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REPORT OF THE WORKING GROUP ON ATLANTO-SCANDIAN HERRING AND CAPELIN

Copenhagen, 27 - 31 October 1986

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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 Working Group on Atlanto-Scandian Herring and Capelin met at ICES headquarters from 27 to 31 October 1986 to:

a) assess the status of the Norwegian spring-spawning herring and capelin in Sub-areas I, II, V, and XIV and advise on any necessary management measures for these stocks;

b) provide time series of catch in numbers, fishing mortality, and stock size at age from VPA for all stocks as far back as possible.

1.2 Participants

J. Carscadden	Canada
H. Gjøsæter	Norway
J. Hamre	Norway
O. Halldórsson	Iceland
H.i. Jákupsstovu	Faroes
P. Kanneworff	Denmark
V. Shleinik (Chairman)	USSR
R. Toresen	Norway
H. Vilhjálmsson	Iceland

2 NORWEGIAN SPRING-SPAWNING HERRING

2.1 Working Papers Presented

The following working papers were presented: "Norwegian spring-spawning herring" by J. Hamre and R. Toresen, and "Spawning efficiency of Atlanto-Scandian herring on the Norwegian Shallow in 1986" by I.V. Borkin and A.I. Krysov.

2.2 Catch Statistics

A national catch quota of 61,380 t was set for Norwegian vessels in 1985. The fishery is regulated with a quota per vessel.

The catch of Norwegian spring-spawning herring from 1972 to 1985 in terms of weight and number is presented in Tables 2.1 and 2.2. A quantity of 10,000 t was added in Table 2.2 for herring of age 3 and older to compensate for unreported catches. These tables also include the by-catches of 0- and 1-group herring in the sprat fishery north of 62°N, and the by-catches of 2-group herring by the USSR and Norway in the capelin fishery in the Barents Sea. In the winter of 1986, a USSR catch of 3-group herring in the Barents Sea is reported to be 26,000 t. The preliminary 1986 catch in Norwegian coastal waters up to 1 November is reported to be 65,000 t.

2.3 Recruitment

2.3.1 Larval survey in 1986

The USSR conducted a herring larval survey in April 1986 as in previous years. The number of herring larvae caught was lower in 1986 compared with 1983, and their distribution was more southern.

2.3.2 The 0-group index from the international 0-group survey

Indices of 0-group Norwegian spring-spawning herring have been estimated for the period 1965-1986 based on data from the international 0-group surveys in the Barents Sea. The estimated indices of abundance for the last 14 years are given in Table 2.3.

The recruitment of herring has been very low in the period since the 0-group surveys started in 1965. However, in spite of the fact that the spawning stock biomass is still at a low level, a very strong year class was recorded in 1983. The strength of this year class has been verified several times by acoustic abundance estimation (Røttingen, 1985; 1986). The estimated 0-group indices of the 1984 and 1985 year classes were on a considerably lower level than that for the 1983 year class. However, compared to the level of recruitment in the 1970s and early 1980s, these year classes were considered as strong at the 0-group level. In 1986, only a few individuals of 0-group herring were caught during the 0-group survey in the Barents Sea. Thus, the estimated logarithmic index this year is zero indicating a weak year class.

2.3.3 Acoustic 0-group estimates in the Barents Sea

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

Year class	Estimated number x 10^{-9}	Time of survey
1983	35.7	Nov 1983
1984	6.2	Nov 1984
1985	41.5	Sep 1985
1986	0	Sep 1986

The estimates for the years 1983-1984 are looked upon as underestimates. The conditions for abundance estimation of 0-group herring in 1985 were more favourable, and the estimate was considered far more reliable than the corresponding estimates for the two previous years. In 1986, no 0-group herring were detected in the Barents Sea.

The correlation between the index of the international 0-group survey and the acoustic 0-group estimates in the Barents Sea in 1983-1985 is rather poor. There has been no doubt about the strength of the 1983 year class since it appeared strong in both surveys. The 1984 year class came out with a fairly high index in

the 0-group survey, but later it failed to appear either at the 0-group stage in late autumn or at the 1-group stage last year. The lack of appearance during the acoustic survey in 1984 can be explained by the lack of coverage due to bad weather conditions. However, the reasons for the almost complete absence of this year class during the acoustic survey last autumn cannot be explained in the same way. The severe decline in the stock of capelin in recent years indicates a dramatic increase in predation pressure caused by the increase in the stocks of cod and haddock in the area. These species are also feeding heavily on small herring, and the disappearance of the 1984 year class is assumed to be caused by predation. According to the acoustic estimate of the 1985 year class last year, it was also found to be abundant as 0-group herring. However, the results from the international survey this autumn also indicate that this year class is severely reduced.

2.3.4 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 2.4.

2.3.5 Acoustic estimates of the 1983 year class in the Barents Sea

The text table below reviews the acoustic abundance estimates of the 1983 year class in the Barents sea:

Time	Abundance of 1983 year class in the Barents Sea ($N \times 10^{-9}$)
Sep 1985	23.3
Jan 1986	14.5
May 1986	5.9

The conditions for acoustic abundance estimation of herring in the Barents Sea have usually not been good. The main problem in September 1985 was small dense schools near the surface, and in January 1986 most of the herring were recorded on the sea bed. In May 1986, the herring were recorded under good weather conditions as a scattering layer in 150-200 m depth. These should normally be good conditions for acoustic abundance estimation. However, an intercalibration in the summer of 1986 showed that the threshold level for the R/V "Eldjarn", which carried out the May 1986 survey, was high for depths below 100-150 m. The May 1986 abundance may, therefore, be underestimated. During the international blue whiting survey in the Norwegian Sea in the summer of 1986, the integrator outputs for recordings for the R/V "Eldjarn" from under 150 m depth were multiplied by 1.82 before application in the abundance estimates (Monstad, 1986).

2.4 Adult Stock

2.4.1 Tagging

With respect to the tagging method and the model used in computing the tagging data, reference is made to the working paper on Norwegian spring-spawning herring presented to the Atlanto-Scandian Herring and Capelin Working Group in 1985.

As in previous years, the herring is assessed in two separate components: a southern and a northern component. The assessment of the adult stock is based on recoveries retained from winter catches taken in the wintering areas and on the spawning grounds. In the winter of 1986, 2,246 t of prespawners caught in the wintering area and on the spawning grounds of the northern stock component were screened for tags and 286 tagged herring were recovered. From 2,586 t of herring caught on the spawning grounds of the southern stock component, 397 tags were recovered. Details of the recoveries are shown in Tables 2.5 and 2.6 for the southern and northern components, respectively. The boundary between the spawning grounds of the two components is at about 63^0N.

The releases allocated to the southern component have given 347 recoveries from catches taken south of 63^0N (r_{ss}) and 50 recoveries in catches from north of that latitude (r_{sn}). For the northern component, r_{nn} and r_{ns} are 272 and 14 respectively. The screened catches by number, age, and component are shown in Table 2.7.

2.4.2 Mortality estimates

Prior to 1982, the herring used for tagging were caught by purse seine, towed to the shore, and kept in keepnets before tagging. This was the tagging procedure used in the 1950s, and in assessing stock size from these data, a tagging mortality of 30% was applied (Dragesund and Jakobson, 1963). In 1982, a new method of tagging was introduced. The herring are now brailed onboard the seiner by a special brailing net and kept in RSV tanks before tagging. This new method of handling the tagged herring seems to have increased the mortality due to tagging (decreased the survival coefficient s). In order to investigate the magnitude of the change in s after 1982, the recoveries are grouped in two time series: the releases in the period 1975-1981 and those tagged in 1982 - 1985 (Tables 2.5 and 2.6). This investigation indicates that s is reduced by some 50% after introducing the new tagging method. For further explanation, reference should be made to the working paper by Hamre and Toresen presented at this meeting and available at the ICES Secretariat.

The estimates of total mortality Z over the period 1975-1981 are derived from recoveries retained from combined samples of winter catches in 1984 - 1986 as shown in Tables 2.5 and 2.6. Using the data combined, the plot of lnK ($K = m/r \times 10^2$) against time in liberty is shown in Figures 2.1A and 2.1B for the southern and northern components, respectively. The 1976 releases in both components and the 1980 releases in the north yield very few recoveries. They are regarded as unsuccessful releases and, therefore, are excluded. Fitting regression lines to the remaining

points, the slopes of the lines (Z values) are estimated to 0.18 and 0.16 for the southern and northern stock components, respectively. These estimates are in accordance with the corresponding estimates obtained last year (Z = 0.17).

2.4.3 Stock abundance estimate

Since there is no change in the fishing mortality in 1982 and 1983 (Table 2.11), the number of surviving tagged herring in 1984 by components is calculated by assuming no change in Z in 1982 and 1983:

$$\left[m'_s\right]_{84} = \left[m'_s\right]_{82} e^{-2[0.18]} = 26{,}598$$

$$\left[m'_n\right]_{84} = \left[m'_n\right]_{82} e^{-2[0.16]} = 39{,}014$$

Due to the uncertainties of the relative tagging mortality before and after 1982, only the releases before 1982 are used in this estimate, and the $(m')_{82}$ values for these releases are shown in the right hand columns of Tables 2.5 and 2.6. The 1976 release in both components and the 1980 release in the southern component are, moreover, considered unsucessful tagging and excluded. The calculated Z values for the years 1975-1981 (0.18 and 0.16) are assumed to be valid for the years 1982 and 1983.

The releases are allocated to components according to the position of the catches from which the bulk of the recoveries are retained, and the recoveries r_{sn} and r_{ns} are considered to represent mixed releases. The former represents tagged and released herring in the southern area, which are expected to belong to the northern stock component, and the latter represents herring tagged in the north but belonging to the southern stock component. The corresponding numbers of surviving tagged herring, m_{sn} and m_{ns}, were calculated by the formulas:

$$m_{sn} = \frac{X \times m'_n - m'_s}{X \times Y - 1} \quad \text{and} \quad m_{ns} = \frac{Y \times m'_s - m'_n}{X \times Y - 1}$$

where $\frac{r_{ss}}{r_{ns}} = X$ and $\frac{r_{nn}}{r_{sn}} = Y$

These two equations are applied to estimate $m_s = m'_s - m_{sn}$ and $m_n = m'_n - m_{ns}$, respectively, where m and m are the actual number of surviving tagged herring in the respective areas by components. For further description of the method, reference is made to the 1985 working paper.

Disregarding tagging mortality, the surviving tagged fish in 1984 by area of component distribution is calculated by inserting the relevant data in the two formulas:

$$m_{s_{84}} = m_s - m_{sn_{84}} = 26,598 - 7,753 = 18,845$$

$$m_{s_{84}} = m'_s - m_{sn_{84}} = 39,014 - 312 = 38,702$$

The 1979 and older year classes are supposed to be fully recruited in 1984 and, assuming 30% tagging mortality as in previous years, the following stock abundance estimate of 5 years and older herring in the spring of 1984 is obtained:

$$N_s = \frac{0.7 \times 18,845 \times 6,582 \times 10^3}{121} = 718 \times 10^6$$

$$N_n = \frac{0.7 \times 38,702 \times 5,906 \times 10^3}{149} = 1,074 \times 10^6$$

$$N = N_s + N_n = 1,792 \times 10^6$$

The corresponding stock abundance estimate made last year is (in millions of individuals):

$$N_{79+} = (N_s + N_n)_{79+} = 804 + 1,470 = 2,274$$

The present estimate is about 25% lower than the estimate made last year, but corresponds with the estimates made in 1984 (1,718). The main reason for the reduced stock abundance calculated this year is the exclusion of the releases after 1982, but the exclusion of the 1975 release in both components and the 1980 release in the southern component has also contributed to this reduction.

2.4.4 Virtual population analysis

The state of stock at 1 January 1986 has been assessed by tuning the VPA against the estimated state of stock in 1984 referring to the 1979 and older year classes. The 1980 and 1981 year classes were assessed by assuming an F value in 1985 equal to the calculated average F of the 1978 and 1979 year classes. The 1982 year class in 1985 is assessed according to the acoustic 0-group estimate in 1982 and the regression function shown in Figure 2.2.

The following input data were applied:

Catch in number per year class	Table 2.2
Weight at age	Table 2.8
Maturation	Table 2.9
Natural mortality M	0.13
Initial stock	Abundance estimates of age 5+ in 1984 from tagging experiments

The results of the VPA back to 1976 are shown in Tables 2.10 and 2.11 and the results of the VPA back to 1961 are shown in Appendix A. The back-calculated stock and corresponding fishing mortality in 1973 - 1981 are in close agreement with the VPA estimates based on the stock abundance estimate obtained from tagging

prior to 1985. According to the stock estimate and VPA made last year, the spawning stock was found to increase from about 500,000 t in 1981 to 840,000 t in 1984. With a calculated F value in 1984 of 0.066 and assuming a similar F in 1985, this stock was projected forward to a level of 850,000 t in 1986.

