19.9			7		7	2.7	2.7
Number (10E-7)	70000	17747	1656	15	89418		
Biomass (t.*10E-3)	2663.5	2718.4	448.9	2.9	5833.7		
Mean length (cm)	10.0	14.6	17.1	16.3	11.1		
Mean volume (ml)	3.8	15.3	27.1	20.0	6.5		

Table 4.4 Stock size in numbers by age, total stock biomass and biomass of the maturing component of the Barents Sea capelin 1973 to 1990. Stock in numbers (10^{-9}) at 1 August, stock and maturing stock biomass (10^{-3} tonnes) at 1 October.

Age	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	1,174	761	509	444	785	951	552	591	443
2	430	636	411	275	236	425	400	232	248
3	52	209	351	203	127	121	148	194	70
4	21	4	101	101	51	17	7	37	19
5	0	0	1	17	9	1	0	0	0
Total no.	1,677	1,610	1,372	1,040	1,208	1,515	1,108	1,058	781
Total biom.	5,292	7,107	7,996	6,563	4,967	4,761	4,141	6,685	3,880
Mat. biom.	1,385	947	2,965	3,258	2,762	2,013	1,202	3,867	1,550
Age	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	612	538	371	24	7	37	20	178	700
2	169	257	224	68	3	2	29	19	178
3	66	64	65	34	3	0	0	1	17
4	3	1	4	2	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
Total no.	849	860	665	128	14	39	49	198	894
Total biom.	4,160	4,230	2,864	823	116	100	427	872	5,834
Mat. biom.	1,365	1,328	1,142	275	63	17	203	181	2,620

Table 5.1: The total annual and seasonal catch of capelin in the Iceland-Geenland-Jan Mayen area since 1964 (in /000 tonnes).

	Winter season		Summer and autumn season				
year	Iceland	Far/Nor	Iceland	Norway	Faroes	EEC	Total
1964	8.6						8.6
1965	49.7						49.7
1966	124.5						124.5
1967	97.2						97.2
1968	78.1						78.1
1969	170.6						170.6
1970	190.8						190.8
1971	182.9						182.9
1972	276.5						276.5
1973	440.9						440.9
1974	461.9						461.9
1975	457.1		3.1				460.2
1976	338.7		114.4				453.1
1977	549.2	24.3	259.7				833.2
1978	468.4	36.2	497.5	154.1	3.4		1.159.6
1979	521.7	18.2	442.0	124.0	22.0		1.127.9
1980	392.0		367.4	118.7	24.2	17.3	919.6
1981	156.0		484.6	91.4	16.2	20.8	769.0
1982	13.2						13.2
1983			133.4				133.4
1984	439.6		425.2	104.6	10.2	8.5	988.1
1985	348.5		644.8	193.0	65.9	16.0	1.268.~~3~~ 2
1986	341.8	50.0	552.5	149.7	65.4	5.3	1.164.7
1987	500.6	59.9	311.3	82.1	65.2		1.019.1
1988	600.6	53.2 56.6	311.4	15.5 11.5	34.8 48.5		~~1.015.5~~ 1028.6
1989	609.1	~~52.0~~ 56.0	53.9	52.7	14.4		782.1 778.1
1990	~~611.5~~ 612.0	66.2 × 74.6?					

[illegible]

N : 62.3
F = 12.3
74.6

Table 5.2 Abundance by number of Capelin year classes as indicated by two different methods of estimation.

Year class	Estimates in August as 1-group	Calculated from estimates of 3- and 4-group spawners	
1981	119	145	146.4
1982	155	147	122.5
1983	286	252	251.6
1984	31	100	101.7
1985	71	142	147.5
1986	101	143	144.1
1987	147	77[1]	
1988	111	-	
1989	36	-	

[1] The 1987 year class is not fully recruited to the surveys of the adult stock and consequently underestimated.

Table 5.3 The percentage of 4-group Capelin in the spawning stock in the years 1981-1990. (The high contribution in 1987 is due to the very rich 1983 year class and was omitted when calculating the mean.)

Year	Percentage
1981	22
1982	7
1983	12
1984	16
1985	34
1986	25
1987	63
1988	21
1989	32
1990	27
Mean	22

Table 5.4 Mean weight (g) of mature 2-3- and 3-4-years-old capelin in autumn and winter in the seasons 1980/1981 - 1989/1990.

Age	Season	Year class	Mean weight autumn	Mean weight winter	Year class	Mean weight autumn	Mean weight winter
1	1980/1981	1977	26.6	27.7	1978	19.3	20.7
2	1981/1982	1978	23.8	25.7	1979	19.2	19.9
3	1982/1983	1979	24.1	25.1	1980	16.5	18.7
4	1983/1984	1980	23.0	25.8	1981	15.9	19.3
5	1984/1985	1981	25.7	27.1	1982	15.8	19.1
6	1985/1986	1982	24.9	27.6	1983	18.1	20.3
7	1986/1987	1983	24.1	25.4	1984	18.1	19.6
8	1987/1988	1984	25.4	28.1	1985	17.9	19.5
9	1988/1989	1985	23.4	23.9	1986	15.6	17.8
10	1989/1990	1986	23.8	24.7	1987	13.4	17.7
Mean			24.5	26.1		17.0	19.3

Table 5.5 Natural mortality rates of the Icelandic capelin as calculated from successive acoustic estimates of spawning stock abundance and catch.

Estimate	Period	Mortality per month
I	1 November 1978 - 31 January 1979	0.045
II	1 November 1979 - 31 January 1980	0.026
III	1 November 1980 - 31 January 1981	0.030
IV	15 November 1981 - 31 January 1982	0.048
V	1 December 1981 - 31 January 1982	0.035
VI	1 November 1982 - 31 January 1983	0.028
VII	1 November 1983 - 31 January 1984	0.034
VIII	15 November 1984 - 31 January 1985	0.035
Mean		0.035
Standard deviation		0.008

<u>Table 5.6</u> Method used to calculate preliminary TAC from acoustic survey of 1-group fish in August (natural mortality = 0.035/month and numbers are expressed in 10^{-9}).

Year class	1989	1988
Acoustic estimate 1 September 1990 (numbers)	36.20	-
Regression	104.60	-
12-month natural mortality	0.66	-
Stock in number 1 August 1991	69.04	-
Maturity ratio	0.70	-
Mature stock (in numbers) 1 August 1991	48.33	12.08
Ratio in spawning stock 1992	0.80	0.20
Mean weight at spawning (g)	19.40	26.30
Spawning stock in numbers 15 March 1992	15.40	3.85
Natural mortality (7,5-months) up to 1 August 1991	1.30	1.30
Spawning stock in numbers 1 August 1991	20.02	5.00
Fishable stock in numbers 1 August 1991	28.31	7.08
Mortality in the fishable stock	0.87	0.87
Fishable stock in numbers 1991/1992	24.63	6.16
Mean weight in the fishable stock	17.40	24.60
TAC ('000 t) 1991/1992	428.50	151.45
Total TAC	579.95	

