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Demersal Fish (Northern) Committee

REPORT OF THE NORTH-EAST ARCTIC FISHERIES WORKING GROUP

Charlottenlund, 22-26 March 1976

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Report of the North-East Arctic Fisheries Working Group

1. Participants

O V Bakurin	U.S.S.R.
A Hylen (Chairman)	Norway
J Janusz	Poland
B W Jones	U.K. (England)
W Mahnke	German Democratic Republic
V P Ponomarenko	U.S.S.R.
C J Rørvik	Norway
A Schumacher	Federal Republic of Germany
G I Tokareva	U.S.S.R.
B Vaske	German Democratic Republic

Dr V M Nikolaev (ICES Statistician) also participated in the meeting.

Terms of Reference

At the 1975 Statutory Meeting of ICES it was decided (C.Res.1975/2:24), that:

> "the North-East Arctic Fisheries Working Group should meet at Charlottenlund from 22 to 26 March 1976 to:
>
> (a) assess TACs for 1977 for cod and haddock;
>
> (b) re-estimate the effective mesh size in use and its effect on mesh assessments. Further attention should be paid to the effect of the mid-water trawl and the effects of various regulatory measures on the size of the spawning stock; and
>
> (c) those countries which have recently commenced fishing in the North-East Arctic should also be invited to participate as members of the Working Group, or to send detailed catch statistics and age composition data to the meeting".

3. The Status of the Fisheries

3.1 Cod (Tables 1-4)

In 1975 the landings were limited by an international quota scheme. Following this the total landings were limited to 810 000 tons. In addition Norway and U.S.S.R. were allowed 40 000 tons each, in addition to their quota, in respect of their catches of Norwegian coastal cod and Murman cod respectively.

The Norwegian coastal cod have for a long time been treated as a separate unit stock both from a genetical and a management point of view.

Since the Murman cod type cannot at this stage be treated as an independent unit stock for management purposes (Doc. C.M.1975/F:6), the catches of Murman cod are included in the U.S.S.R. landings data for 1974 and 1975 which were used for assessments of the North-East Arctic cod stock.

Total landings are given for Sub-area I and Divisions IIa and IIb in Table 1 and the totals for each country in Table 2. Preliminary estimates of the 1975 landings show a decrease from 1 100 000 tons in 1974 to about 835 000 tons in 1975, a figure which may be compared with the total allowable catch of

850 000 tons (810 000 tons + 40 000 tons of Murman cod). Reductions in the landings were observed in all regions from 1974 to 1975. In Sub-area I and Division IIb the reductions are estimated to be 21 and 33% respectively, while the reduction in Division IIa was 5%. The 1970 year class, and to a lesser extent the 1969 year class, contributed the main part of the catches in Sub-area I and Division IIb. No specific year class or year classes dominated the Division IIa catches.

3.2 Haddock (Tables 5-7)

The quota agreement in 1975 did not provide for any limitation of haddock catches. Normally only a small amount of directed fishing for haddock takes place, and most of the haddock is taken as by-catch in the cod fishery. Total catches in 1975 were about 178 000 tons compared with 221 000 tons in 1974. A decrease was observed in the landings from all three fishing areas. The 1969 year class contributed the main part of the catches from Divisions IIa and IIb, while the 1969 and 1970 year classes dominated in the landings from Sub-area I.

4. Virtual Population Analyses (Tables 8-15)

Assessments were made for cod and haddock using the data for 1950-73 as used last year, together with updated age compositions for 1974 and preliminary age compositions for 1975. U.S.S.R. landings of Murman cod and haddock were incorporated in the data for 1974 and 1975.

For cod a natural mortality of 0.30 has been used by this Working Group in its previous analyses. However, this parameter is seldom known with any degree of accuracy, and since there are indications that a value lower than 0.3 may be appropriate the Working Group found it useful at this stage to make an alternative assessment for a value of natural mortality of 0.20. However, the Group is of the opinion that more studies are needed before any decision can be taken as to which natural mortality rate is the more appropriate for the North-East Arctic cod. In the meantime, all assessments will be made for $M = 0.30$ and $M = 0.20$.

Age compositions for total landings of cod and haddock used as input data for the VPA are given in Table 8 and 13 respectively. Calculated fishing mortality rates are given in Tables 9, 11 and 14. The assumed values for fishing mortality in 1975 are also indicated in these tables. In deciding on the input F values for 1975 the following points were considered:

Year class strength data from pre-recruit surveys;

The expected exploitation pattern allowing for some concentration of fishing on the 1970 year class;

The overall level of fishing mortality that would be expected in relation to the reported catches;

The changes in estimated fishing effort.

Stock sizes in numbers by age group at the beginning of each year are given in Tables 10, 12 and 15.

5. The State of the Stocks

5.1 Fishing mortality

Estimates of fishing mortality rates for 1974 and 1973 will be influenced by the values of F assumed for 1975.

5.1.1 North-East Arctic cod

The fishing mortality appears to have remained relatively stable on the older fish during the more recent years. However, the fishing mortality on the 3 year old cod in 1973 and the 4 year old cod in 1974 appears to have been

higher than it used to be in the past. This is likely to be the result of a concentration of fishing on the very rich 1970 year class.