The present assessment shows a similar growth in the spawning stock in the 1970s and in the beginning of the 1980s, but flattens out at a maximum of 635,000 t in 1984. This is mainly due to poor recruitment from the 1980 year class. The 1981 year class is also very poor, and since the fishing mortality is increased in 1984, the stock decreases to 580,000 t in 1985. The fishing mortality is further increased in 1985, and although the recruitment from the 1982 year class is somewhat improved, the stock has continued to decrease and is estimated at about 540,000 t in 1986.

2.4.5 Catch and stock prognosis

Due to a reduced growth rate for that portion of the 1983 year class which is distributed in the Barents Sea, the prognosis of catch and stock size for the period 1987-1988 was run in two separate sections, as last year.

2.4.5.1 Input data for the component in Norwegian coastal waters

The input data (Table 2.12) refer to the stock component at 1 January 1986. The estimate of the 1985 year class as 1-year-olds is taken from the 0-group acoustic estimate (Table 2.4). The estimates of the 1984 and 1983 year classes are derived from the acoustic estimates of 0-group herring (Table 2.4) reduced by an annual conversion factor (C) of 0.41. This estimate of C was obtained from the relationship between the numbers of 3-year-old herring from VPA and the 0-group acoustic estimates (Figure 2.2). The estimates for ages 4 and older were from the VPA.

The fishing pattern was changed from that used in last year's assessment. The fishing pattern in 1986 was assumed to be the same as in 1985 when most of the fishing occurred in the south. Results from the 0-group acoustic surveys (Table 2.4) indicated that most of the 1982 and 1983 year classes occurred in the north and, therefore, the fishing patterns were adjusted accordingly. The maturity ogive was the same as that used in the VPA.

The weights in the catch have also changed from those used last year. Previously, the catches were taken in the autumn, but now catches will be taken throughout the year and average annual weights are used.

2.4.5.2 Input data for the Barents Sea component

Only the 1983 year class is considered in this prognosis because the strengths of other year classes are considered to be negligible compared to the 1983 year class. The input data (Table 2.13) refer to the stock component at 1 January 1986. The estimate of the 1983 year class (14.5×10^9) was the January 1986 acoustic estimate obtained during the joint Norwegian-USSR acoustic survey. The value of $M = 0.40$ was in order to compensate for the expected predation before the stock left the Barents Sea in the

summer of 1986. The maturity ogive, weight in the catch, and weight in the stock were the same as used last year.

2.4.5.3 Results of prognosis

The results of the prognoses for the coastal component and the Barents Sea component are given in Tables 2.14 and 2.15, respectively. The combined prognosis for 1987 and 1988 is given in the text table below and in Figure 2.3. This combined prognosis

1986			1987				1988	
Stock biomass	SSB	C	Stock biomass	SSB	F	C	Stock biomass	SSB
1,791	543	123	1,772	755	0.00	0	2,317	1,635
					0.02	40	2,278	1,607
					0.04	89	2,232	1,572
					0.07	159	2,166	1,521
					0.11	242	2,086	1,464
					0.14	306	2,024	1,416

Weights are in '000 t.

assumes that both components are completely mixed or subjected to the same fishing mortality.

These results are less optimistic than the prognosis made last year, with the largest difference occurring in the coastal component.

In 1985, the spawning stock biomass was estimated at 840,000 t, which was about 200,000 t above the 1984 stock estimate. The present stock estimate is 540,000 t, which is about 300,000 t less than predicted. The difference is due to the overestimate in 1985 which can be explained by changes in the tagging method.

3 BARENTS SEA CAPELIN

3.1 Working Papers Presented

The following working papers were presented: "The Barents Sea Capelin" by H. Gjøsæter, "On peculiarities of capelin approaches to coasts for spawning in spring 1986" by N.G. Ushakov, "Soviet investigations of larval capelin in the Barents Sea in 1986" by N.V. Mukhina and E.I. Seliverstova, and "Report of the joint Norwegian/USSR acoustic survey of capelin, herring, and polar cod in the Barents Sea in September-October 1986".

3.2 Regulation of the Barents Sea Capelin Fishery

Since 1979, the Barents Sea 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. Since 1984, the fishery has been closed from 1 May to

1 September. A minimum landing size of 11.0 cm has been enforced and a minimum mesh size of 16 mm introduced.

3.3 Catch Statistics

The international catch by country in the years 1965-1986 is given in Table 3.1. The capelin catch (USSR and Norway combined) in numbers by age and month for the period 1 September 1985 - 30 April 1986 is given in Table 3.2. No catches have been taken in the autumn of 1986.

3.4 Stock Size Estimates

3.4.1 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 3.3. From 1981 to 1985, there has been a constant larval production, aside from a 20% reduction in 1984. In 1986, however, no larvae were caught in the Norwegian larval survey. This can partly be explained by the late approach of the capelin to the coast, and consequently a late spawning this year. Some spawning is known to have taken place in the Varangerfjord area (this is confirmed by plankton sampling conducted in the area in June), but the extent is not known. Judging from the migration route of the aproaching capelin this year, probably very little spawning has taken place further west. The Norwegian larval cruise covered the area to the west of 35^0 E, but no larvae were observed.

A Soviet larval survey based on the ring trawl and IKS-80 egg nets was carried out from 24 March to 15 July. Larval capelin were found only at three coastal stations of the Kola section on 14-15 July (Figure 3.1). A total of 772 larvae was captured with an average length of 11.9 mm.

This result confirms the results of a Soviet investigation on the capelin approaches to the coast for spawning and also a joint investigation in the Barents Sea in January which showed that the spawning stock in 1986 was at an extremely low level.

During the international 0-group survey in the Barents Sea in August (Anon., 1986), 0-group capelin was observed in only a few trawl hauls spread over most of the surveyed area and in a small continuous area in the southeastern part of the Sea (Figure 3.2). No index was calculated for capelin. However, the narrow distribution area and the low density of larvae indicates the 1986 year class to be even poorer than the 1985 year class.

3.4.2 Acoustic stock estimates

The 1986 acoustic survey was carried out in the period 6 September - 13 October as a joint Soviet-Norwegian cruise. The distribution of capelin in 1986 is shown in Figure 3.3. Five research vessels (three Norwegian and two Soviet) participated in

this survey. The following abundance estimates by year class were obtained:

Year class	Number (10^{-9})	Mean weight (g)	Biomass (10^{-3} t)
1985 (1984)	8 (35)	4.2 (4.3)	32 (150)
1984 (1983)	3 (47)	11.7 (8.7)	40 (389)
1983 (1982)	3 (21)	14.3 (13.0)	42 (268)
1982 (1981)	0.2 (1)	16.0 (15.6)	2 (14)

The estimates of the same age groups in 1985 are shown in parenthesis for comparison. The 1985 year class is 5 times lower by number than the 1-group measured last year.

The 1984 year class is less than 10% of the size by number of the 2-group measured last year and is the lowest 2-group estimate ever obtained.

The strength of the 1983 year class is likewise the lowest 3-group estimate recorded and is about 7 times lower by number than the 3-group estimate obtained last year.

In addition, the 4-year-old fish have almost disappeared from the stock.

The observed mean weights of the various age groups are slightly above those measured last year. Nevertheless, the total stock biomass is estimated to be 116,000 t (Table 3.4), compared to 820,000 t in 1985.

It is assumed that the acoustic method of estimating stock abundance underestimates stock size in general, and it is likely that the relative error will be larger when the stock density is low. Moreover, the occurrence of the capelin together with a dominating stock of polar cod has added a new source of error to the abundance estimate of the capelin stock. Nevertheless, it must be concluded that the stock is now seriously depleted and may also suffer from recruitment failure in the years to come.

3.4.3 History of catch and stock

Table 3.5 provides information on stock size and mortality of the Barents Sea capelin stock since 1974. The model-dependent quantities are calculated from the same assumptions as used by the Working Group in 1984 (adjusting the 1982 estimate). The model used is documented in a paper by Hamre and Tjelmeland (1982) and in a working paper presented to the 1985 Working Group meeting. The computation of the various quantities in the table is explained below.

Stock size by 1 January

This quantity is calculated by taking the stock size estimate in September of the previous year and reducing it by fishing and natural mortality in the last three months of the year.

The natural mortality is estimated using the model "CAPELIN" for two periods with different levels of mortality: the mortality was 0.051 per month from 1973-1978 and 0.072 per month from 1979-1984. These two periods were chosen not only because annual estimates revealed that a change to higher mortalities took place around 1978-1979 (Figure 3.4), but also because biological considerations make such a change plausible. The total stock of capelin was much reduced that year, both because the growth rate was faster resulting in a larger-than-usual proportion of the stock that matured, spawned, and died and because fishing was heavy. If the stocks of capelin predators took an equal amount of capelin as in previous years, this must have led to an increased natural mortality. As the natural mortality and the length at maturity cannot be separated in the estimations, the maturing length is also decisive for the calculations of stock sizes. For the two periods mentioned, the length at maturity was 14.01 cm and 13.94 cm, respectively. For 1984-1985, the natural mortality was estimated to be 0.14 per month for a length at maturity of 13.06. These values are also tentatively used for the 1985-1986 period.

Spring catch and autumn catch

The catch per season is the sum of Norwegian and Soviet catches. The catches from other countries are negligible.

Spawning stock size by 31 March

An estimate of the abundance of the mature portion of each age group contributing to the spawning stock is calculated from the total population by the model according to the length at maturity. This estimation is done by January, and the spawning stock is reduced by catch and natural mortality in January, February, and March.

Stock at 1 August

The number of 2- to 5-year-old fish is back-calculated from the acoustic stock estimate in September, adjusting for the catch in August and prior to the survey in September.

For the 1-year-old capelin, the stock size is back-calculated from the acoustic estimate of the year class as 2-year-olds the next September, adjusting for the catch in the previous 14 months.

Autumn fishing mortality

The fishing mortality in the autumn by age group is calculated from the stock size estimate at 1 August, the estimated natural mortality, and the catch in the autumn season.

3.4.4 Management considerations

The natural mortalities for immature capelin, estimated on a yearly basis, are shown in Figure 3.4. Prior to 1978, this mortality was at a low and constant level. From this year onwards, the mortality estimates fluctuate around an increasing mean value. From 1982 to 1985, the natural mortalitiy has increased almost fourfold. The fishing mortalities on immature fish in the

autumn fishery (represented by the mean fishing mortalities for the 2- and 3-year-olds) are also depicted in Figure 3.4. Although there is an increasing trend in the fishing mortality during the period, the fishing has probably had a small impact on the stock compared to the natural mortality, except in the years 1982 and 1983.

In the report of the Atlanto-Scandian Herring and Capelin Working Group meeting in 1985, it was pointed out that the decline of the capelin stock exceeds by far what can be explained by the fishery, and is probably connected to the substantial change in the Barents Sea ecosystem observed in recent years. This change is first of all reflected in a series of four strong year classes of cod and haddock, and is probably connected to an increased inflow of Atlantic water in the period. For the capelin stock, these changes have led to an increased natural mortality and recruitment failure. The serious decline in the capelin stock size observed in 1986 supports these considerations.

Thus, the Working Group concludes that the decline in the stock size is not primarily a problem of overfishing, but is mainly an effect of natural causes.

Up to 1985, the larval investigations indicated a constant larval production, and the recruitment failure observed for the 1984 and 1985 year classes was explained by an increased predation on the 0- and 1-group stage rather than by an effect of an insufficient spawning stock. However, in 1986, the larval production has probably been very small, and the expectations for the 1986 year class are consequently poor. This low larval production is also supported by the results of the international 0-group survey. Therefore, at least three poor year classes will recruit to the stock, and it is expected that the stock will remain at the present low level in the coming years.

Based on the present low estimate of capelin abundance, the poor recruitment of the 1984-1986 year classes, and the increased natural mortality due to predation by the cod and haddock stocks which are increasing in abundance, the Working Group recommends that no fishing of Barents Sea capelin should take place in 1987.

4 THE ICELANDIC CAPELIN

4.1 The Fishery

The total annual and seasonal catch of capelin in the Iceland-East Greenland-Jan Mayen area since 1964 is shown in Table 4.1.

On the basis of the October survey, a TAC for the whole 1985/1986 season was set at 1,280,000 t. The final catch figure for the 1985/1986 season is 1,307,000 t (Table 4.1). Surveying carried out in February 1986 indicated that the target of 400,000 t of capelin spawning in 1986 was attained.

In February 1986, Iceland carried out an acoustic survey of the distribution and abundance of immature capelin of the 1984 and 1983 year classes which will constitute the fishable stock in the 1986/1987 season. The survey yielded an abundance estimate by number of 72.3×10^9 and 52.6×10^9 for the above year classes,

respectively. This stock estimate indicated that the abundance in number of the fishable stock in the 1986/1987 season might be similar to that of the previous 1985/1986 season.

Due to the large variations in mean weight which may occur from one year to another, as well as in the maturity ratio of the younger year class, a TAC of 800,000 t was set for the July-November 1986 period. A TAC for the December 1986/March 1987 period could then be set after a new stock abundance estimate became available in late October 1986.