Figure 2.1

FISH STOCK SUMMARY
STOCK: Herring - Va (Summer)
19.10.1990

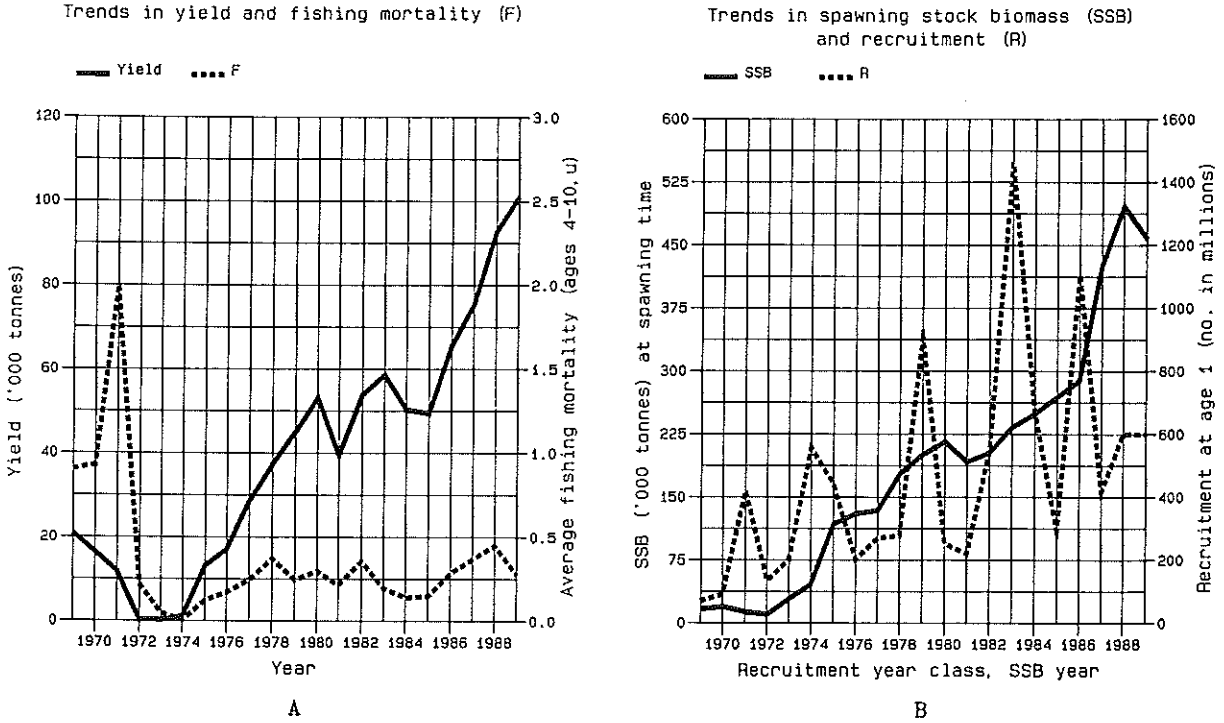


Figure 2.1 (Cont'd)