5.1.2 North-East Arctic haddock

Fishing mortality appears to have been relatively high on the older fish in 1974. This might to some extent have been caused by a directed trawl fishing in the early part of the year in Division IIa and in the second half of the year in Division IIb. A higher fishing mortality appears on the younger fish after the recruitment of the very rich 1969 year class.

5.2 Recruitment

As in previous years estimates of the abundance of pre-recruit year classes were available from the International 0-Group Surveys and also from the U.S.S.R. Young Fish Surveys (Tables 16 and 17).

5.2.1 Cod

The 1970 year class is now well established as being very abundant. Of the subsequent year classes that of 1971 appears to be average or below average, and that of 1972 to be of average abundance. The 1973 year class was estimated to be very abundant in the 0-Group Survey but more recent information from the U.S.S.R. Young Fish Surveys suggests that subsequent survival was poor and that it is now much less abundant and probably only of average strength. It is possible that this year class has suffered from predation or adverse environmental conditions. The 1974 year class has been recorded as weak in both the 0-Group Surveys and the U.S.S.R. Young Fish Survey. In the 0-Group Surveys the 1975 year class was abundant. The values of absolute abundance at 3 years old used in the catch prediction calculations have been updated on the basis of the most recent information and these are shown in Table 18.

5.2.2 Haddock

The 1971 year class was a poor one and the latest U.S.S.R. Survey data indicate that the 1972 and 1973 year classes are both below average abundance. The 1974 year class was estimated to be good in the 0-Group Survey and this is confirmed by the first estimates from the U.S.S.R. surveys. In the 0-Group Survey the 1975 year class was the most abundant one since these surveys began. Revised estimates of absolute year class strength have been prepared for use in the catch prediction calculations and these values are shown in Table 19.

5.3 Spawning Stock Biomass

Estimates of spawning stock biomass were prepared using the stock numbers in each year as estimated by VPA and weight-at-age data given in Table 20. The mature stock has been taken as fish of 8 years and older for cod and as fish of 6 years and older for haddock. For cod two estimates were calculated corresponding to values of natural mortality of M = 0.2 and 0.3. These estimates of spawning stock biomass are given in Tables 18 and 19, and the trend with time is illustrated in Figures 1 and 2.

The spawning stock biomass calculated by the method described above gives an estimate of the biomass of the adult stock at the beginning of each year. For cod, there is a fishery for mature fish in which the majority of the fish in the catch are caught before they spawn. A better estimate of the biomass of the stock which actually spawns would be the spawning stock biomass at the beginning of each year minus the weight of the mature part of the catch in this. In this report, however, no correction has been made for the catches in this fishery, and all spawning stock biomass estimates relate to the stock biomass at the beginning of the year.

For cod there was a marked decline in spawning stock biomass from 1950 to 1965 with some temporary recovery in the late 1950s when a series of abundant year classes recruited to the spawning stock. After 1965 there was a recovery to a new peak in 1971-72 when the very abundant 1963 and 1964 year classes reached maturity. Since then spawning potential declined to a very low level again. However, the spawning stock is now increasing again and a continued improvement can be expected up to 1978-79 provided catch limitation is maintained.

For haddock the spawning stock biomass has fluctuated about a level of 150 000 tons, and there is no indication of any long-term decline comparable with that for cod. The large peak in 1956 was the result of the recruitment to the spawning stock of the very abundant 1950 year class. Although the 1969 year class appears to be almost equivalent in abundance to the 1950 year class, it is making a much smaller contribution to the spawning stock because higher fishing mortality rates up to age 6 have resulted in reduced survival to the age of maturity.

6. Yield per Recruit

Yield or yield per recruit curves have been calculated for cod and haddock for exploitation patterns expected in 1976 (Table 20). In recent years there has been a tendency for the exploitation pattern to change from year to year. This has been due to low stock size and variable recruitment. When a strong year class recruits to the fishery, fishing effort tends to concentrate on that year class with a resultant increase in fishing mortality which changes the traditional exploitation pattern. For cod two values of natural mortality have been used, M = 0.2 and 0.3. In order to make comparison easier these curves are presented in Figure 3 as yield curves, rather than yield/recruit curves, to allow for the difference in estimated year class strengths for the two rates of mortality (M = 0.2, $\bar{R}_3$ (year classes 1947 to 1969) = 736; M = 0.3, $\bar{R}_3$ = 1 066). Thus, the lower yield per recruit values calculated for M = 0.3 are compensated for, to some extent, by higher recruitment estimates. It has been assumed that recruitment is constant at all levels of fishing mortality. For haddock the single curve for M = 0.2 (Figure 4) has been plotted as a yield/recruit curve. For both cod and haddock the corresponding curves of equilibrium spawning stock biomass (or spawning stock biomass per recruit) are also plotted in the Figures. The F values in the Figures refer to the value of the fishing mortality coefficient on the age groups subject to full exploitation.