When the October 1986 survey was completed, Norwegian and Icelandic capelin catches amounted to 150,000 and 280,000 t, respectively, and Faroese and Danish vessels had caught 70,000 t under Greenlandic license.

4.2 The October 1986 Stock Abundance Estimate

The autumn 1986 acoustic survey was carried out during the period 4-22 October. Two vessels participated and obtained the following abundance estimate by year class:

Year class	Number ($\times 10^{-9}$)	Mean weight (g)	Biomass (10^{-3} t)
1985	58.6	4.0	237.1
1984	20.5	17.8	364.9
1983	29.9	24.1	719.3
1982	0.3	28.8	9.7
Total	109.3	12.2	1,331.0

Further details of this stock estimate are given in Table 4.2.

Judging by the maturity stage, approximately 1,090,000 t, comprising practically all the capelin belonging to the 1983 and 1984 year classes, will mature and spawn in March 1987. The maturity ratio in the younger year class is, thus, very high which probably results from favourable feeding conditions as well as its relatively low abundance.

During the year's survey, there was little interference by drift ice except in the westernmost part of the distribution area of the juvenile 1985 year class. Otherwise, conditions for surveying were normal for this time of the year, with the possible exception of schooling near the surface at night in parts of the distribution area of the adults which, therefore, may be somewhat underestimated. The distribution and relative abundance of 1- to 3-group capelin in October 1986 is shown in Figure 4.1. The distribution of the 0-group in August 1986 is shown in Figure 4.2.

When taking account of the natural mortality rate M = 0.035/month (Table 4.3), as well as catch in numbers in the July-October 1986 period (Table 4.4), the February 1986 and October 1986 estimates of the abundance in number of the 1983 year class are in good agreement. Compared in the same way the October 1986 estimate of the 1984 year class is, however, much lower than that obtained last February.

The age distribution in the catches taken in the 1986 summer/autumn season is, on the other hand, practically the same as recorded in the October 1986 survey. Consequently, the abundance of the 1984 year class must have been overestimated in February 1986 compared to the estimate obtained in October 1986.

4.3 TAC for the December 1986 - March 1987 Period

The October 1986 stock abundance estimate was accepted as valid and used as a basis for calculating the TAC.

The following assumptions were made:

a) All capelin 13.5 cm and larger will mature to spawn in 1987. This length at maturity is derived from maturity observations made during the survey. These capelin will be in the catch during the whole fishing season.

b) Immature capelin will be an insignificant proportion of the catch in the present season.

c) Natural mortality rate will be M = 0.035/month.

d) The mean weight of the 1984 and 1985 year classes will increase by 1.0 and 2.2 g, respectively (Figure 4.3).

e) There will be 400,000 t left to spawn in 1987.

Based on these assumptions, it is calculated that the October 1986 survey results correspond to a TAC of 660,000 t to be evenly distributed over the 4-month period November 1986 - February 1987. At the time of the October survey, about 370,000 t of the TAC for the July-November period remained to be taken. Consequently, it is recommended that the TAC for December 1986 - February 1987 be set at about 300,000 t.

4.4 TAC for the Summer - Autumn 1987 Season

According to the age composition, as well as the present maturity stage of the 1984 year class in the October 1986 survey, the fishery will be almost entirely based on the 1985 year class (the present 1-group capelin).

In the last two seasons, TACs have been recommended for the summer/autumn period on the basis of results of acoustic surveys carried out in February 1985 and 1986 as well as forecasts of average weights and using a fixed mortality rate. TACs for the remaining parts of the seasons were then set on the basis of surveys carried out in the autumn in the same years.

It is now clear, however, that the forecast of the abundance of the younger year class (1984) in the present fishable stock must have been overestimated in the February 1986 survey. Alternative methods of forecasting the abundance of 2-group capelin by number at the beginning of the fishing season have, therefore, been considered.

The abundance by number of 1-group capelin of the 1981-1985 year classes has been measured in acoustic surveys carried out in August 1982-1986. The resulting estimates have been plotted against the abundance of these same year classes as measured later in their lives, taking account of catches and mortality rates. These comparisons, however, give unacceptable deviations and cannot be considered suitable for recommendations of TACs.

Apart from the adult or fishable capelin, which have been the main target of the autumn acoustic surveys of stock abundance, 1-group juveniles are also recorded. It has always been clear that the 1-group is underrepresented in the autumn surveys, probably mainly because of trawl selection. Nevertheless, when 1-group abundance by number as recorded in autumn is plotted against the acoustic estimate of the same year classes in the following autumn, taking account of catch and the mortality rate, a high correlation coefficient of r = 0.93 is obtained for the six pairs of data available (Figure 4.4).

On the basis of the 1986 October survey, the 1-group abundance by number of 58.6×10^9 thus corresponds to about 68×10^9 fish by the end of October 1987 or 75×10^9 on 1 August in the same year. Based on this criterion, a TAC for the 1987-1988 seasons has been calculated making the following assumptions:

1) The 1987-1988 fishable stock and, therefore, the 1988 spawning stock will consist almost exclusively of the 1985 year class.

2) The mean weight in the fishable stock will be the same as the average weight of 2-group capelin in the autumn surveys in the period 1979-1986 or 16.5 g (Table 4.4).

3) The mean weight in the 1988 spawning stock will be 17.8 g.

4) The natural mortality rate will be M = 0.035/month.

5) There will be 400,000 t left to spawn in 1988.

Based on these criteria, it has been calculated that the TAC for the 1987-1988 season could be about 700,000 t, spread evenly over the period. This corresponds to 450,000 t for the period August-November 1987 based on the same criteria as used for the 1986-1987 season.

It is expected that additional information on immature capelin of the 1984 year class will be obtained from surveys during January-February 1987. The Working Group, therefore, recommends that advice on the TAC for the 1987 summer and autumn season be deferred until spring 1987.

5 BIOLOGICALLY SAFE LIMITS

5.1 Introduction

In addition to the terms of reference given in Section 1.1 of this report, the Working Group also addressed the issue of "Safe Biological Limits" as requested by the Chairman of ACFM (letter dated 20 January 1986). As a basis for considering this topic, the Working Group used, as guidelines, the questions adopted by

the Irish Sea and Bristol Channel Working Group. These questions are as follows:

1) Is there any evidence from the stock-recruit data that recruitment is reduced at the lowest levels of spawning stock which have been observed in the historic series?

2) Is the spawning stock currently at a level which is lower than any previously observed?

3) Does spawning biomass show a declining trend, which, taken with available evidence on recruitment, might indicate that a historically low level will be reached in 1986 or 1987?

4) What level of F in 1987 would be needed to reduce the spawning stock biomass to an historically low level in 1988 and what would the corresponding catch be in 1987?

5.2 Norwegian Spring-Spawning Herring

According to historical stock-recruit data, this stock has suffered from recruitment failure after the spawning biomass declined below 2.5 million t (Dragesund et al., 1980). The stock was at a very low level during the early 1970s, and although there has been an increase in abundance during the 1970s and 1980s, the spawning stock is still far below that biomass.

The Working Group, therefore, concluded that the Atlanto-Scandian herring should still be defined as a depleted stock.

5.3 Barents Sea Capelin

In the 1970s and early 1980s, the Barents Sea capelin stock was managed by a target spawning stock biomass of 500,000 t. There is strong evidence that the stock is presently at the lowest level ever recorded. The 1984 and 1985 year classes have been reduced to very low levels because of increased predation on the 0- and 1-group stage and the 1986 year class will be low in abundance because of poor larval production. The spawning stock has shown a drastic decline, not only because of overfishing, but because of natural factors such as increased predation, resulting in increased natural mortality.

Because of the low stock size, poor recruitment, and increased predation, the Working Group advises that no fishing should occur on this stock.

The Working Group notes that changes in stocks of cod, herring, and capelin now occurring in the Barents Sea ecosystem have been observed before. During 1962, the capelin fishery was a complete failure apparently because of very low capelin stocks (no capelin abundance estimates are available). At that time, the 1959 and 1960 year classes of both cod and herring were strong.

5.4 Icelandic Capelin

For Icelandic capelin, both recruitment and the spawning stock are at a high level. During the early 1980s, this capelin stock was very low in abundance but now has recovered. The aim in managing this stock has been to maintain a minimum spawning stock biomass of 400,000 t. So far, this target spawning biomass has shown to be adequate in maintaining proper recruitment.

6 REFERENCES

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Table 2.1 International catches of Norwegian spring-spawning herring (t) since 1972.

Year	Catches of adult herring in winter	Mixed herring fishery in autumn[1]	By-catches of 0- and 1-group herring in the sprat fishery	USSR-Norway by-catch in the capelin fishery (2-group)	Total
1972	-	9,895	3,266[2]	-	13,161
1973	139	6,602	276	-	7,017
1974	906	6,093	620	-	7,619
1975	53	3,372	288	-	3,713
1976	-	247	189	-	436
1977	374	11,834	498	-	12,706
1978	484	9,151	189	-	9,824
1979	691	1,866	307	-	2,864
1980	878	7,634	65	-	8,577
1981	844	7,814	78	-	8,736
1982	983	10,447	225	-	11,655
1983	3,857	13,290	907	-	18,054
1984	18,730	29,463	339	-	48,532
1985	29,363	37,187	197	4,300	71,047

[1] Includes also by-catches of adult herring in other fisheries.

[2] In 1972, there was also a directed herring 0-group fishery.

Table 2.2 Catch in numbers (x 10^{-3}) of Norwegian spring-spawners. Unreported catches are included for age 3 and older herring.

Age	1972	1973	1974	1975	1976	1977	1978
0	347,100	29,300	65,900	30,600	20,100	43,000	20,100
1	41,000	3,500	7,800	3,600	2,400	6,200	2,400
2	20,400	1,700	3,900	1,800	1,200	3,100	1,200
3	35,376	2,389	100	3,268	23,248	22,103	3,019
4	3,476	25,220	241	132	5,436	23,595	12,164
5	3,583	651	24,505	910	-	336	20,315
6	2,481	1,506	257	30,667	-	-	870
7	694	278	196	5	13,086	419	-
8	1,486	178	-	2	-	10,766	620
9	198	-	-	-	-	-	5,027
10	-	-	-	-	-	-	-
11	494	-	-	-	-	-	-
12	593	-	-	-	-	-	-
13	593	-	-	-	-	-	-
14	-	178	-	-	-	-	-
15	-	-	-	-	-	-	-

Age	1979	1980	1981	1982	1983	1984	1985
0	32,600	6,900	8,300	22,600	127,000	33,857	28,571
1	3,800	800	1,100	1,100	4,679	1,700	13,149
2	1,900	400	11,900	200	1,675	2,489	207,224
3	6,352	6,407	4,166	13,817	3,183	4,483	15,615
4	1,866	5,814	4,591	7,892	21,191	5,388	11,268
5	6,865	2,278	8,596	4,507	9,521	62,083	11,605
6	11,216	8,165	2,200	6,258	6,181	18,202	77,203
7	326	15,838	4,512	1,960	6,823	12,638	27,803
8	-	441	8,280	5,075	1,293	15,608	18,306
9	-	8	345	6,047	4,598	7,215	22,631
10	2,534	-	103	121	7,329	16,338	7,268
11	-	2,688	114	37	143	6,478	16,552
12	-	-	964	37	40	-	14,496
13	-	-	-	37	143	-	-
14	-	-	-	-	862	-	-
15	-	-	-	-	-	1,652	-

Table 2.3 Abundance indices for O- group herring in the Barents Sea, 1973-1986 (Toresen, 1985; Anon., 1986).

Year	log index
1973	0.05
1974	0.01
1975	0.00
1976	0.00
1977	0.01
1978	0.02
1979	0.09
1980	0.00
1981	0.00
1982	0.00
1983	1.77
1984	0.34
1985	0.23

Table 2.4 Norwegian spring-spawners. Acoustic abundance of O-group herring in Norwegian coastal waters in 1975-1985 ($N \times 10^{-6}$).

Year	Area			Total
	62^0N-65^0N	65^0N-68^0N	North of $68^0 30'$	
1975	328	692	55	1,075
1976	415	2,610	750	3,775
1977	70	305	37	412
1978	302	511	392	1,205
1979	909	2,260	288	3,457
1980	12	4	218	234
1981	263	2	1	265
1982	64	571	2,301	2,936
1983	323	4,543	8,864	13,730
1984	4	467	930	1,401
1985	441	354	208	1,003

Table 2.5 Details of tagging samples, southern component of Norwegian spring-spawning herring.