FISH STOCK SUMMARY
STOCK: Herring - Va (Summer)
19.10.1990

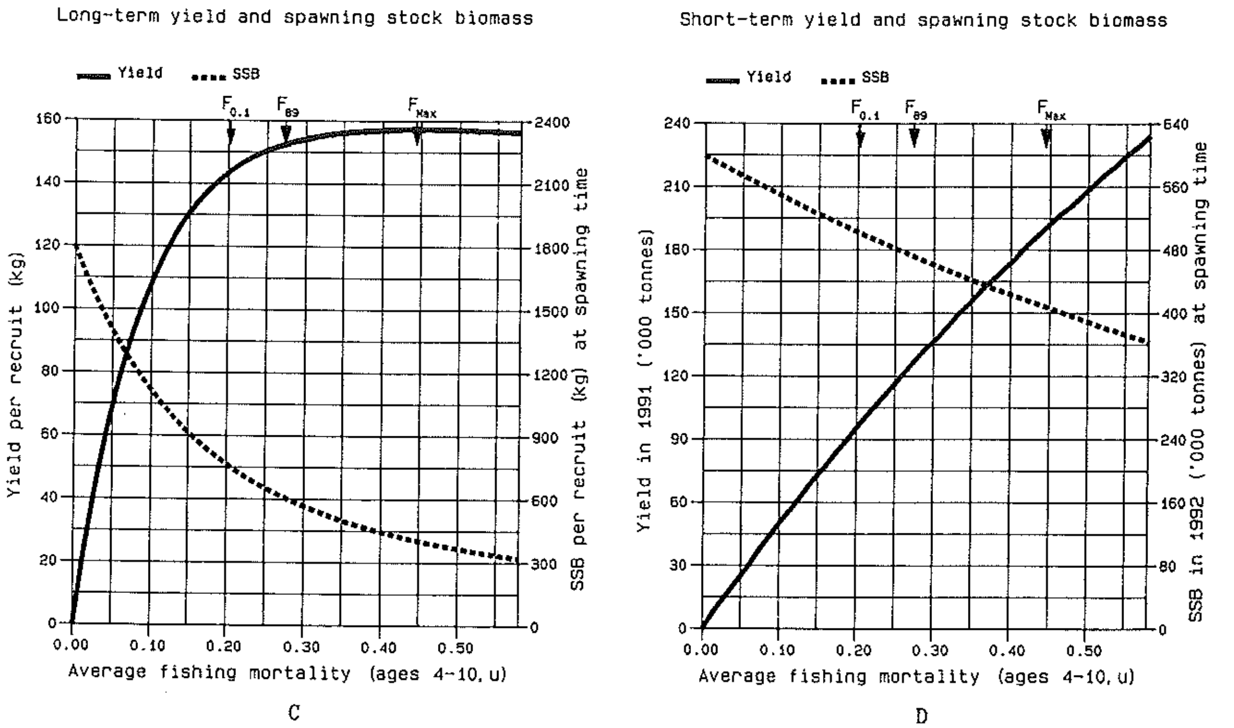


Figure 2.2

Icelandic Summer-Spawning Herring. Catch in 1990 90.000t

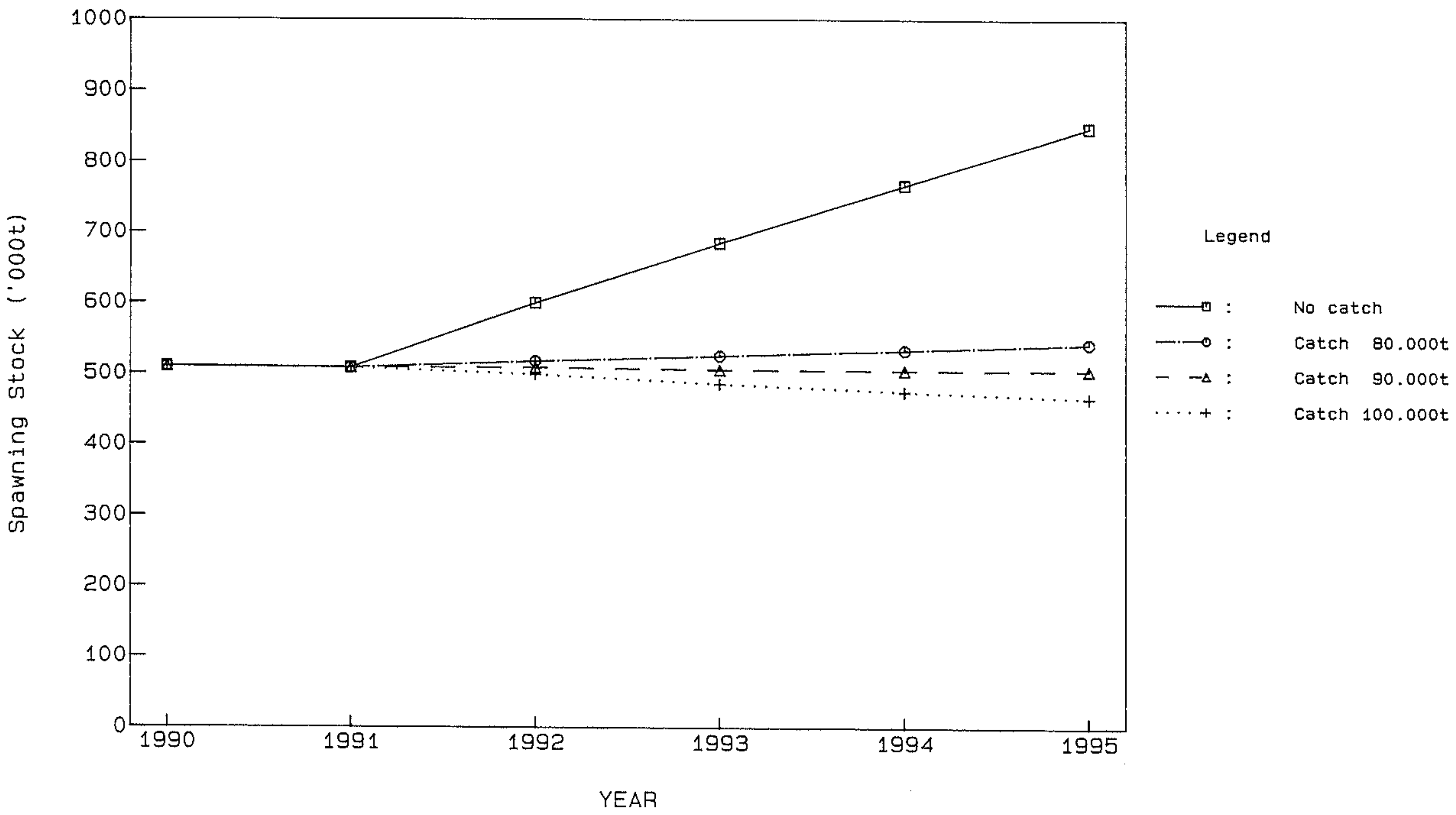


Figure 3.1 Sum of squared residuals against F (year class 1983+)

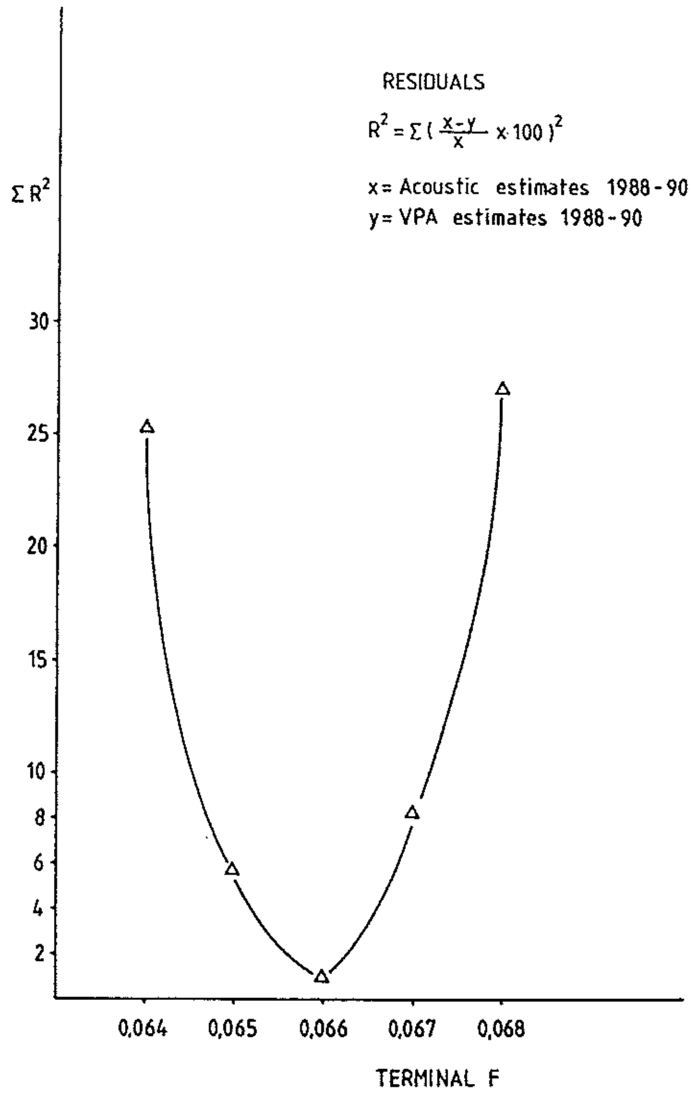


Figure 3.2 Logaritm of abundance, year class 1983+ (Acoustic estimates), against year.

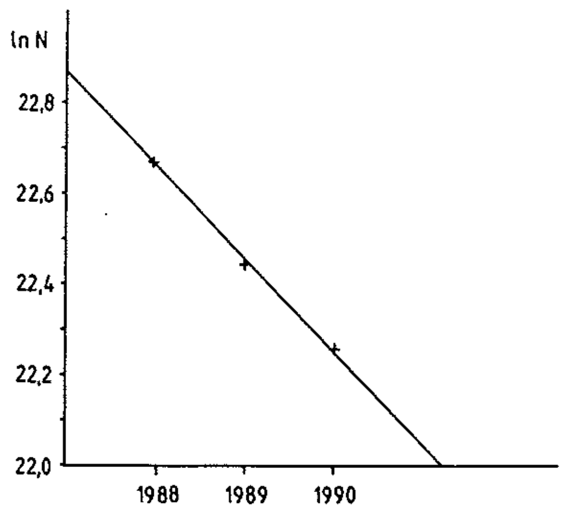
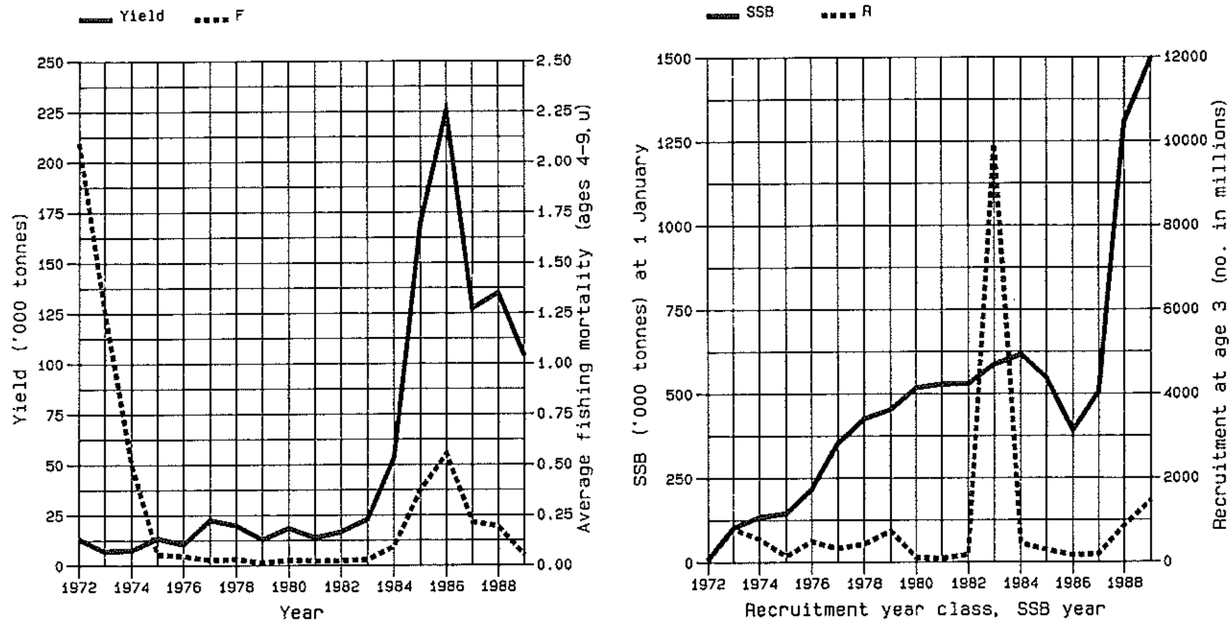