For cod the current estimate of fishing mortality on the fully exploited age groups is F = 0.4-0.5, which corresponds to F_{max} on the curve for M = 0.3. On the curve for M = 0.2, F_{max} = 0.25 and for F increasing above F_{max}, yield decreases more rapidly than on the curve for M = 0.3 which is almost flat-topped.

For haddock the present level of fishing mortality on the fully exploited age groups is about F = 0.8 at which point the yield per recruit is about 20% below F_{max} = 0.25. With this exploitation pattern, the decline of equilibrium spawning stock biomass with increasing F is less rapid than that for cod.

Increases in yield per recruit might be obtained with exploitation patterns different from the present ones. The possibilities for varying the exploitation patterns are almost infinite but in order to give some indication of the effect of varying the age at first capture (t_c), yield per recruit curves have been calculated for a range of values of t_c (Figures 5 and 6). In calculating these curves knife-edge selection has been assumed (i.e. F on age groups up to t_c is zero and on age groups t_c and above the full level of F applies). This differs from the curves described above which were calculated from a model representing the present situation in which F varies with age and therefore the F values on the abscissae of these two sets of figures are not comparable.

For cod it can be seen that the yield per recruit increases with increasing age at first capture over the range of t_c from 4 to 6 years. The gains in yield per recruit with increasing t_c are greater for M = 0.2 than for M = 0.3. In making comparisons between the curves for the two levels of M, the differences in yields for a given t_c will be less than the differences in yield per recruit because of the different estimates for recruitment which would have to be used.

For haddock the yield per recruit also increases with increasing age at first capture over the range of t_c from 4 to 6 years.

It is difficult to give a value for the mean age at first capture in the knife-edge selection models which is equivalent to the mean age at first capture for the present exploitation pattern where F varies with age. However, as a rough guide the present mean age at first capture for cod is about 5 years, and for haddock about 4 years.

7. Calculation of Total Allowable Catch (TAC)

Data used in calculating predicted catches are given in Table 20. For cod, the stock size at the beginning of 1976 was calculated from the stock size in 1975 as estimated from VPA and the corresponding estimates of fishing mortality rates.

It was assumed that the catch in 1976 would be equal to the agreed TAC (850 000 tons). The fishing mortality rate which would generate this catch was estimated using the exploitation pattern shown in Table 20. This exploitation pattern has been changed slightly from that used for 1975 to allow for some concentration of fishing effort on the 1970 and 1973 year classes. The predicted stock size at the beginning of 1977 (Table 20) was then calculated from the 1976 stock and the corresponding F values. The sizes of the recruiting year classes were as given in Table 18.

For haddock a similar procedure was adopted. The exploitation pattern as given in Table 20 was used for all the years 1975-77. There is no agreed limit on the catches of haddock for 1976 and the values of F used for 1976 to calculate the stock size at the beginning of 1977 (Table 20 and text table below) were those that the Group considered to be likely in relation to the expected trend in the cod fishery.

To convert predicted catches in numbers into catches in weight the age/weight relationships given in Table 20 were used. Reported total weights of landings in recent years were compared with weights of landings calculated from the sum of products of numbers landed and mean weight at age. For cod, this comparison showed no consistent discrepancy but in the case of haddock the calculated weights of landings were consistent underestimates. To correct for this, the calculated predicted catches were increased by 26%.

In making its recommendation for cod TACs for 1977 the Working Group had to consider the need to increase the size of the spawning stock. The immediate objective of a spawning stock size at least as large as that in the period 1970-72 is likely to be realised by 1977-78. The Group recommends, however, that as a longer-term objective the aim should be to maintain the spawning stock biomass at about 1 million tons. An analysis of the stock/recruitment relationship (Garrod and Jones, 1974) indicated that the optimum spawning stock size would be that which prevailed in the early 1950s, when the spawning stock biomass was about 1 million tons. In addition there is a need to reduce the overall level of fishing mortality to bring it closer to, or even below, the value giving the maximum yield per recruit with the present exploitation pattern. The actual value of F_{max} with the present exploitation pattern would depend on the value of the natural mortality coefficient (M = 0.3, F_{max} = 0.45; M = 0.2, F_{max} = 0.25).

To take a catch in 1976 equal to the TAC of 850 000 tons would require a fishing mortality on the fully exploited age groups of F = 0.4 or F = 0.47 for M = 0.2. If the same TAC was to apply in 1977 this would bring about a further small reduction in fishing mortality and the spawning stock biomass could be expected to reach 1 million tons by 1978. The results of these calculations are summarised in the text table below.

Cod

	Natural Mortality	0.2	0.3
1975	*Spawning stock biomass (thousands of tons)	233	276
1976	Catch (thousands of tons)	850	850
	Fishing mortality on fully exploited age groups	0.47	0.4
	*Spawning stock biomass (thousands of tons)	309	362
1977	Catch (thousands of tons)	850	850
	Fishing mortality	0.43	0.39
	*Spawning stock biomass (thousands of tons)	637	709
1978	*Spawning stock biomass (thousands of tons)	1 040	1 101

* Spawning stock biomass at the beginning of each year.