Year of release	m'_s	1986		1984 + 1985				$(m'_s)82$
		r_{ss}	r_{sn}	r_{ss}	r_{sn}	Σr_s	ln K_s	
1975	5,000	7	-	8	1	16	1.14	1,418
1976	7,998	-	1	10	1	12	1.90	2,716
1977	16,044	14	7	29	3	53	1.11	6,523
1978	11,988	13	6	19	8	46	0.96	5,835
1979	5,995	16	3	21	3	43	0.32	3,494
1980	19,994	19	13	31	7	70	1.05	13,949
1981	24,967	71	14	107	10	202	0.21	20,854
Sum 1975-1981		140	44	225	33	442		54,789
Sum excluding 1976 and 1980		121	30	184	25	360		38,124

Year of release	1986 recoveries				
	m_s	r_{ss}	r_{sn}	Σr_s	ln K
Σ1982	38,124	121	30	151	0.92
1982	12,380	15	1	16	2.04
1983	15,891	46	3	49	1.18
1984	15,338	99	12	111	0.32
1985	14,981	66	4	70	0.76
Sum 1982-1985		226	20	246	

Table 2.6 Details of tagging samples, northern component of Norwegian spring-spawning herring.

Year of release	m'_n	1986		1984 + 1985				$(m'_n)82$
		r_{nn}	r_{ns}	r_{nn}	r_{ns}	Σr_n	ln K_n	
1975	20,991	21	1	10	3	35	1.79	6,849
1976	15,946	4	-	7	3	14	2.43	6,106
1977	23,989	34	-	16	-	50	1.57	10,779
1978	19,998	27	-	23	4	54	1.31	10,545
1979	8,797	12	-	11	-	23	1.34	5,443
1980	15,988	26	1	21	1	49	1.18	11,610
1981	9,977	29	-	21	-	50	0.69	8,502
Sum 1975-1981		153	2	109	11	275		59,834
Sum excluding 1976		149	2	102	8	261		53,728

Year of release	1986 recoveries				
	m_n	r_{nn}	r_{ns}	Σr_n	ln K_n
Σ1982	53,728	149	2	151	1.26
1982	14,884	16	2	18	2.11
1983	17,925	36	2	38	1.55
1984	13,975	32	5	37	1.33
1985	19,000	39	3	42	1.51
Sum 1982-1985		123	12	135	

Table 2.7 Effectively screened catches (C) in 1986 (in '000s, C_N in '000s, C_W in t) of Norwegian spring-spawning herring.

Component		Year class									C	C_N	C_W
		1983	1982	1981	1980	1979	1978	1977	1976	1975+			
Southern	n	947	1,551	877	398	4,088	888	433	595	578	10,335	10,495	2,845
	%	9	15	8	4	40	9	4	6	6			
Northern	n	249	208	62	214	827	1,307	501	907	2,412	6,639	6,722	2,246
	%	4	3	-	3	12	20	8	14	36			

Table 2.8 Average weight in stock (1 January), in grammes, Norwegian spring spawners, 1975-1985.

Age	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
3	181	181	181	180	178	175	170	170	155	140	155
4	259	259	259	294	232	283	224	204	249	204	233
5	342	342	342	326	359	347	336	303	304	295	281
6	384	384	384	371	385	402	378	355	368	338	348
7	409	409	409	409	420	421	387	383	404	376	371
8	444	444	444	461	444	465	408	395	424	395	408
9	461	461	461	476	505	465	397	413	437	407	428
10	520	520	520	520	520	520	520	453	436	413	442
11	543	543	543	543	551	534	543	468	493	422	434
12	412	412	412	500	500	500	512	512	480	459	456
13	412	412	412	500	500	500	512	500	470	449	469
14	412	412	412	500	500	500	512	500	500	427	460
15	412	412	412	500	500	500	512	500	500	437	460
16	412	412	412	500	500	500	512	500	500	437	445

Table 2.9 VIRTUAL POPULATION ANALYSIS.

NORWEGIAN SPRING SPAWNING HERRING

PROPORTIONS OF MATURITY

UNIT:

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
3	.500	.730	.130	.100	.250	.300	.100	.100	.100	.100
4	.900	.890	.900	.620	.500	.500	.480	.500	.500	.500
5	1.000	1.000	1.000	.950	.970	.900	.700	.690	.900	.900
6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.710	.950	1.000
7	1.000	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	1.000
9	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
11	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
13	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
16+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.10 VIRTUAL POPULATION ANALYSIS.

NORWEGIAN SPRING SPAWNING HERRING

STOCK SIZE IN NUMBERS UNIT: thousands

BIOMASS TOTALS UNIT: tonnes

ALL VALUES ARE GIVEN FOR 1 JANUARY

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
3	886256	574123	119442	588088	409589	394498	633658	87254	70703	602895	0
4	10101	756455	483447	102055	510450	353659	342506	543477	73658	57889	514782
5	559	3825	642153	413125	87867	433421	306248	293365	457391	59621	40307
6	2173	472	3044	544850	356336	75023	372558	264096	248690	343595	41513
7	215700	1907	414	1862	467935	305254	63818	321265	226642	201345	229629
8	79	177160	1284	365	1330	396067	263817	54204	275713	187186	150810
9	88	68	145490	551	317	757	340033	226906	46586	227497	147246
10	76	76	59	123046	483	271	544	292920	194940	33988	178598
11	51	66	66	51	105676	423	142	189	250351	155893	23058
12	44	44	57	57	44	90277	265	90	54	213768	121409
13	29	38	38	49	49	38	78369	198	42	29	174145
14	17	17	32	32	42	42	32	68781	42	36	25
15	14	14	14	27	27	36	36	27	59589	36	31
16+	14	14	14	27	27	36	36	27	36	36	61
TOTAL NO	1115172	1514279	1395553	1774192	1940174	2049802	2401843	2153400	1904199	2083813	
SPS NO	671034	1276056	1243294	1185475	1375121	1553482	1561574	1635427	1745573	1506302	
TOT.BIOM	255806	380937	444262	551769	644416	646970	711316	749733	669179	671923	
SPS BIOM	175003	331328	411344	441144	517514	545852	550195	614003	635063	579400	

Table 2.11 VIRUTAL POPULATION ANALYSIS.

NORWEGIAN SPRING SPAWNING HERRING

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

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1976-83
3	.028	.042	.027	.012	.017	.011	.024	.040	.070	.028	.025
4	.841	.034	.027	.020	.034	.014	.025	.042	.081	.232	.130
5	.002	.098	.034	.018	.028	.021	.016	.035	.156	.232	.032
6	.000	.002	.362	.022	.025	.032	.018	.025	.081	.273	.061
7	.067	.266	.005	.206	.037	.016	.033	.023	.061	.159	.081
8	.014	.067	.716	.003	.434	.023	.021	.026	.062	.110	.163
9	.012	.016	.038	.002	.027	.659	.019	.022	.181	.112	.099
10	.014	.014	.018	.022	.002	.515	.467	.027	.094	.258	.135
11	.021	.016	.016	.021	.027	.357	.324	1.573	.028	.120	.292
12	.025	.025	.019	.019	.025	.011	.161	.633	.051	.075	.115
13	.054	.029	.029	.022	.022	.029	.001	1.418	.026	.037	.200
14	.065	.065	.034	.034	.026	.026	.034	.013	.026	.030	.037
15	.080	.080	.080	.040	.040	.030	.030	.040	.030	.030	.053
16+	.080	.080	.080	.040	.040	.030	.030	.040	.030	.030	.053
(3- 4)W	.038	.037	.027	.013	.026	.013	.024	.042	.076	.046	
(5-10)W	.066	.069	.037	.021	.032	.022	.019	.027	.103	.185	

Table 2.12

List of input variables for the ICES prediction program.

NORWEGIAN SPRING-SPAWNING HERRING: COASTAL COMPONENT
The reference F is the mean F for the age group range from 5 to 9

The number of recruits per year is as follows:

Year	Recruitment
1986	1003.0
1987	2900.0
1988	2900.0

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
1	1003.0	.05	.90	.00	.065	.010
2	570.0	.05	.90	.00	.155	.085
3	2270.0	.03	.13	.10	.194	.155
4	515.0	.23	.13	.50	.257	.235
5	40.0	.23	.13	.90	.314	.281
6	42.0	.27	.13	1.00	.360	.348
7	230.0	.16	.13	1.00	.390	.371
8	151.0	.11	.13	1.00	.418	.408
9+	645.0	.11	.13	1.00	.445	.428

Table 2.13

List of input variables for the ICES prediction program.

NORWEGIAN SPRING-SPAWNING HERRING: BARENTS SEA COMPONENT
The reference F is the F of age group 5

The number of recruits per year is as follows:

Year	Recruitment
1986	14500.0
1987	.0
1988	.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
3	14500.0	.03	.40	.00	.081	.056
4	.0	.03	.13	.10	.146	.081
5	.0	.03	.13	.62	.202	.146
6	.0	.03	.13	.95	.216	.202

Table 2.14

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

NORWEGIAN SPRING-SPAWNING HERRING: COASTAL COMPONENT

Year 1986					Year 1987					Year 1988	
factor	ref. F	stock biomass	sp.stock biomass	catch	factor	ref. F	stock biomass	sp.stock biomass	catch	stock biomass	sp.stock biomass
1.0	.13	979	545	96	.0	.00	1006	678	0	1105	884
					.1	.02			13	1087	868
					.2	.04			36	1070	852
					.4	.07			71	1036	821
					.6	.11			105	1003	792
					.8	.14			137	971	765
					1.0	.18			168	941	736
					1.2	.21			198	912	710
					1.4	.25			227	884	685
					1.6	.28			255	857	661
					1.8	.32			282	831	638
					2.0	.35			308	806	615

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 5 to 9

Table 2.15

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

NORWEGIAN SPRING-SPAWNING HERRING: BARENTS SEA COMPONENT

Year 1986					Year 1987					Year 1988	
factor	ref. F	stock biomass	sp.stock biomass	catch	factor	ref. F	stock biomass	sp.stock biomass	catch	stock biomass	sp.stock biomass
1.0	.05	812	0	27	.0	.00	766	77	0	1212	751
					.2	.01			7	1205	747
					.6	.02			22	1191	739
					1.0	.03			36	1178	730
					1.5	.04			55	1162	720
					2.0	.06			71	1146	710
					2.5	.07			88	1130	700
					3.0	.08			104	1114	691
					4.0	.11			137	1083	672
					5.0	.14			169	1053	653
					6.0	.17			200	1024	635

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 F of age group 3

Table 3.1 International catch of Barents Sea capelin ('000 tonnes) in the years 1965-1985.

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	1,421	812	-	2,233
1984	811	624	42	1,477
1985	453[1]	398	-	851
1986	72[2]	51[2]	-	123[2]

[1] Preliminary figure.

[2] Preliminary catch winter 1986.

Table 3.2 Capelin catches in the Barents Sea in August-December 1985 and in January-April 1986 in numbers ($\times 10^{-3}$).

Age	1985					1986			
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	-	0.46	0.01	0.16	0.14	-	-	-	-
2	-	5.21	0.58	0.50	0.43	0.01	0.002	0.01	0.002
3	-	6.06	0.69	0.62	0.54	0.44	0.05	0.44	1.00
4	-	0.32	0.07	0.11	0.09	0.67	0.10	0.78	2.95
5	-	-	-	0.003	0.02	0.05	0.02	0.11	0.56
6	-	-	-	-	-	0.003	-	0.01	0.02
7	-	-	-	-	-	-	-	0.001	0.001

Table 3.3 Larval index for Barents Sea capelin.

Year	Index
1981	9.71
1982	9.88
1983	9.94
1984	8.15
1985	9.25
1986	-

Table 3.4 Acoustic estimate, autumn 1986, for Barents Sea capelin.

Total length (cm)	Age				Total number ($\times 10^{-7}$)	Biomass tonnes ($t \times 10^{-3}$)	Biomass (Cum.)
	1	2	3	4+			
6.5- 7.0	37	-	-	-	37	0.4	-
7.0- 7.5	26	-	-	-	26	0.3	-
7.5- 8.0	19	-	-	-	19	0.2	-
8.0- 8.5	25	1	-	-	26	0.4	-
8.5- 9.0	37	-	-	-	37	0.7	-
9.0- 9.5	33	1	-	-	34	0.9	-
9.5-10.0	59	-	-	-	59	2.5	-
10.0-10.5	95	-	-	-	95	1.8	-
10.5-11.0	132	5	-	-	137	3.6	-
11.0-11.5	118	7	-	-	125	6.2	-
11.5-12.0	95	9	-	-	104	6.4	-
12.0-12.5	39	18	2	-	59	4.3	-
12.5-13.0	22	34	3	-	59	4.9	-
13.0-13.5	12	47	6	-	65	6.2	-
13.5-14.0	-	61	33	-	94	10.0	-
14.0-14.5	-	56	42	-	98	12.2	62.6
14.5-15.0	-	41	66	2	109	15.1	50.4
15.0-15.5	-	30	74	9	113	17.6	35.3
15.5-16.0	-	26	40	4	70	12.2	17.7
16.0-16.5	-	4	20	-	24	4.5	5.5
16.5-17.0	-	1	4	-	5	1.0	1.0
Number	749	341	290	15	1,395	-	-
Biomass (10^{-3} t)	31.8	39.7	41.5	2.4	-	115.5	-
Mean length (cm)	10.35	13.85	14.89	15.32	11.55	-	-

Table 3.5 The development of the Barents Sea capelin stock since 1974.