Figure 3.3

FISH STOCK SUMMARY
STOCK: Norwegian Spring Spawning Herring
19.10.1990

Trends in yield and fishing mortality (F)

Trends in spawning stock biomass (SSB) and recruitment (R)



A

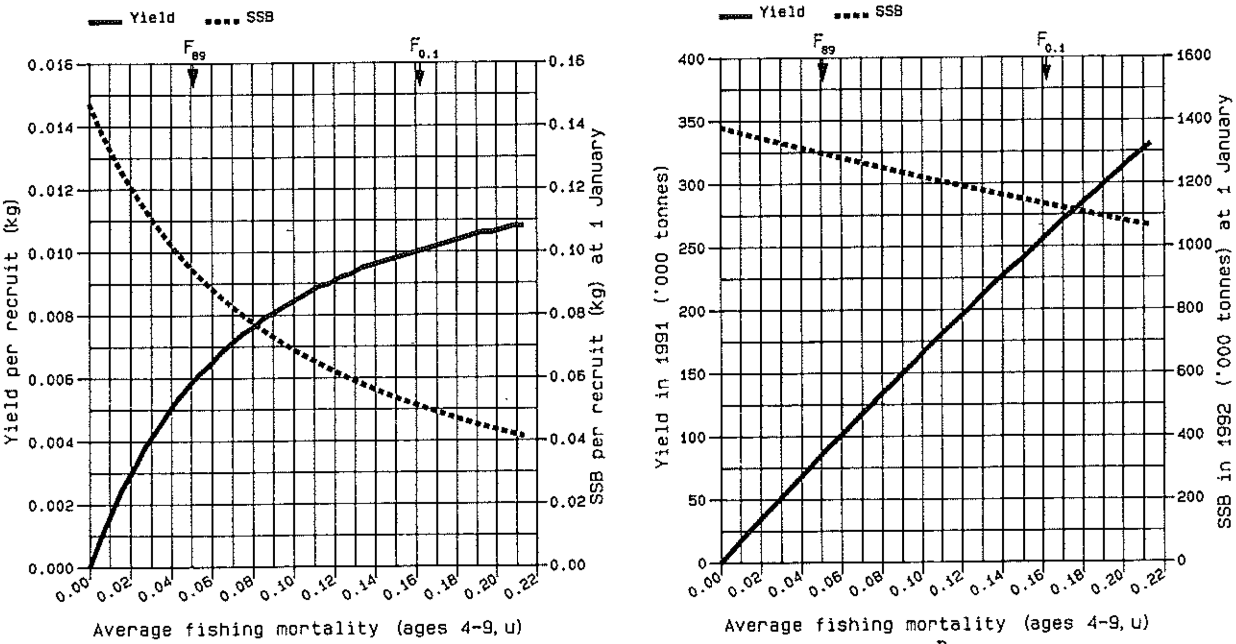
B

Figure 3.3 (Cont'd)

FISH STOCK SUMMARY
STOCK: Norwegian Spring Spawning Herring
19.10.1990

Long-term yield and spawning stock biomass

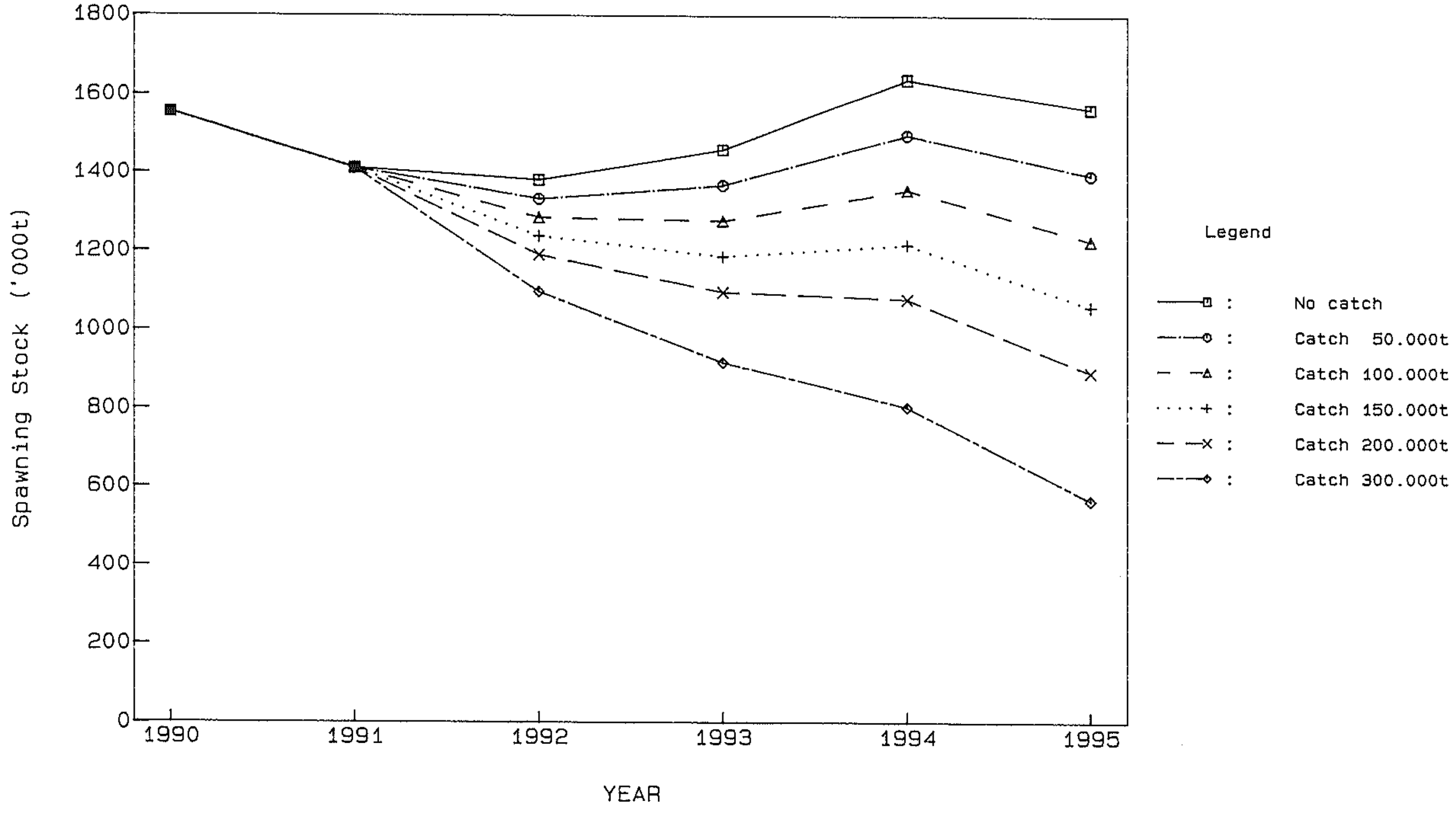
Short-term yield and spawning stock biomass