Although in the above strategy the spawning stock biomass reaches 1 million tons in 1978 this is to a large extent due to the recruitment of the very abundant 1970 year class to the mature stock, and this size of spawning stock could be maintained into 1979 only if the TAC for earlier years was reduced below 850 000 tons.

For haddock the Working Group estimated the likely effects on the haddock fishery if the cod catch was maintained at 850 000 tons. The results are summarised in the text table below:

Haddock

	Natural Mortality	0.2
1975	*Spawning stock biomass (thousands of tons)	186
1976	Catch (thousands of tons)	121
	Fishing mortality on fully exploited age groups	0.7
	*Spawning stock biomass (thousands of tons)	143

ctd.

text table (ctd)

	Natural Mortality	0.2
1977	Catch (thousands of tons)	113
	Fishing mortality	0.7
	*Spawning stock biomass (thousands of tons)	91
1978	*Spawning stock biomass (thousands of tons)	78

* Spawning stock biomass at the beginning of each year.

The Working Group recommends that the TAC for cod for 1977 should be maintained at 850 000 tons (including landings of Murman cod). This would permit the continued recovery of the spawning stock and would also go some way towards reducing fishing mortality to the value giving maximum yield per recruit with the present selection pattern.

In the longer term the regulation of the cod stock should be considered in relation to additional objectives which would provide further biological or economic benefits. These could include changes in the pattern and level of exploitation.

The Working Group considers that it would be difficult to regulate the haddock fishery independently of the cod fishery. However, if the Commission considered it desirable to introduce a TAC for haddock, this could be set at the level that would be expected as a by-catch while fishing for the recommended TAC for cod. In these circumstances the appropriate TAC for haddock for 1977 would be 110 000 tons.

The present level of fishing mortality is much higher than that required to give the maximum yield per recruit with the present exploitation pattern and as a long-term result yield would be increased if fishing mortality was reduced. A reduction in fishing mortality would also provide some protection for the spawning stock which in the foreseeable future is expected to decline.

The Working Group therefore recommends that consideration should be given to the possibility of reducing fishing mortality on haddock.

Any regulations designed to reduce fishing mortality would require a TAC for haddock lower than that mentioned above.

8. Midwater Trawl

In the previous report it was stated that a part of the trawler fleet operating in the North-East Arctic has been using midwater trawls in the fishery for Arcto-Norwegian cod and haddock. The effects of midwater trawls on the stocks, compared with the effects of bottom trawls, will depend on their relative selectivities and also on the behaviour and vertical distribution of fish. Experiments carried out by Norway in March 1975 gave selection factors of the same order for both gears. These experiments also indicated that due to their different behaviour young fish might be more available to pelagic trawls than to bottom trawls.

Additional selectivity experiments have been undertaken by the Federal Republic of Germany which confirm the results of the Norwegian experiments as far as the selection factors are concerned. As to the length composition of the catches, the cod caught by bottom trawl were, on average, somewhat bigger than those caught by midwater trawl, but the abundance of smaller cod in the midwater trawl catches was less pronounced than in the Norwegian experiments. This difference could be

explained by differences in the time and area of the experiments. In the case of haddock the length compositions of catches from the two types of gear show remarkable differences. The midwater trawl catch consisted mainly of bigger fish, whereas with the bottom trawl a considerable proportion of young fish (24.5 cm modal length) was caught, but here again the results might be influenced by differences in time and area.

Since the information available to the Working Group does not allow a generalised statement as to the effect of midwater trawls on the stocks in the North-East Arctic, the danger of heavy exploitation of young fish by midwater trawling - particularly in a situation where a good year class is recruiting to the fishery - could be eliminated or at least reduced by strict observance of the mesh regulations in force and by prohibiting any attachment to nets which may reduce the selectivity of the cod end.

During the next few years the biomass of the North-East Arctic cod is expected to increase. Improving abundance of older fish together with a continuation of a catch limitation scheme could be expected to reduce the incentive to fish with gears, or in areas, which yield catches with a large proportion of small fish.

9. Mesh Assessment

The North-East Arctic Fisheries Working Group indicated two years ago that there were doubts as to what was the effective mesh size used in the trawl fishery. A study of the data from the International Inspection at Sea in 1975 was made, but the Working Group could not reach any conclusive results. No mesh assessments were therefore made.

However, any increase in the effective trawl mesh size would result in an increase in the average age at first capture. An indication of the likely benefits of increases of age at first capture is given in Section 6.

10. Reference

Garrod, D J and Jones, B W, 1974. Stock and recruitment relationship in the North-East Arctic cod stock and its implications for management of the stock. J.Cons.int.Explor.Mer, 36(1):35-41.

Table 1. Cod.
Total nominal catch by fishing areas
(metric tons).