1974				M = 0.051	LM = 14.01	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	-	-	-	76,083	-	-
2	-	9.3	-	63,562	1,139.5	0.02
3	-	439.4	120	20,877	1,059.0	0.05
4	-	2,746.6	56	436	42.2	0.11
5	-	991.6	104	8	-	-
Σ		4,186.9	280	160,966	2,240.7	

1975				M = 0.051	LM = 14.01	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	-	-	-	50,895	-	-
2	58,867	250.3	-	41,076	1,364.9	0.03
3	48,181	1,009.6	138	35,050	1,795.5	0.05
4	15,225	3,499.3	64	10,108	613.8	0.06
5	300	390.5	-	107	-	-
Σ		5,149.7	203	137,236	3,774.2	

1976				M = 0.051	LM = 14.01	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	-	-	-	44,445	-	-
2	39,378	83.8	-	27,492	1,726.2	0.07
3	30,586	672.5	117	20,325	2,752.4	0.15
4	25,547	4,400.1	578	10,074	1,960.0	0.22
5	7,284	2,802.5	520	1,661	394.0	0.28
Σ		7,958.9	1,215	103,997	6,832.6	

(cont'd)

Table 3.5 (cont'd)

1977				M = 0.051	LM = 14.01	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	-	-	-	78,519	-	-
2	34,388	683.0	-	23,609	4,517.9	0.22
3	19,764	1,424.9	291	12,733	2,617.9	0.24
4	13,320	5,022.1	454	5,064	862.5	0.19
5	6,084	3,028.7	381	902	146.2	0.18
Σ		10,158.7	1,126	12,0827	8,144.5	

1978				M = 0.051	LM = 14.01	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	-	-	-	95,113	99.5	-
2	60,752	53.6	-	42,547	2,875.2	0.07
3	14,327	1,227.5	68	12,050	1,726.5	0.16
4	7,568	3,507.3	401	1,699	265.3	0.17
5	3,165	1,780.8	206	96	19.8	0.23
Σ		6,569.2	675	151,505	4,986.3	

1979				M = 0.072	LM = 13.94	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	-	-	-	55,220	30.5	-
2	73,510	8.1	-	40,024	2,767.2	0.07
3	30,408	1,047.2	29	14,829	3,047.5	0.24
4	7,814	2,883.5	252	681	224.1	0.41
5	1,082	634.9	-	4	2.2	0.84
Σ		4,573.7	281	110,758	6,071.5	

(cont'd)

Table 3.5 (cont'd)

1980				M = 0.072	LM = 13.94	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	-	-	-	59,131	90.4	-
2	38,418	10.0	-	23,195	683.9	0.03
3	25,575	468.1	70	19,420	2,109.0	0.12
4	7,817	3,834.8	49	3,996	334.1	0.09
5	290	344.7	-	38	7.5	0.23
Σ		4,657.6	119	105,780	3,224.9	

1981				M = 0.072	LM = 13.94	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	-	-	-	44,327	203.0	-
2	41,094	59.0	-	24,831	2,596.7	0.11
3	15,581	339.9	337	7,002	1,564.9	0.26
4	11,777	3,452.0	1,226	1,920	372.3	0.22
5	2,505	1,417.1	204	43	15.8	0.48
Σ		5,268.0	1,767	78,123	4,752.7	

1982				M = 0.072	LM = 13.94	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	-	1.0	-	61,204	107.0	-
2	30,691	47.1	-	18,526	2,139.0	0.06
3	15,142	1,127.7	214	8,464	2,443.0	0.32
4	3,588	1,655.7	259	357	149.0	0.55
5	1,030	513.9	109	-	6.0	-
Σ		3,345.4	582	88,551	4,844.0	

(cont'd)

Table 3.5 (cont'd)

1983				M = 0.072	LM = 13.94	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	–	4.0	–	53,790	298.1	0.01
2	42,519	40.0	–	25,705	3,634.9	0.16
3	11,131	1,298.8	68	6,383	2,671.9	0.56
4	3,890	3,371.2	55	78	120.7	–
5	127	718.9	–	–	0.2	–
Σ		5,432.9	122	85,956	6,725.8	

1984				M = 0.140	LM = 13.06	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	–	–	–	37,122	219.9	–
2	37,200	6.6	–	22,428	2,109.6	0.10
3	14,897	839.7	251	6,528	1,571.6	0.28
4	2,270	2,264.6	–	442	165.0	0.48
5	–	225.2	–	–	9.0	–
Σ		3,336.1	251	66,520	4,075.1	

1985				M = 0.140	LM = 13.06	
Age	Stock 1 Jan 10^{-7}	Catch spr. 10^{-7}	Sp. stock 10^{-3} t	Stock 1 Aug 10^{-7}	Catch aut. 10^{-7}	F aut.
1	–	–	–	–	78.6	–
2	25,660	35.1	–	6,821	672.6	0.17
3	13,870	571.0	240	3,414	790.8	0.52
4	3,253	1,698.5	104	157	59.3	0.15
5	173	326.4	–	–	–	–
Σ		2,631.0	344	10,392	1,601.3	

Table 4.1 The total annual and seasonal catch of capelin in the Iceland - East Greenland - Jan Mayen area since 1964 (in '000 t).

Year	Winter season		Summer and autumn season				Total
	Iceland	Far/Nor	Iceland	Norway	Faroes	EEC	
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	457.6	-	3.1	-	-	-	460.7
1976	338.7	-	114.4	-	-	-	453.1
1977	549.2	25.0	259.7	-	-	-	833.9
1978	468.4	38.4	497.5	154.1	-	-	1,158.4
1979	521.7	17.5	441.9	126.0	2.5	-	1,109.6
1980	392.0	-	367.2	118.6	24.4	14.3	916.5
1981	156.0	-	484.6	91.4	16.2	20.8	769.0
1982	13.0	-	-	-	-	-	13.0
1983	-	-	133.3	-	-	-	133.3
1984	439.6	-	425.2	104.6	10.2	8.5	988.1
1985	348.5	-	644.8	188.7	81.4		1,263.4
1986[1]	342.0	49.9	380.0	154.3	69.7		995.9

[1] Preliminary.

Table 4.2 Biomass computations for capelin, October 1986, Iceland - Jan Mayen - East Greenland.

Average length: cm
Average volume: ml
No. in region: n x 10^{-6}
Weight in region: t x 10^{-3}
Condition: 1,000 x vol/length^3
C = 2.820 x 10^6 x $l^{-1.910}$
Region: all

Length (cm)	Age 1	2	3	4	5	6+	g	Total	Weight	Average volume
8.0- 8.4	109	-	-	-	-	-	-	109	-	2.0
8.5- 8.9	4,270	-	-	-	-	-	-	4,270	8	2.1
9.0- 9.4	7,561	-	-	-	-	-	-	7,561	22	2.9
9.5- 9.9	12,766	-	-	-	-	-	-	12,766	43	3.4
10.0-10.4	11,358	-	-	-	-	-	-	11,358	43	3.8
10.5-10.9	8,312	-	-	-	-	-	-	8,312	36	4.4
11.0-11.4	6,229	-	-	-	-	-	-	6,229	30	5.0
11.5-11.9	4,467	-	-	-	-	-	-	4,467	26	5.9
12.0-12.4	2,345	72	-	-	-	-	-	2,417	16	6.6
12.5-12.9	794	112	-	-	-	-	-	906	7	8.0
13.0-13.4	376	406	22	-	-	-	-	804	7	9.0
13.5-13.9	-	967	-	-	-	-	967	967	10	10.7
14.0-14.4	26	1,500	50	-	-	-	1,576	1,576	19	12.5
14.5-14.9	-	3,583	379	-	-	-	3,962	3,962	57	14.5
15.0-15.4	-	3,915	1,991	16	-	-	5,922	5,922	96	16.4
15.5-15.9	-	2,914	3,378	-	-	-	6,292	6,292	114	18.2
16.0-16.4	-	3,007	5,383	42	-	-	8,432	8,432	172	20.5
16.5-16.9	-	1,818	4,738	-	-	-	6,556	6,556	155	23.7
17.0-17.4	-	1,080	6,460	103	-	-	7,643	7,643	194	25.5
17.5-17.9	-	793	4,170	82	-	-	5,045	5,045	142	28.3
18.0-18.4	-	246	2,044	43	-	-	2,333	2,333	73	31.6
18.5-18.9	-	50	853	24	-	-	927	927	32	34.9
19.0-19.4	-	24	312	26	-	-	362	362	14	40.8
19.5-19.9	-	-	17	-	-	-	17	17	-	42.0
20.0-20.4	-	-	65	-	-	-	65	65	3	47.7
Number	58,613	20,487	29,862	336	-	-	50,099	109,298		
Av.length	10.33	15.56	16.86	17.54	-	-	16.38	13.11		
Weight	237.1	364.9	719.3	9.7	-	-	1,088.9	1,331.0		
Av.vol.	4.0	17.8	24.1	28.8	-	-	21.7	12.2		
Cond.	3.6	4.6	4.9	5.2	-	-	4.8	4.1		

Table 4.3 Natural mortality rates of the Icelandic capelin as calculated from successive acoustic estimates of spawning stock abundance and catch.

Estimate	Period	Mortality rate/month
I	1 Nov 1978 - 31 Jan 1979	0.045
II	1 Nov 1979 - 31 Jan 1980	0.026
III	1 Nov 1980 - 31 Jan 1981	0.030
IV	15 Nov 1981 - 31 Jan 1982	0.048
V	1 Dec 1981 - 31 Jan 1982	0.035
VI	1 Nov 1982 - 31 Jan 1983	0.028
VII	1 Nov 1983 - 31 Jan 1984	0.034
	Mean	0.034
	S.dev.	0.008

Table 4.4 Average weight of 2-group capelin in autumn surveys in the years 1979-1986.

Year	Average weight (g)
1979	15.7
1980	19.3
1981	19.4
1982	15.7
1983	15.1
1984	14.8
1985	14.1
1986	17.8
Total average	16.5

Figure 2.1 Plot of ln K ($K = \frac{m}{r} \times 10^2$) against time at liberty. A = Southern component, B = Northern component.

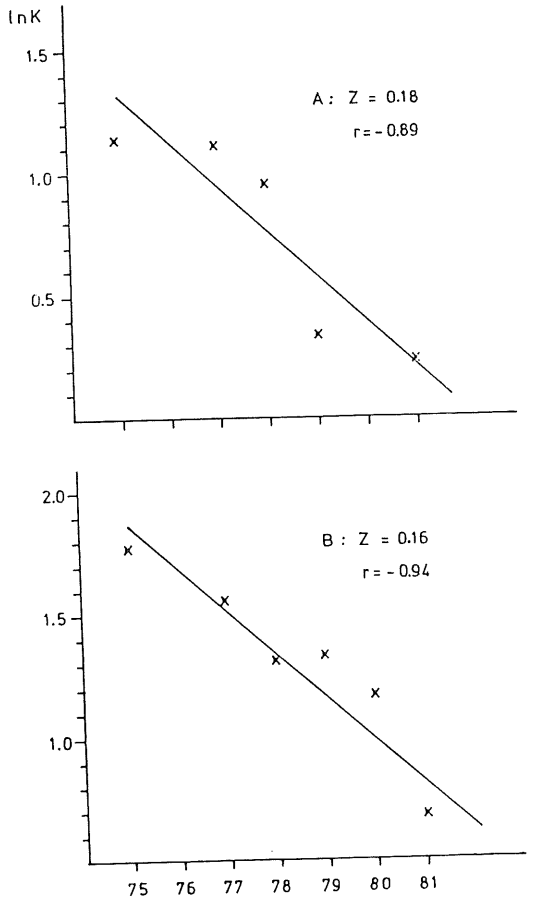


Figure 2-2 Relationship between age 3 numbers from VPA and 0-group estimates from acoustic survey.