C

D

Figure 3.4 Norwegian Spring-Spawning Herring. Catch in 1990 82.000t



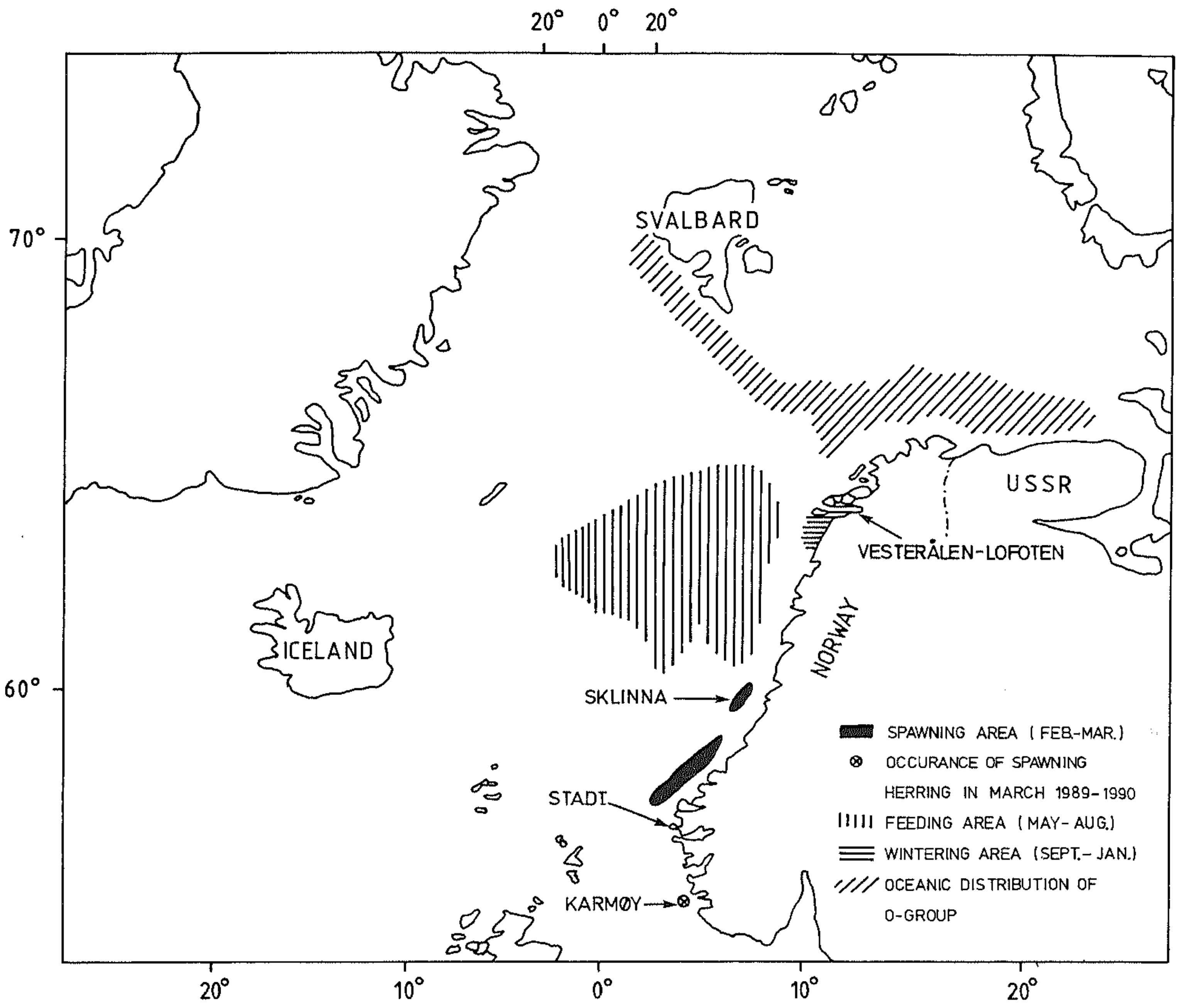


Figure 3.5 Distribution of Norwegian spring-spawning herring, 1987-1990.

Figure 4.1 Distribution of 0-group capelin.

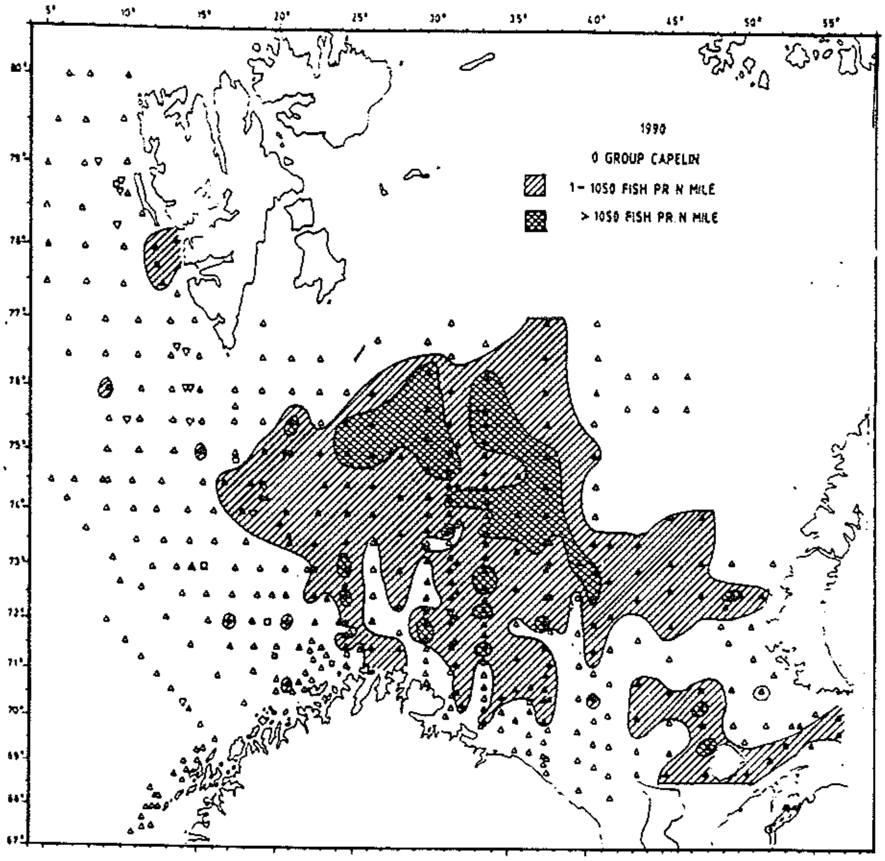


Figure 4.2 Estimated total density distribution of capelin.
(tonnes/square nautical mile)