Year	Sub-area I	Division IIb	Division IIa	Total catch
1960	375 327	91 599	155 116	622 042
1961	409 694	220 508	153 019	783 221
1962	548 621	220 797	139 848	909 266
1963	547 469	111 768	117 100	776 337
1964	206 883	126 114	104 698	437 695
1965	241 489	103 430	100 011	444 930
1966	292 253	56 653	134 805	483 711
1967	322 798	121 060	128 747	572 605
1968	642 452	269 160	162 472	1 074 084
1969	679 373	262 254	255 599	1 197 226
1970	603 855	85 556	243 835	933 246
1971	312 505	56 920	319 623	689 048
1972	197 015	32 982	335 257	565 254
1973	492 716	88 207	211 762	792 685
1974	723 489	254 730	124 214	1 102 433
1975*	545 060	170 435	120 216	835 711

* Provisional figures.

Table 2. Cod.
Nominal catch (metric tons, whole weight) by countries.
(Sub-area I and Divisions IIa and IIb combined)

Year	Faroe Islands	France	German Dem.Rep.	Germany Fed.Rep.	Norway	Poland	U.K.	U.S.S.R.	Others	Total All countries
1960	3 306	22 321		9 472	231 997	20	141 175	213 400	351	622 042
1961	3 934	13 755	3 921	8 129	268 377	-	158 113	325 780	1 212	783 221
1962	3 109	20 482	1 532	6 503	225 615	-	175 020	476 760	245	909 266
1963	-	18 318	129	4 223	205 056	108	129 779	417 964	-	775 577
1964	-	8 634	297	3 202	149 878	-	94 549	180 550	585	437 695
1965	-	526	91	3 670	197 085	-	89 962	152 780	816	444 930
1966	-	2 967	228	4 284	203 792	-	103 012	169 300	121	483 704
1967	-	664	45	3 632	218 910	-	87 008	262 340	6	572 605
1968	-	-	255	1 073	255 611	-	140 387	676 758	-	1 074 084
1969	29 374	-	5 907	5 343	305 241	7 856	231 066	612 215	133	1 197 226
1970	26 265	44 245	12 413	9 451	377 606	5 153	181 481	276 632	-	933 246
1971	5 877	34 772	4 998	9 726	407 044	1 512	80 102	144 802	215	689 048
1972	1 393	8 915	1 300	3 405	394 181	892	58 382	96 653	166	565 287
1973	1 916	17 028	4 684	16 751	285 184	843	78 808	387 196	276	792 686
1974	5 717	46 028	4 860	78 507	287 276	9 898	90 894	540 801 [1]	38 453	1 102 434
1975*	11 262	29 206	9 981	31 484	287 300	7 435	99 824	345 271 [1]	11 778	833 541

* Provisional figures.

1) Murman cod included.

Table 3. Cod.
Estimates of total international fishing effort
in Sub-area I and Divisions IIa and IIb.

Year	SUB-AREA I				DIVISION IIb				DIVISION IIa			
	National Effort		Total International Effort		National Effort		Total International Effort		National Effort		Total International Effort	
	U.K.[1]	USSR[2]	U.K. units	USSR units	U.K.	USSR	U.K. units	USSR units	U.K.	Norway[3]	U.K. units	Norwegian units
1960	95	43	512	91	42	11	97	34	39	10	252	26
1961	94	53	518	109	51	22	173	39	30	9	255	20
1962	93	61	590	94	51	16	168	29	34	10	210	21
1963	78	62	635	91	45	9	120	22	29	7	176	19
1964	42	30	351	55	49	17	136	32	36	6	157	17
1965	42	25	367	62	37	11	95	4	33	5	150	16
1966	63	33	387	69	23	16	71	29	46	5	199	15
1967	51	30	395	61	10	12	110	13	50	5	261	22
1968	86	45	584	67	9	24	151	26	52	6	288	15
1969	115	45	593	72	24	19	197	26	73	5	272	18
1970	122	35	573	77	24	15	122	27	55	5	346	16
1971	82	23	576	74	4	27	79	34	48	5	523	14
1972	71	41	418	111	7	11	65	17	35	6	602	14
1973	96	61	860	94	18	12	161	16	27	7	485	14
1974	92	48	906	86	9	18	243	42	29	5	435	16
1975*	109	31	1 211	90	7	19	176	36	28	4	366	15

1) Hours fishing x average tonnage x 10^{-6} = millions on ton-hours.

2) Hours fishing (catch/catch per hour fishing) x 10^{-4}.

3) Number of men fishing at Lofoten x 10^{-3}.

* Provisional figures.

Table 4. Cod.
Catch per unit effort (metric tons, round fresh) in Sub-area I and Divisions IIa and IIb.

Year	SUB-AREA I		DIVISION IIb		DIVISION IIa	
	U.K.[1]	USSR[2]	U.K.	USSR	U.K.	Norway[3]
1960	0.075	0.42	0.105	0.31	0.067	3.0
1961	0.079	0.38	0.129	0.44	0.058	3.7
1962	0.092	0.59	0.133	0.74	0.066	4.0
1963	0.085	0.60	0.098	0.55	0.066	3.1
1964	0.058	0.37	0.092	0.39	0.070	4.8
1965	0.066	0.39	0.109	0.49	0.066	2.9
1966	0.074	0.42	0.078	0.19	0.067	4.0
1967	0.081	0.53	0.106	0.87	0.052	3.5
1968	0.110	1.09	0.173	1.21	0.056	5.1
1969	0.113	1.00	0.135	1.17	0.094	5.9
1970	0.100	0.80	0.100	0.80	0.066	6.4
1971	0.056	0.43	0.071	0.16	0.062	10.6
1972	0.047	0.34	0.051	0.18	0.055	11.5
1973	0.057	0.56	0.054	0.57	0.043	6.8
1974	0.080	0.90	0.104	0.77	0.028	3.4
1975*	0.077	0.85	0.100	0.43	0.033	3.4

1) U.K. data - tons per 100 ton-hours fishing.