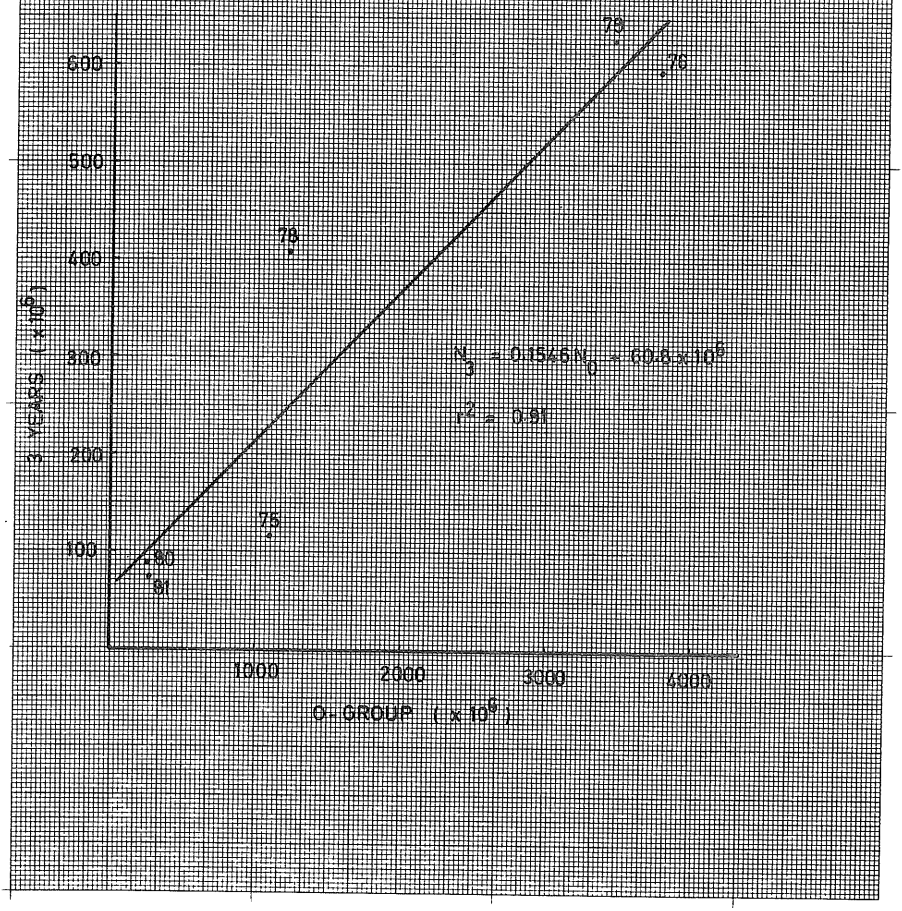
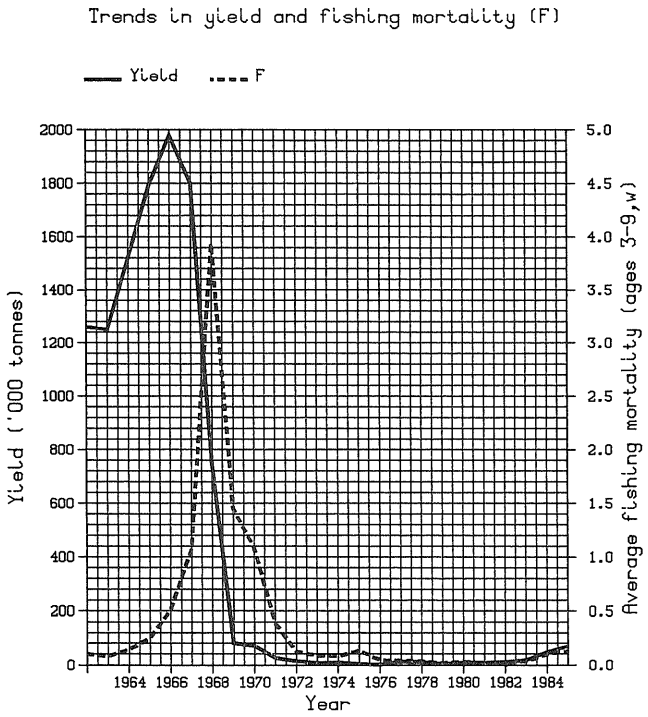


Figure 2.3

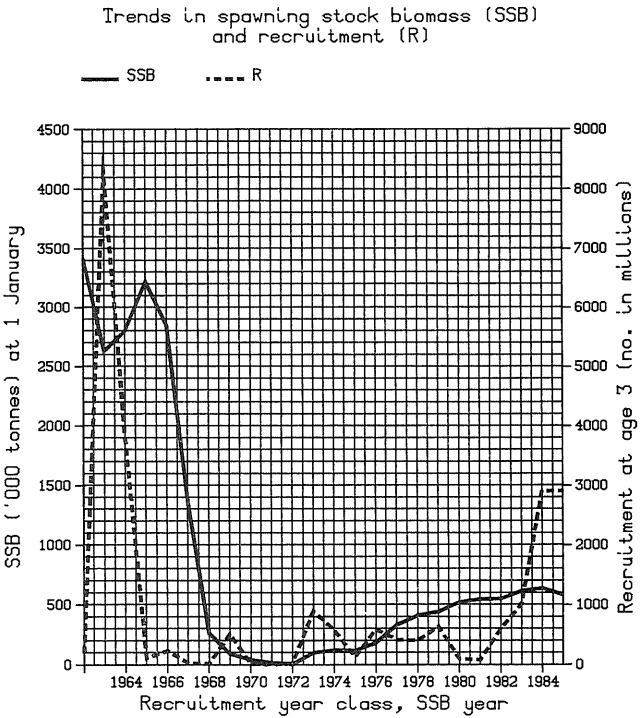
FISH STOCK SUMMARY

STOCK: Norwegian Spring-Spawning Herring

10–11–1986



A



B

(cont'd)

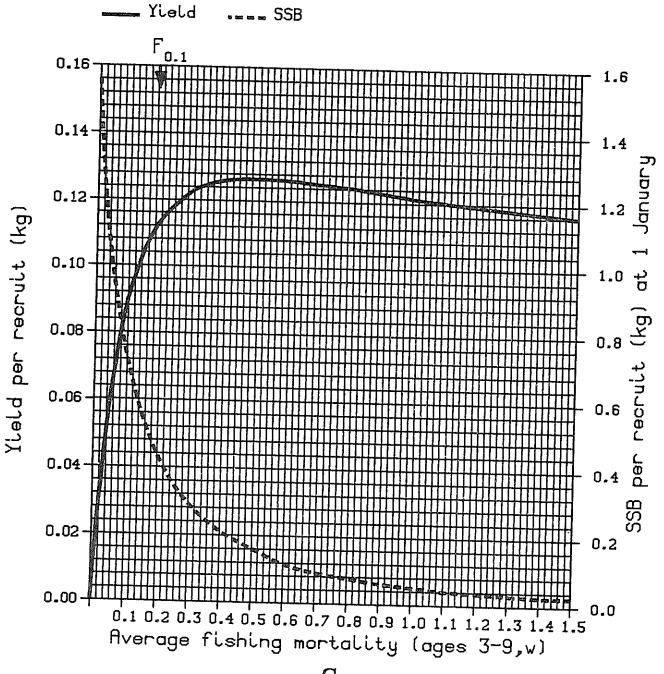
Figure 2.3 (cont'd)

FISH STOCK SUMMARY

STOCK: Norwegian Spring-Spawning Herring

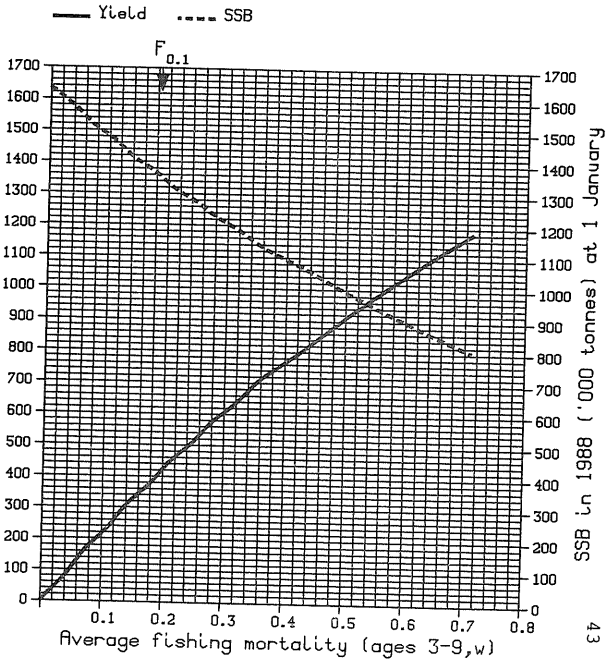
10–11–1986

Long-term yield and spawning stock biomass



C

Short-term yield and spawning stock biomass



D

Figure 3.1 Stations taken at the Soviet larval survey, July 1986. Numbers denote the number of capelin larvae caught. The length distribution of the larvae is also shown. (-.-.-. = 1,000-m isobath).

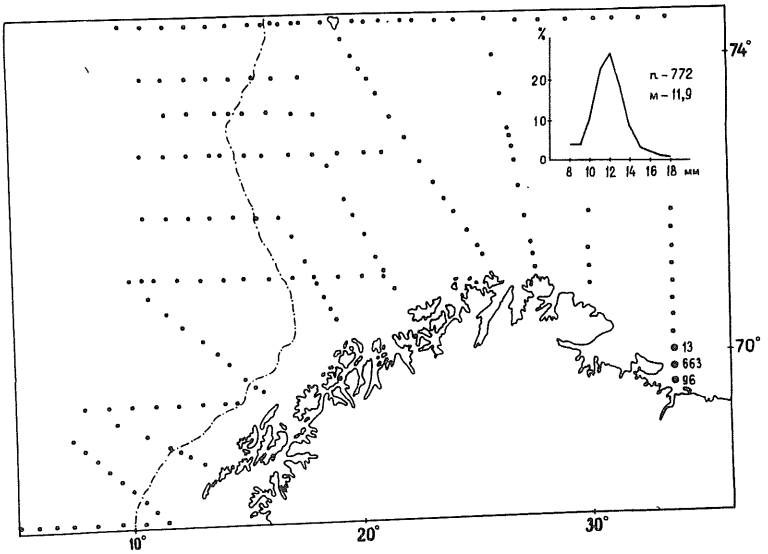


Figure 3.2 0-group distribution of capelin, August 1986.

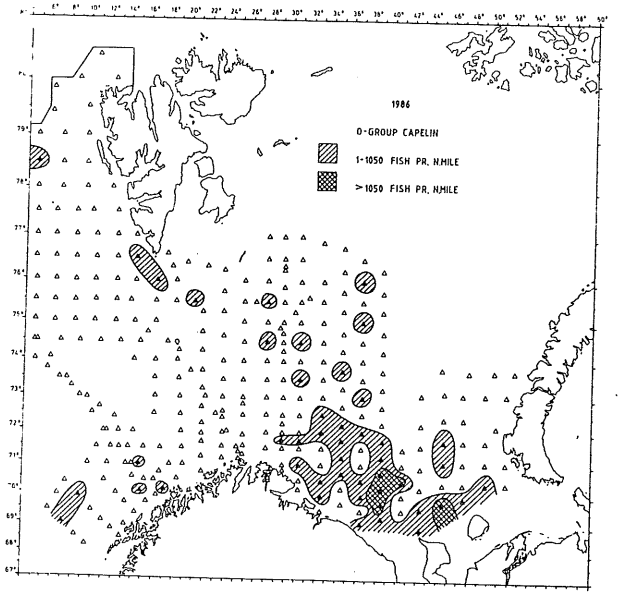


Figure 3.3 Estimated total density distribution of capelin (t/n mi^2).

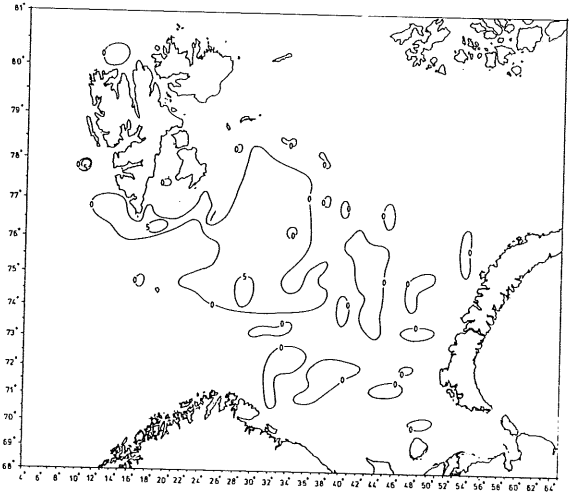


Figure 3.4 Natural mortality of immature fish per year (M) (mean of ages 2-3 and ages 3-4) estimated on a yearly basis by the model CAPELIN, and fishing mortality (F) in the autumn fishing season (mean of age 2 and age 3). The natural mortality for the period 1985-1986 is a preliminary figure.