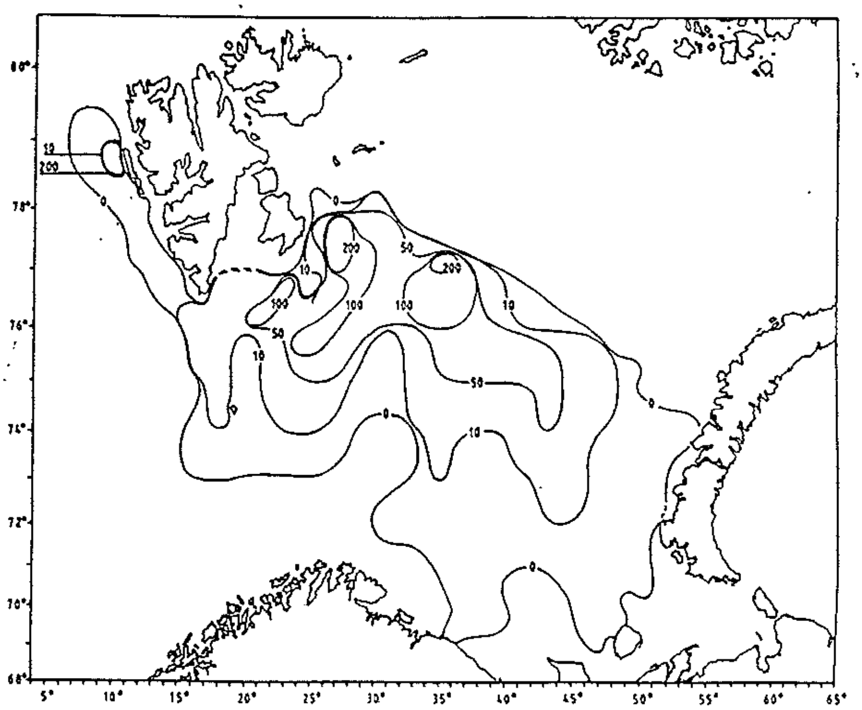


Figure 4.3 Stock-recruitment relation of Barents Sea capelin (Hamre 1988).

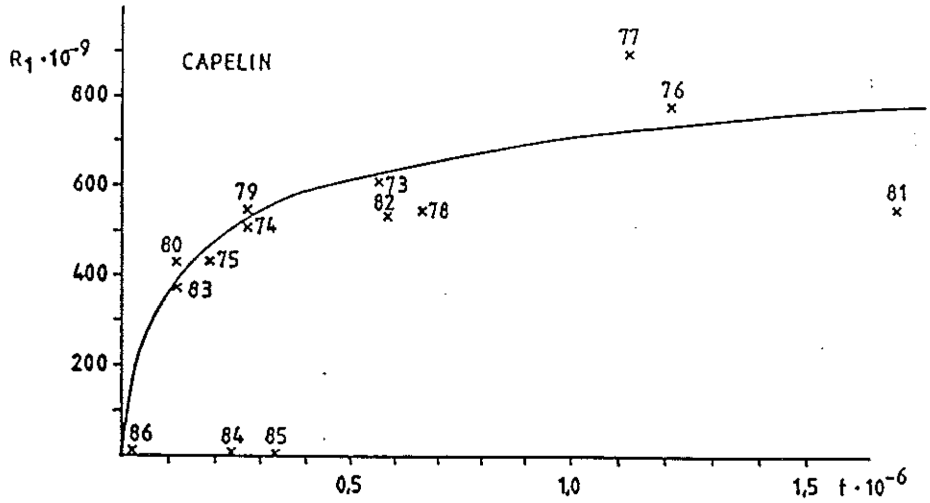


Figure 4.4 Sustainable yield (C_1) and M-output biomass (C_2) for Barents Sea capelin at different levels of spawning stock (B_s). Broken lines apply to winter fishing only, solid lines to autumn fishing only (Hamre and Tjelmeland 1982).

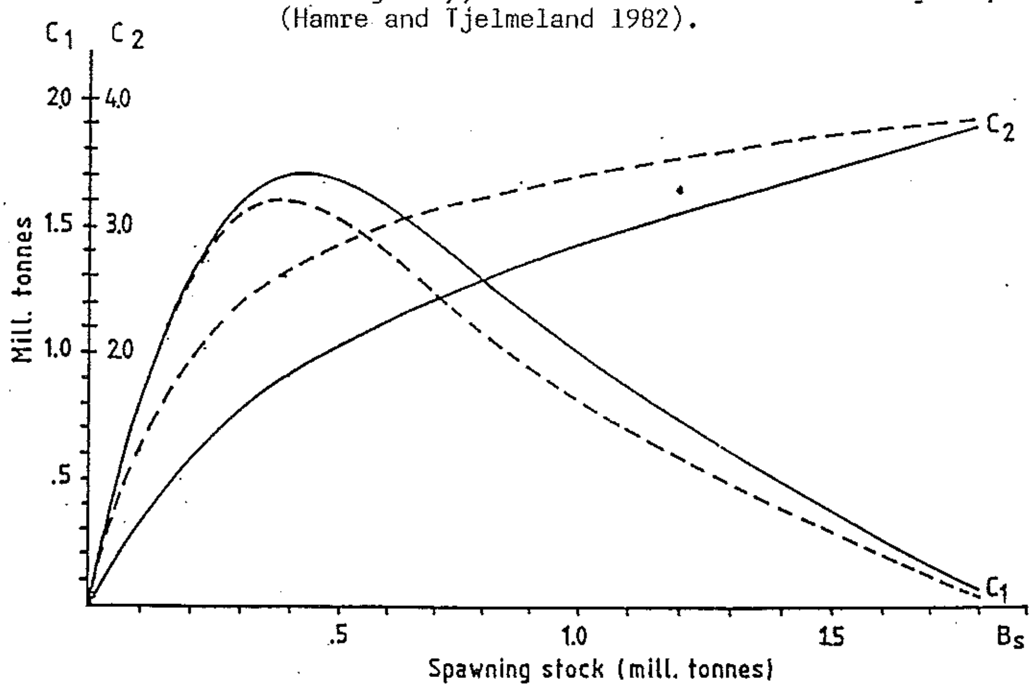


Figure 5.1 The relation between two different estimates of the abundance of the 1981-1986 year classes of capelin. Numbers are in 10^{-9}.