2) USSR data - tons per hour fishing.

3) Norwegian data - tons per gill net boat week at Lofoten.

* Provisional figures.

Table 5. Haddock.
Total nominal catch by fishing areas (metric tons).

Year	Sub-area I	Division IIb	Division IIa	Total
1960	125 675	1 854	27 925	155 454
1961	165 165	2 427	25 642	193 234
1962	160 972	1 727	25 189	187 888
1963	124 774	939	21 031	146 744
1964	79 056	1 109	18 735	98 900
1965	98 505	939	18 640	118 079
1966	124 115	1 614	34 892	160 621
1967	108 066	440	27 980	136 486
1968	140 970	725	40 031	181 726
1969	88 960	1 341	40 208	130 509
1970	59 493	497	26 611	86 601
1971	56 300	435	21 567	78 302
1972	221 183	2 155	41 979	265 317
1973	283 728	12 989	23 348	320 065
1974	159 037	15 068	47 033	221 138
1975*	129 777	8 782	39 915	178 474

* Provisional figures.

Table 6. Haddock.
Nominal catch (in metric tons) by countries.
(Sub-area I and Divisions IIa and IIb combined).

Year	Faroe Islands	France	German Dem.Rep.	Germany Fed.Rep.	Norway	Poland	U.K.	USSR	Others	Total
1960	172	-	-	5 597	47 263	-	45 469	57 025	125	155 651
1961	295	220	-	6 304	60 862	-	39 650	85 345	558	193 234
1962	83	409	-	2 895	54 567	-	37 486	91 940	58	187 438
1963	17	363	-	2 554	59 955	-	19 809	63 526	-	146 224
1964	-	208	-	1 482	38 695	-	14 653	43 870	250	99 158
1965	-	226	-	1 568	60 447	-	14 345	41 750	242	118 578
1966	-	1 072	11	2 098	82 090	-	27 723	48 710	74	161 778
1967	-	1 208	3	1 705	51 954	-	24 158	57 346	23	136 397
1968	-	-	-	1 867	64 076	-	40 129	75 654	-	181 726
1969	2	-	309	1 490	67 549	-	37 234	24 211	25	130 820
1970	541	-	656	2 119	36 716	-	20 423	26 802	-	87 257
1971	81	-	16	896	45 715	49	16 373	15 778	3	78 911
1972	137	-	829	1 433	46 700	1 433	17 166	196 224	2 223	266 145
1973	1 212	3 214	22	9 583	86 767	325	32 408	186 534	-	320 065
1974	925	3 601	454	23 409	66 164	3 045	36 293	78 548[1)]	8 699	221 138
1975*	70	2 285	437	14 903	61 056	1 080	27 740	65 136[1)]	5 767	178 474

* Provisional figures.

1) Murman haddock included.

Table 7. Haddock.
Catch per unit effort and estimated total international effort.

Year	Catch per Effort (U.K.) Kilos/100 ton-hours			Estimated Total International Effort in U.K. Units $\frac{\text{Total Catch in Tons} \times 10^{-6}}{\text{Tons/100 Ton-Hours Sub-area I}}$
	Sub-area I	Divisions IIa	Divisions IIb	
1960	33	34	2.8	4.7
1961	29	36	3.3	6.7
1962	23	42	2.5	8.2
1963	13	33	0.9	11.2
1964	18	18	1.6	5.5
1965	18	18	2.0	6.6
1966	17	34	2.8	9.4
1967	18	25	2.4	7.6
1968	19	50	1.0	9.6
1969	13	42	2.0	10.0
1970	7	31	1.0	12.4
1971	8	25	3.0	9.8
1972	14	18	23.0	19.0
1973	22	20	20.0	14.5
1974	20	74	14.0	11.1
1975*	15	60	4.0	11.9

* Provisional figures.