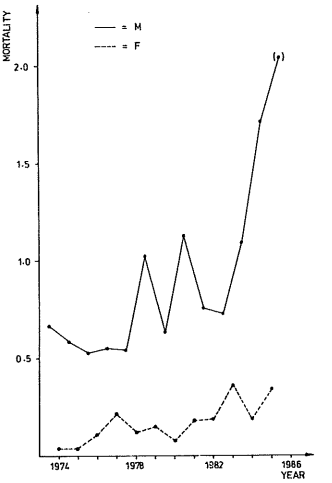
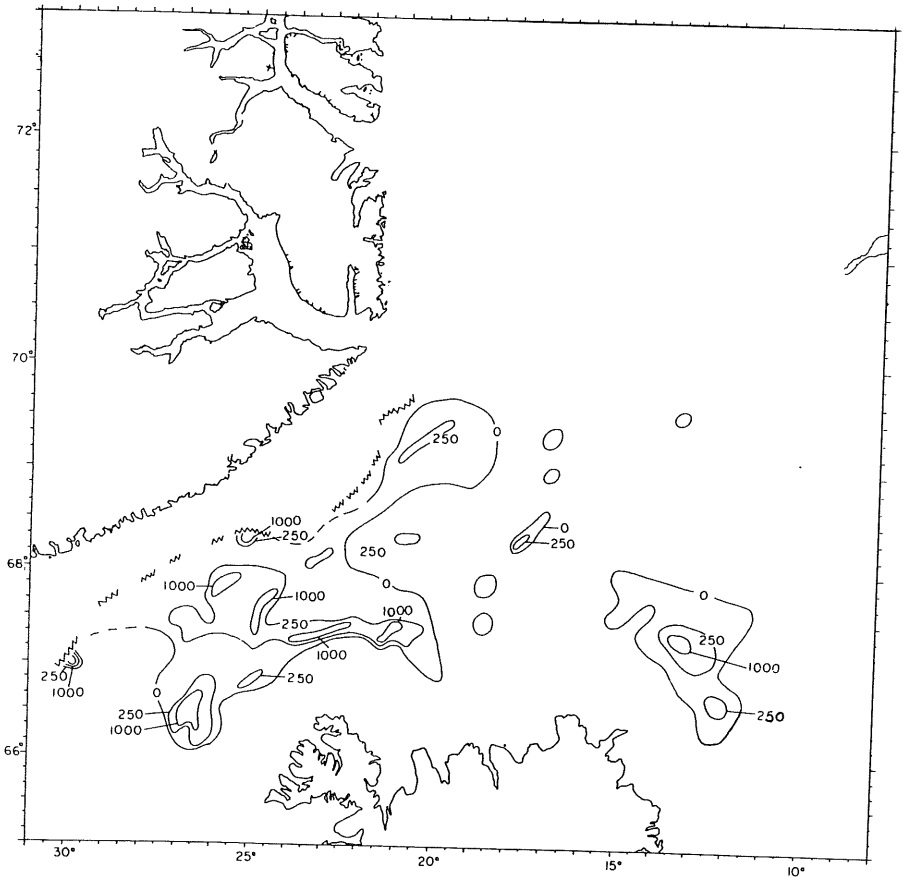


Figure 4.1 The relative distribution and density of 1- to 3-group capelin of the 1983-1985 year classes, 4-22 October 1986.



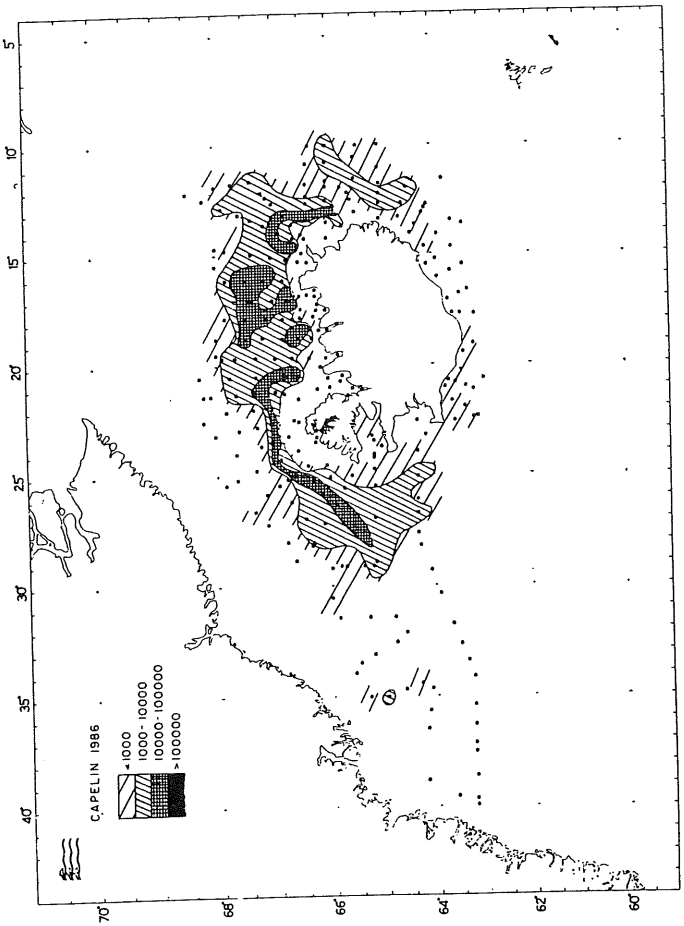


Figure 4.2 Distribution of 0-group capelin in August 1986.

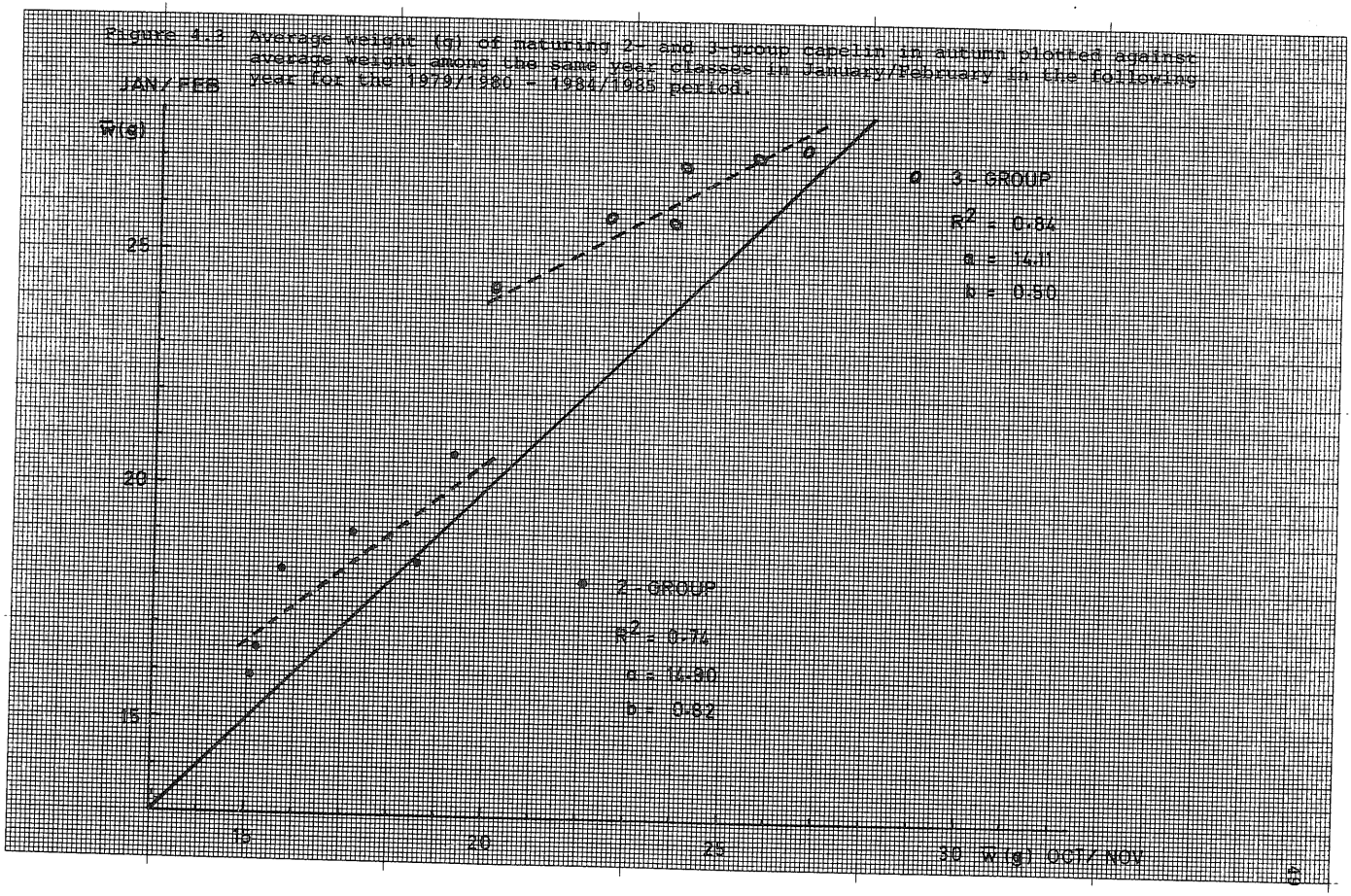
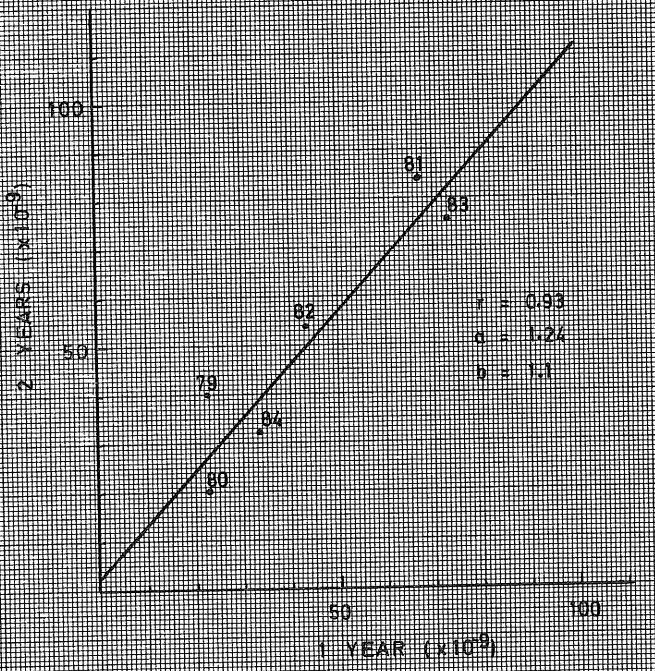


Figure 4.3 Average weight (g) of maturing 2- and 3-group capelin in autumn plotted against average weight among the same year classes in January/February in the following year for the 1979/1980 - 1984/1985 period.

Figure 4.4 The abundance by number of 1-group capelin (1979-1984 year classes) in acoustic autumn surveys plotted against the abundance of the same age groups as recorded one year later taking account of the catch and mortality rate in the fishing season.



Appendix A, Table 1 VIRTUAL POPULATION ANALYSIS. NORWEGIAN SPRING SPAWNING HERRING. CATCH IN NUMBERS. UNIT: thousands.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
0	3695200	4807000	3613000	2303000	3926500	426800	1785000	561200	119300	30570	547100	29500
1	4081100	2119200	2723500	3780900	362800	9877100	437000	507100	529400	42900	41000	3500
2	1041300	2045300	220500	2853600	1678000	70400	388500	141900	33200	85100	20400	1700
3	1345800	760400	114600	89900	2048700	1392300	99100	198200	6500	1820	35576	2389
4	8000	835800	599000	256200	26900	3254000	1380500	800	18600	1020	3476	25200
5	3100	5300	2045800	568400	406600	26600	1387400	8800	600	1240	3583	651
6	7200	1800	13700	2199700	1306000	421300	14200	4700	3500	360	2481	1506
7	20200	3600	1500	19500	2834500	1132000	94000	700	3300	1110	694	278
8	11900	18300	3000	14900	57900	1220800	134100	11700	1000	1130	1486	178
9	59100	9300	24900	7400	14500	8900	345100	33600	13400	360	198	1
10	52600	107700	29300	19100	17400	5700	2000	36000	26200	4410	1	1
11	11700	92500	95600	40000	26200	3500	1100	500	28100	6910	494	1
12	31350	174100	82400	100500	11000	8500	800	200	500	5450	593	1
13	44200	92500	153000	107800	69100	8900	2500	200	100	1	593	1
14	54700	79600	122800	138700	72100	17500	2600	200	200	20	1	178
15	65600	60400	45800	104000	96700	14300	1800	400	100	121	1	1
16+	88700	124900	291000	179100	460000	90100	15200	2000	1900	1	1	1
TOTAL	12005200	12163900	10654000	13582700	13804700	13478700	6589500	1498000	785300	182453	457478	64887

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	65900	30600	20100	43000	20100	52600	6900	8300	22600	127000	33857	28571
1	7800	3600	2400	6200	2400	3800	800	1100	1100	4679	1700	13149
2	5900	1800	1200	3100	1200	1900	400	11900	200	1675	2489	207224
3	100	3268	23248	22103	3019	6352	6407	4166	13817	3183	4483	15615
4	241	132	5436	23595	12164	1866	15814	4591	7392	21191	5588	11268
5	24505	910	1	336	20315	6865	2278	8596	4507	9521	62083	11605
6	257	30667	1	1	870	11216	8165	2200	6258	6131	18202	77205
7	196	5	15086	419	1	326	15858	4512	1960	6823	12638	27803
8	1	2	1	10766	620	1	441	8280	5075	1293	15608	18506
9	1	1	1	1	5027	1	8	345	6047	4598	7215	22631
10	1	1	1	1	1	2534	1	103	121	7329	16338	7268
11	1	1	1	1	1	1	2688	114	37	143	6478	16552
12	1	1	1	1	1	1	1	964	37	40	1	14496
13	1	1	1	1	1	1	1	1	37	143	1	1
14	1	1	1	1	1	1	1	1	1	862	1	1
15	1	1	1	1	1	1	1	1	1	1	1652	1
16+	1	1	1	1	1	1	1	1	1	1	1	1
TOTAL	102908	70992	65481	109528	65723	67467	59745	55175	69691	194663	188135	471695

Appendix A, Table 2 VIRTUAL POPULATION ANALYSIS. NORWEGIAN SPRING SPAWNING HERRING.