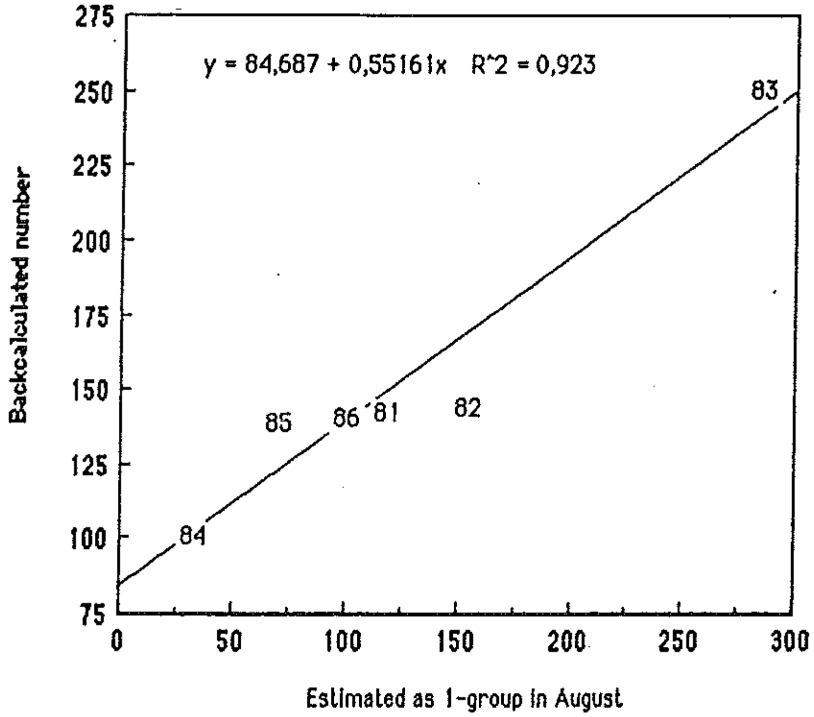
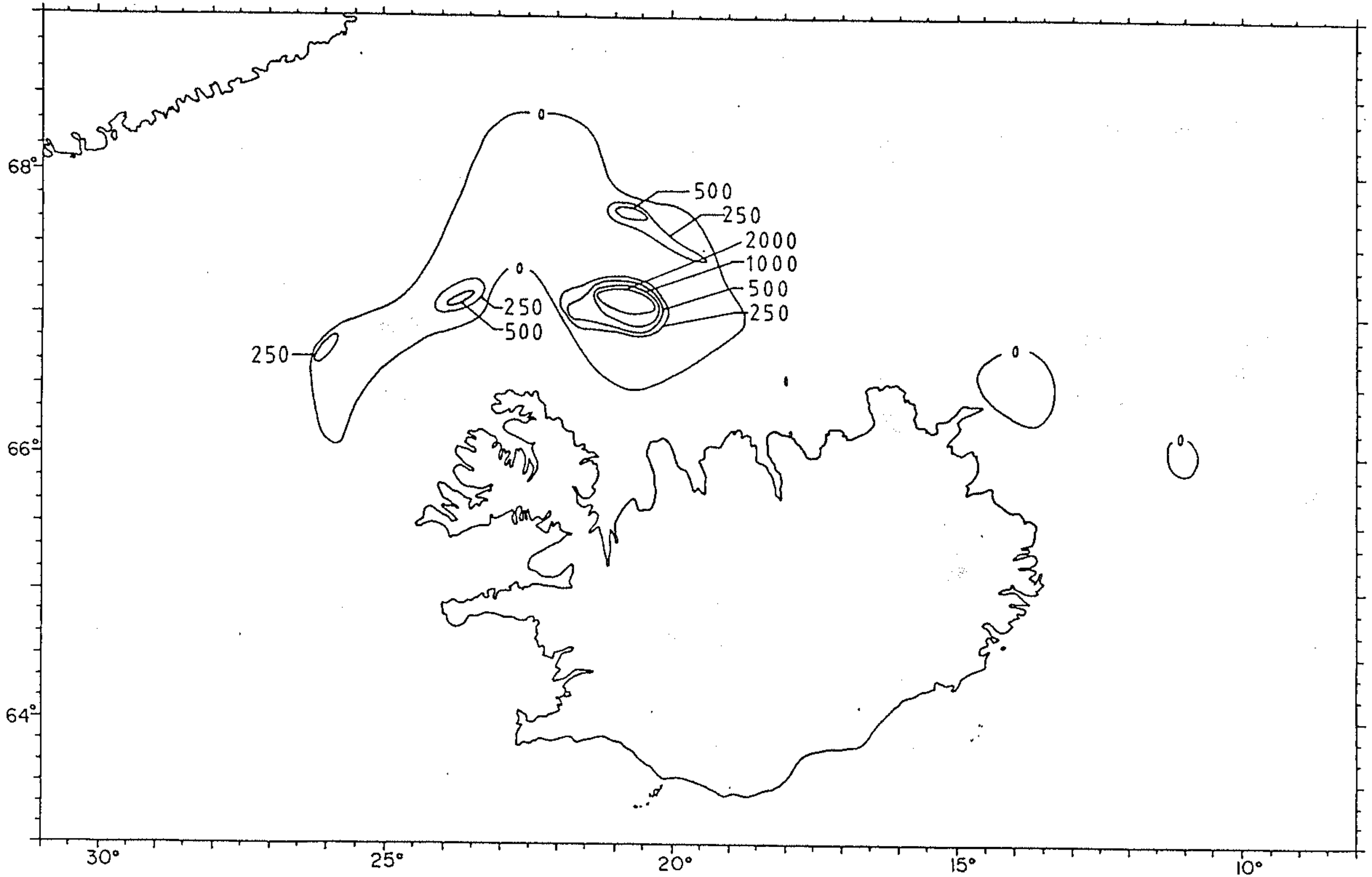


Figure 5.2 The distribution and relative density of capelin, August - September 1990.



APPENDIX

COMMENTS ON METHODOLOGY

by

G. Stefánsson

1. Choice of Reference F

Recent trend at ICES has been towards using only unweighted mean fishing mortalities as reference values. This may not always be appropriate, as will be shown in the following.

The choice of a reference fishing mortality depends mainly on the purpose of the computation. The purposes are usually either (a) to obtain a single value which describes the fishing intensity, i.e., relates in some fashion to effort or (b) to obtain a measure of the effect of fishing on the stock. These two purposes are totally different and lead in a natural fashion to different choices of averaging.

When considering the effect of fishing activities on the stock, one may equivalently ask the question of how a specific age group collection fares during a year. Thus one may ask for a measure of how the 5+ group in 1987 (N(5+,87)) declined during that year (to N(6+,88)). The natural measure of the stock decrease is the F value which is based on the Z which gives:

$$N(6+,88) = N(5+,87) * e^{-Z(5+,87)}$$

This corresponds to the total mortality measure:

$$Z^{*} = \ln(N(5+,87)/N(6+,88))$$

and this is of course essentially an average of the Z-values for individual age groups, with weights which are high for high stock numbers. Thus one is lead in a natural way to compute as a reference point the average fishing mortality, weighted by the stock in numbers.

Of course, care must be taken when using these reference points. Firstly, they will (and should) change greatly when a large year class enters the fisheries. If all the age groups in the average are fully selected, then this is merely an indication that the stock with the new large year class is under much less pressure than before the year class entered.

As a rather extreme example, one can start with a fishery with 10 fully recruited year classes, all equal in size 100 million and a constant F of 0.1 (giving a catch of 317 million if M = 0.2). In this case all averages give the same fishing mortality.

In the other extreme, a fishery may consist of a single year class of size to 1000 million and minute other year classes. If catches of 317 million are taken from this year class every year, then the fishing mortality on that single year class is 0.1 and this is in fact the total fishing mortality inflicted on the stock. If a weighted average by stock is used, then the result is 0.1, but an unweighted average yields 0.01.

Finally, suppose a new year class of size 1000 million enters a stock which had 10 equal year classes of size 100 million, so that the total stock goes from 1,000 million to 2,000 million and now has 11 year classes. If, in this case, the entire fleet redirects attention to the new year class, maintaining constant effort (F = 0.1), then the catches stay the same and the fishing mortality is split into 0.1 on 1/2 the stock and 0 on the other half. As far as the effect on the stock is concerned, it is much better measured by using a weighted F of 0.05 than an unweighted F of 0.0091, i.e., the overall F has been halved due to the doubling in stock size, but it has not gone down by a factor of 10. By comparison, an F based on the Z-measure mentioned above becomes

$$-\ln(2000/1559.5) - 0.2 = 0.0488,$$

which, as expected, is close to the weighted mean.

Using weighted mean Fs certainly has drawbacks. In particular, it must be quite certain that interest lies equally in all the age groups which are used in the weighting. Usually this is the same as saying that only fully recruited age groups are used in the average, i.e., the selection pattern increases untill it reaches a peak, after which it is flat and only the flat portion is used.

If care is not paid to this, then a large recruiting year class with a low relative selection will adversely lower the average. The true problem here is not really the weighting, but rather the comparison of apples and oranges, when an average is taken of fishing mortalities over age groups which are not all recruited to the same extent. Such an average can probably never appropriately reflect the effect of fishing on the stock (unless the pattern is specifically accounted for, e.g., by using the annual fishing mortalities from the separable VPA).