Table 8. Age composition of the total catches of COD (in 000's) 1966-75. Input for the VPA.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
3	55 937	34 467	3 709	2 307	7 164	7 754	35 536	294 262	91 855	46 371
4	55 644	160 048	174 585	24 545	10 792	13 739	45 431	131 493	437 377	63 852
5	34 675	69 235	267 961	238 511	25 813	11 831	26 832	61 000	203 772	233 882
6	42 539	22 061	107 051	181 239	137 829	9 527	12 089	20 569	47 006	114 941
7	37 169	26 295	26 701	79 363	96 420	59 290	7 918	7 248	12 630	29 283
8	18 500	25 139	16 399	26 989	31 920	52 003	34 885	8 328	4 370	9 096
9	5 077	11 323	11 597	13 463	8 933	12 093	22 315	19 130	2 523	2 566
10	1 495	2 329	3 657	5 092	3 249	2 434	4 572	4 499	5 607	1 333
11	380	687	657	1 913	1 232	762	1 215	677	2 127	1 802
12	403	316	122	414	260	418	353	195	322	608
13	77	225	124	121	106	149	315	81	151	200
14	9	40	70	23	39	42	121	59	83	14
15+	70	14	46	46	35	25	40	55	62	38

Table 9. Fishing mortalities for COD, 1966-75, estimated by VPA for M = 0.30.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975*
3	0.03	0.02	0.02	0.02	0.03	0.01	0.03	0.13	0.14	0.04
4	0.08	0.12	0.16	0.17	0.10	0.07	0.12	0.14	0.33	0.15
5	0.16	0.15	0.34	0.39	0.31	0.18	0.22	0.26	0.36	0.33
6	0.31	0.17	0.40	0.46	0.47	0.20	0.31	0.30	0.36	0.40
7	0.40	0.36	0.35	0.67	0.54	0.43	0.28	0.34	0.34	0.45
8	0.49	0.58	0.46	0.83	0.73	0.73	0.55	0.62	0.40	0.50
9	0.60	0.73	0.68	1.01	0.85	0.80	0.96	0.79	0.44	0.50
10	0.63	0.71	0.64	0.86	0.86	0.69	0.97	0.58	0.64	0.50
11	0.37	0.77	0.50	0.98	0.59	0.56	1.08	0.40	0.70	0.50
12	0.53	0.69	0.33	0.80	0.37	0.46	0.64	0.55	0.39	0.50
13	0.39	0.75	0.74	0.74	0.55	0.42	0.89	0.33	1.41	0.50
14	0.32	0.41	0.63	0.32	0.64	0.50	0.85	0.46	0.76	0.50
15+ *	0.65	0.65	0.65	0.65	0.65	0.65	0.80	0.80	0.80	0.50

* Assumed values.

Table 10. Stock size of COD 1966-75 (in 000's) estimated by VPA for M = 0.30.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
3	2 262 710	1 842 750	245 348	173 652	310 689	647 328	1 654 580	2 757 920	819 513	1 367 500
4	850 154	1 628 330	1 335 600	178 579	126 667	224 025	472 906	1 195 290	1 791 620	528 617
5	264 033	582 189	1 069 470	840 342	111 338	84 607	154 202	311 495	773 120	955 272
6	182 422	165 987	372 146	564 436	420 008	60 517	52 578	91 355	178 785	399 565
7	130 022	98 947	104 128	184 805	264 489	194 333	36 703	28 663	50 171	92 498
8	54 644	64 763	50 957	54 441	69 971	114 353	93 664	20 449	15 072	26 429
9	12 840	24 809	26 730	23 847	17 653	24 953	40 915	39 882	8 117	7 456
10	3 662	5 223	8 843	10 024	6 404	5 576	8 317	11 618	13 455	3 873
11	1 413	1 451	1 907	3 464	3 150	2 016	2 079	2 333	4 804	5 236
12	1 116	724	497	856	964	1 293	849	525	1 154	1 767
13	273	486	270	264	286	494	603	331	224	581
14	38	137	171	95	94	122	239	183	176	41
15+	102	20	67	67	51	37	55	76	85	61

Table 11. Fishing mortalities for COD 1966-75 estimated by VPA for M = 0.20.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975*
3	0.04	0.03	0.03	0.02	0.04	0.02	0.03	0.17	0.18	0.05
4	0.10	0.15	0.21	0.23	0.14	0.10	0.15	0.17	0.41	0.18
5	0.21	0.18	0.41	0.48	0.40	0.23	0.29	0.32	0.43	0.40
6	0.38	0.20	0.47	0.54	0.56	0.25	0.38	0.37	0.43	0.47
7	0.47	0.43	0.40	0.76	0.62	0.51	0.34	0.42	0.41	0.53
8	0.57	0.67	0.52	0.93	0.83	0.82	0.64	0.74	0.48	0.59
9	0.69	0.84	0.78	1.14	0.96	0.91	1.09	0.91	0.53	0.59
10	0.72	0.82	0.73	0.98	0.99	0.77	1.14	0.68	0.76	0.59
11	0.43	0.90	0.58	1.14	0.69	0.67	1.20	0.49	0.82	0.59
12	0.61	0.80	0.39	0.92	0.44	0.53	0.76	0.62	0.46	0.59
13	0.47	0.86	0.87	0.84	0.64	0.49	1.02	0.39	1.58	0.59
14	0.38	0.48	0.73	0.38	0.74	0.57	0.96	0.53	0.90	0.59
15+*	0.75	0.75	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.59