MEAN WEIGHT AT AGE OF THE STOCK UNIT: kilogram

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
0	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.001	.001
1	.008	.008	.008	.008	.008	.008	.008	.008	.008	.015	.010	.010
2	.047	.047	.047	.047	.047	.047	.047	.047	.047	.080	.020	.085
3	.100	.100	.100	.100	.100	.100	.100	.100	.100	.140	.050	.170
4	.219	.185	.194	.186	.185	.180	.100	.100	.209	.190	.090	.259
5	.291	.253	.213	.199	.219	.228	.206	.145	.272	.225	.140	.342
6	.309	.294	.264	.236	.222	.269	.266	.270	.230	.250	.210	.384
7	.316	.312	.317	.260	.249	.270	.275	.300	.295	.275	.240	.409
8	.324	.329	.363	.363	.306	.294	.274	.306	.317	.290	.270	.404
9	.326	.327	.353	.350	.354	.324	.285	.308	.323	.310	.300	.461
10	.335	.334	.349	.370	.377	.420	.350	.318	.325	.325	.325	.520
11	.338	.341	.354	.360	.391	.430	.325	.340	.329	.335	.335	.534
12	.334	.349	.357	.378	.379	.366	.363	.368	.380	.345	.345	.412
13	.347	.341	.359	.387	.379	.368	.408	.360	.370	.355	.355	.500
14	.354	.358	.365	.390	.361	.433	.388	.393	.380	.365	.365	.500
15	.358	.375	.402	.394	.383	.414	.378	.397	.391	.390	.390	.500
16+	.358	.375	.402	.394	.383	.414	.378	.397	.391	.390	.390	.500

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
1	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010
2	.085	.085	.085	.085	.085	.085	.085	.085	.085	.085	.085	.085
3	.170	.181	.181	.181	.180	.178	.175	.170	.170	.155	.140	.155
4	.259	.259	.590	.259	.294	.232	.283	.224	.204	.249	.204	.233
5	.342	.342	.342	.343	.326	.359	.347	.336	.303	.304	.295	.281
6	.384	.384	.384	.384	.371	.385	.402	.378	.355	.358	.358	.348
7	.409	.409	.409	.409	.409	.420	.421	.387	.383	.404	.376	.371
8	.444	.444	.444	.444	.461	.444	.465	.408	.395	.424	.395	.408
9	.461	.461	.461	.461	.476	.505	.405	.397	.413	.437	.407	.428
10	.520	.520	.520	.520	.520	.520	.520	.520	.453	.436	.413	.442
11	.543	.543	.543	.543	.543	.551	.534	.543	.468	.493	.422	.434
12	.412	.412	.412	.412	.500	.500	.500	.512	.512	.480	.459	.456
13	.500	.500	.500	.500	.500	.500	.500	.500	.500	.470	.449	.469
14	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500	.427	.460
15	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500	.437	.460
16+	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500	.437	.460

Appendix A, Table 3 VIRTUAL POPULATION ANALYSIS. NORWEGIAN SPRING SPAWNING HERRING.

PROPORTIONS OF MATURITY

UNIT:

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
0	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.000	.040	.020	.000	.010	.000	.000	.000	.000	.000	.000	.100
4	.110	.080	.060	.340	.150	.010	.000	.620	.060	.100	.000	.500
5	.670	.320	.280	.350	1.000	.230	.010	.890	.150	.250	.100	.900
6	1.000	.900	.620	.760	.960	1.000	.760	.950	.310	.600	.250	1.000
7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.170	.900	.600	1.000
8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.900	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
13	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
16+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.100	.100	.100	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.500	.500	.500	.730	.130	.100	.250	.300	.100	.100	.100	.100
4	.900	1.000	.900	.890	.900	.620	.500	.500	.480	.500	.500	.500
5	1.000	1.000	1.000	1.000	1.000	.950	.970	.900	.700	.690	.900	.900
6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.710	.950	1.000
7	1.000	1.000	1.000	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	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
13	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
16+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Appendix A, Table 4 VIRUTAL POPULATION ANALYSIS. NORWEGIAN SPRING SPAWNING HERRING.

NATURAL MORTALITY COEFFICIENT UNIT: Year-1

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
0	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
1	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
2	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
3	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
4	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
5	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
6	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
7	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
8	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
9	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
10	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
11	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
12	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
13	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
14	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
15	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130
16+	.160	.160	.160	.160	.160	.160	.160	.160	.160	.130	.130	.130

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
1	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
2	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
3	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
4	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
5	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
6	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
7	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
8	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
9	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
10	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
11	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
12	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
13	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
14	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
15	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130
16+	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130	.130

Appendix, Table 5 VIRTUAL POPULATION ANALYSIS. NORWEGIAN SPRING SPAWNING HERRING.

FISHING MORTALITY COEFFICIENT UNIT: Year-1 VARIABLE NATURAL MORTALITY COEFFICIENT

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
0	.791	.220	.255	1.170	.280	.464	1.326	.321	.364	.482	2.516	.023
1	.585	1.625	.179	.440	1.378	2.634	1.211	2.425	.541	.849	2.634	.143
2	.124	.629	.699	.275	.340	.469	.956	2.190	1.604	.144	1.277	.968
3	.099	.120	.060	.664	.310	.500	3.194	2.037	.547	.296	.076	.427
4	.051	.057	.082	.170	.403	1.114	4.547	.260	1.505	.148	1.353	.066
5	.043	.041	.185	.154	.527	.852	4.701	.758	.303	.521	.995	.953
6	.077	.030	.137	.296	.593	1.301	1.787	.599	.692	.282	1.886	1.666
7	.118	.062	.050	.280	.747	1.671	1.205	.347	1.115	.494	1.229	1.265
8	.069	.142	.064	.441	1.295	1.473	.930	.423	1.165	1.556	3.034	1.226
9	.095	.068	.279	.215	.969	1.312	1.562	.603	1.203	2.380	1.859	.016
10	.089	.239	.301	.342	1.044	1.428	1.259	.629	1.385	2.139	.032	.032
11	.125	.215	.330	.817	1.049	.575	1.269	.594	1.579	2.591	2.978	.038
12	.169	.265	.285	.655	.526	1.221	.235	.797	2.656	1.727	3.318	.045
13	.148	.282	.575	.700	1.545	1.057	1.717	.081	1.241	.054	1.515	.054
14	.214	.411	.384	.659	1.545	1.822	1.034	.571	.104	.850	.065	2.544
15	.210	.370	.420	.690	1.410	1.950	1.000	.400	.600	.080	.080	.080
16+	.210	.370	.420	.690	1.410	1.950	1.000	.400	.600	.080	.080	.080
(3- 9)W	.099	.077	.145	.249	.514	1.073	3.935	1.450	1.085	.585	.121	.084

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.079	.165	.024	.072	.036	.036	.055	.079	.026	.023	.105	.050
1	.007	.005	.016	.009	.005	.008	.001	.010	.012	.006	.000	.050
2	.218	.002	.002	.024	.002	.004	.001	.017	.002	.022	.004	.050
3	.117	.264	.028	.042	.027	.012	.017	.011	.024	.040	.070	.028
4	.063	.206	.841	.054	.027	.020	.034	.014	.025	.042	.081	.252
5	.079	.330	.002	.098	.034	.018	.028	.021	.016	.035	.156	.232
6	1.251	.125	.000	.002	.362	.022	.025	.032	.018	.025	.081	.273
7	1.022	.058	.067	.266	.003	.206	.057	.016	.033	.023	.061	.159
8	.011	.021	.014	.067	.716	.005	.434	.025	.021	.026	.062	.110
9	.016	.012	.012	.016	.058	.002	.027	.659	.019	.022	.181	.112
10	.018	.018	.014	.014	.018	.022	.002	.515	.467	.027	.094	.258
11	.038	.021	.021	.016	.016	.021	.027	.337	.324	1.573	.028	.120
12	.045	.045	.025	.025	.019	.019	.025	.011	.161	.633	.031	.075
13	.054	.054	.054	.029	.029	.022	.022	.029	.001	1.418	.026	.037
14	.065	.065	.065	.065	.034	.054	.026	.026	.034	.013	.026	.030
15	.080	.080	.080	.080	.080	.040	.040	.030	.030	.040	.030	.030
16+	.080	.080	.080	.080	.080	.040	.040	.030	.030	.040	.030	.030
(3- 9)W	.081	.134	.043	.041	.033	.017	.029	.018	.021	.032	.101	.129

Appendix A, Table 6 VIRTUAL POPULATION ANALYSIS. NORWEGIAN SPRING SPAWNING HERRING.

STOCK SIZE IN NUMBERS UNIT: thousands

BIOMASS TOTALS UNIT: tonnes

ALL VALUES ARE GIVEN FOR 1 JANUARY

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
0	7237852	26248484	17304228	3559957	17329808	1237135	2583425	2201776	220626	84650	392926	1352183
1	9897950	2797327	17947628	11425170	941960	11160204	663064	584016	1360944	79237	45918	27378
2	9621608	4700154	469465	12784030	6269538	202248	683060	168326	44058	675041	29769	2894
3	21064440	7240406	2134776	198775	8271972	3302119	107830	228361	16058	7548	313188	7292
4	175060	16251970	5469830	1713541	67206	5167460	1964493	3768	25380	7916	4929	417529
5	30485	141304	13078898	4293563	1224482	49640	1445354	17740	2476	4802	5997	1119
6	84083	65727	115953	9263260	3135695	616152	18045	11192	7083	1559	3060	1947
7	196355	65020	54350	80199	5873190	1477206	143016	2574	5233	3020	1033	408
8	192174	149151	52090	44932	55539	2370973	236841	36530	1551	1464	1618	265
9	704804	152796	110255	41624	24629	12958	463253	79663	20400	413	245	68
10	667514	546166	121636	71077	28665	7967	2973	82799	37148	5218	34	34
11	1071338	520371	366413	76741	43035	8599	1629	719	37634	7922	540	29
12	5640500	805693	358376	224467	28902	12841	4124	390	338	6670	636	24
13	346179	4058047	526587	229691	99401	14555	3227	2779	130	20	853	20
14	395821	254316	2609438	308341	97237	22078	4309	494	2134	37	17	201
15	373727	210306	143711	1514616	135959	17671	3041	1306	238	1677	14	14
16+	505329	434888	913101	385323	646752	111341	25683	6530	4521	14	14	14
TOTAL	N058166256	64642643	61776744	46221312	44293976	26291156	8353868	3429564	1786325	887207	1000789	1811917
SPS	N010152057	8078462	9326038	12108442	11363858	4735432	916269	386767	115635	33473	8728	383853
TOT-BIOM	6091992	6506304	6198176	5221180	4009000	2766386	800451	108905	58126	68022	30522	112853
SPS BIOM	3412300	2625194	2799247	3218654	2846313	1357830	259791	87469	37227	10195	2104	99573

(cont'd)

Appendix A, Table 6 (cont'd)

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	924217	216189	899213	656316	609260	988080	137839	116722	923683	6010830	363316	624390
1	1159916	749894	161251	770778	556074	516174	857113	114579	94903	789925	5159188	287358
2	21207	1011213	655108	139529	671011	468477	449692	734316	99581	82504	689248	4528668
3	966	14979	886256	574125	119442	588018	409589	394498	633658	87254	70703	602895
4	4177	754	10101	756455	433447	102055	510450	353659	342506	543477	75638	57889
5	343050	3442	539	3825	642153	413125	87867	433421	306248	293565	457391	59621
6	579	278304	2173	472	5044	544856	356336	75023	372538	264696	248690	345595
7	323	95	215700	1907	414	1862	467935	305254	63818	321265	226642	201345
8	101	102	79	177160	1234	365	1550	390067	263817	54204	275713	187186
9	68	88	88	68	145490	551	317	757	340053	226906	46386	227497
10	59	59	76	76	59	123048	435	271	344	292920	194940	35988
11	29	51	51	66	66	51	105676	423	142	189	250351	155893
12	24	24	44	44	57	57	44	90277	265	90	34	213768
13	20	20	20	38	38	49	49	38	78569	198	42	29
14	17	17	17	17	32	32	42	42	32	68731	42	36
15	14	14	14	14	14	27	27	36	36	27	59589	36
16+	14	14	14	14	14	27	27	36	36	27	36	36
TOTAL NO	2454581	2275260	2850724	3080705	3211899	3746923	3364818	3015619	3320011	9036460	8115950	7524230
SPS NO	551460	391595	756545	1270056	1245294	1185475	1375141	1553482	1561574	1635427	1745573	1506302
TOT.BIOM	133075	204876	314095	400995	507279	597714	691046	710770	721651	770474	778310	1061197
SPS BIOM	119002	112438	180585	331528	411544	441144	517514	545852	550195	614003	635063	579400