When the primary interest lies in using a single measure to describe effort, then the effect of a large recruiting year class must not be that of lowering the measure too much. One way of taking care of this is to attempt to take an unweighted average over several year classes. It must be noted, however, that even in this case, the interpretation of the average is highly uncertain. It may be tempting to say that a stock is fished at a level of F = 0.5, when the fishing mortalities are (0.1,0.3,0.8,0.8). However, a much more reasonable measure is simply 0.8 - this being the correct multiplier for a selection pattern. Naturally, in cases where most of the fishing is concentrated on few, young age groups, the fishing mortality on the older ages may be too badly known for this approach to be feasible, but it is felt that this is the most reasonable approach when applicable.

Finally, it should be noted that when averages over fully recruited age groups are used, these can be used as is for interpreting current levels, short-term projections and long-term projections. Unweighted and weighted averages will be measurements of that same overall mean.

In many cases, minor changes on younger age groups will have little effect on the yield curve and thus this measure will often be quite robust to small changes. Deviations used to adapt short-term projections to foreseeable changes in selection on young age groups will, therefore, be more or less comparable with longer-term yield predictions. As a measure of fishing effort, the F corresponding to the flat portion of the selection curve (weighted or unweighted) will be a consistent measure in most cases.

2. Tuning with Acoustic Data

The stock size of the Icelandic summer spawners has been estimated using several years of acoustic data, as indicated in Section 2.5. The following note describes the procedure in some more detail and indicates why the Laurec-Shepherd tuning procedure has not been used. The method used was introduced in Halldorsson et al., 1986 and has been used for Icelandic Summer Spawners for some years (Anon., 1990; Anon., 1989). A similar procedure has been used this year for the Norwegian spring spawners, and the following also reflects on the differences in the procedures.

Denote by N(a,y) the number of individuals of age a in year y in the stock and by ac(a,y) the corresponding acoustic estimate. Let N(a+,y) and ac(a+,y) denote the total number of age a and greater. Then the stock, N(a+,y) is a tunable parameter, whereas the acoustic estimates are independent measurements of those values. Thus the correct approach is to consider ac(a+,y) an independent variable in a regression and N(a+,y) a dependent variable. The dependent variable is a function of the catch-at-age and the input F values, which take essentially the roles of x-variables and parameters in a regression setting.

It is then quite feasible to regress ac(a+,y) on N(a+,y) to obtain a measure of correlation and sum of squared deviations from the regression line (SSE). One such sum of squares is obtained for each setting of the input fishing mortalities.

Since simultaneous estimation of all the fishing mortalities in the last year is fraught with problems, the usual approach is to use the acoustic survey in the last year to estimate the selection pattern in the final year, leaving only the multiplier to be estimated.

The solution to the estimation problem is thus obtained simply by running repeated VPAs with different fishing mortality multipliers, regressing the acoustic estimates against stock size for each VPA and finding the value of F which minimizes the sum of squares.

In the above, no assumption needs to be made on whether the acoustic estimate is unbiased, since the regression can be used to eliminate any constant bias. The existence of bias can be tested as follows. First the above regressions are performed where a slope and an intercept are estimated along with the F value. Thus a sum of squares for a full model (SSE(F)) is obtained with t-3 degrees of freedom. Next, the F value is estimated by fixing the slope to be 1 and the intercept to be 0. This yields a sum of squares for a reduced model, SSE(R), with t-1 degrees of freedom. The two sums of squares can now be used in an ordinary F-test for testing the joint hypothesis that the slope is 1 and the intercept is 0.

These tests were carried out in Halldorsson et al., 1986, and the test results were such that the hypothesis was not rejectable. Therefore, a 1-1 relationship has been assumed between the acoustic estimates and the stock size, when tuning. In this case the method reduces to a simple minimization over F of the squared differences between the acoustic and VPA estimates..

The stock estimates of the juveniles in the last year have no effect on the fitted F-value or SSE and are therefore not truly tuned with the procedure. Further, acoustic estimates of juvenile herring are sometimes not feasible at the same time as the surveys of the adult stock are performed and in some years no estimates are obtainable for the juveniles. In such cases the most reasonable approach is to estimate the stock size of the juveniles by finding the stock size in the last year which via back-calculation gives a value corresponding to an earlier acoustic estimate of those year classes. The resulting pattern of fishing mortalities should probably not be used for projections, but the stock estimates can be used for short-term catch forecasts.

The choice of which age groups to aggregate before tuning is usually based on which age groups are generally considered fully recruited, both to the fishery and to the survey (although exceptions exist - it is essential to include the 1983 year class when the Norwegian Summer Spawners are considered). When this type of aggregation is performed, there will be little if any age-determination errors in the acoustic index and one should, therefore, expect a better-behaved tuning. However, as described in Stefansson (1987), it is quite feasible to use an age-disaggregated acoustic index and do several regressions, adding the SSEs across the age groups. This approach is similar to that used by ADAPT, although quite a bit simpler. The method was originally invented to account for varying cathcabilities in the different age groups.

The method has, however, not been widely used and has only been tested on CPUE data, where it is essential to age-disaggregate before tuning. The acoustic surveys do not always obtain a measure of all age groups, resulting in zero values in some of the age groups. This may be due to lack of coverage of the full stock or due to variation in the samples taken for age determination. Whatever the reason, the presence of zeroes will result in extra complications in many fitting procedure, since it is often natural to use logarithmic transforms or ratios when fitting or regressing. In any case, it is certainly clear that if the survey covers a number of year classes fully (or equally well), then the aggregate index will contain much less variability than the individual indices.

For these reasons the Working Group has used aggregated indices for tuning.

Among the virtues that the current approach has over using, for example, the Laurec-Shepherd procedure, are (1) it is based on a well-formulated statistical method (2) it accommodates some parsimony in the final selection pattern and (3) it allows formal testing of assumptions such as whether the acoustic survey really measures the entire stock. The Laurec-Shepherd method is an ad hoc tuning method, which does not conform to standard statistical methodology (e.g., it cannot yield confidence intervals), often yields very unreasonable selection pat terns in the final year and cannot yield any formal tests of whether the acoustic survey really measures the stock (although some ad hoc tests are available).

The criterion used for the Icelandic summer spawners was to minimize over F the sum of squared differences between the acoustic measurements and the VPA values (possibly using a regression). Terminal F for the Norwegian Spring Spawners was estimated by considering the sum of squares of

$$\frac{ac(a+,y)-N(a+,y)}{ac(a+,y)}$$

Of course, this is not the same criterion as using squared differences. Another natural candidate for a criterion is the difference between log-transformed values. These three criteria were tested for the Icelandic Summer Spawners and resulted in terminal F values as in the following table:

Method	F
ac-N	0.29
ln(ac)-ln(N)	0.28
(ac-N)/ac	0.32

These methods thus yield very similar results.

Finally, it must be noted that only 3 acoustic estimates are available for the Norwegian summer spawners and hence it is not feasible to attempt to estimate a slope and an intercept in a regression. This would require estimation of 3 parameters (slope, intercept and F) and only 3 degrees of freedom are available. However the simple plot of ln(ac(3+)) _vs_ time (Figure 3.2) with the same Z as the stock does indicate that the surveys are at least proportional to the stock size (i.e., no intercept should be needed in a regression of survey against stock).

It should be noted that it is necessary to continually assess the quality of the acoustic surveys and the best indications of the surveys' qualities is through comparisons with tuned VPA.