* Assumed values

Table 12. Stock size of COD (in 000's) 1966-75 estimated by VPA for M = 0.20.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
3	1 584 980	1 300 110	164 741	112 165	202 857	436 579	1 160 310	2 069 160	621 843	1 048 170
4	623 933	1 247 180	1 033 320	131 530	89 750	159 618	350 438	917 901	1 429 020	426 391
5	199 900	460 655	876 892	688 842	85 600	63 755	118 294	245 980	633 071	777 554
6	147 658	132 450	314 798	477 511	350 215	46 920	41 552	72 728	146 578	335 562
7	109 124	82 707	88 580	161 775	228 679	163 378	29 845	23 169	41 078	77 850
8	46 782	56 026	44 130	48 563	61 654	101 009	80 650	17 323	12 467	22 300
9	11 070	21 746	23 412	21 444	15 746	22 033	36 353	34 849	6 751	6 291
10	3 162	4 529	7 715	8 825	5 618	4 948	7 276	9 960	11 506	3 268
11	1 182	1 255	1 633	3 052	2 698	1 711	1 880	1 903	4 136	4 418
12	959	627	416	749	803	1 109	720	463	951	1 491
13	225	425	232	231	245	424	534	275	204	490
14	32	115	147	79	81	106	214	157	152	34
15+	89	18	58	58	44	32	49	67	76	51

Table 13. Age composition of the total catches of HADDOCK (in 000's) 1966-75. Input for the VPA.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
3	26 157	15 918	657	1 520	23 004	1 979	230 229	70 204	9 684	10 181
4	22 469	41 373	67 632	1 963	2 408	24 359	22 246	258 773	41 701	14 369
5	62 724	13 505	41 267	44 526	1 870	1 258	42 849	24 018	88 111	35 160
6	28 840	25 736	7 748	18 956	21 995	918	3 196	6 872	5 827	50 911
7	5 711	8 878	15 599	3 611	7 948	9 279	1 606	418	4 138	2 164
8	578	1 617	5 292	4 925	1 974	3 056	6 736	422	382	1 206
9	435	218	655	1 624	1 978	826	2 630	1 680	617	106
10	188	176	182	315	726	1 043	896	525	2 043	138
11	186	155	101	43	166	369	988	146	935	465
12	25	76	115	43	26	130	538	340	276	130
13	8	27	18	14	52	27	53	68	458	35
14	7	7	19	2	19	4	42	13	143	22

Table 14. Fishing mortalities for HADDOCK 1966-75 estimated by VPA for M = 0.20.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975*
3	0.13	0.06	0.04	0.11	0.18	0.02	0.32	0.38	0.17	0.11
4	0.39	0.31	0.41	0.18	0.25	0.28	0.40	0.72	0.41	0.42
5	0.59	0.44	0.59	0.52	0.26	0.20	1.19	1.04	0.58	0.74
6	0.71	0.52	0.49	0.59	0.53	0.20	1.17	0.60	0.79	0.80
7	0.81	0.49	0.69	0.44	0.53	0.45	0.62	0.44	0.93	0.80
8	0.44	0.57	0.62	0.49	0.46	0.40	0.70	0.32	0.96	0.80
9	0.56	0.29	0.48	0.39	0.37	0.35	0.73	0.37	1.10	0.80
10	0.33	0.46	0.42	0.45	0.31	0.34	0.82	0.31	1.09	0.80
11	0.90	0.50	0.53	0.16	0.45	0.25	0.62	0.30	1.44	0.80
12	0.23	1.30	0.89	0.45	0.14	0.79	0.71	0.45	1.51	0.80
13	0.35	0.42	1.45	0.24	1.74	0.21	0.92	0.18	2.32	0.80
14*	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.67	0.80

* Assumed values.

Table 15. Stock size of HADDOCK (in 000's) 1966-75 estimated by VPA for M = 0.20.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
3	236 130	286 795	16 755	16 116	157 328	91 915	924 388	242 123	66 724	107 641
4	75 608	169 750	220 444	13 125	11 824	108 090	73 466	549 951	135 217	45 907
5	153 840	41 738	101 799	119 804	8 978	7 515	66 596	40 188	219 256	73 293
6	61 892	69 842	22 061	46 426	58 211	5 669	5 020	16 557	11 572	100 675
7	11 183	24 923	34 131	11 119	21 053	27 965	3 815	1 277	7 409	4 279
8	1 791	4 065	12 451	14 012	5 865	10 120	14 576	1 687	671	2 385
9	1 112	948	1 881	5 463	7 059	3 032	5 544	5 919	1 002	210
10	730	521	580	953	3 015	4 004	1 741	2 191	3 338	273
11	340	429	269	312	498	1 816	2 341	627	1 322	920
12	132	113	212	130	217	259	1 155	1 033	382	257
13	29	86	25	72	68	154	96	465	541	69
14	17	17	46	5	46	10	102	31	320	44

Table 16. ARCTO-NORWEGIAN COD.
Year class strength. The number per hour fishing for U.S.S.R. Young Fish Surveys is for 2 year old fish.

Year class	USSR Survey No. per Hour Trawling			USSR Assessment	0-Group Surveys	Virtual Population No. of 3-year-olds x 10^{-6} *	
	Sub-area I	Division IIb	Mean			M = 0.2	M = 0.3
1957	12	16	13	-Average		791	1 060
1958	16	24	19	+Average		919	1 251
1959	18	14	16	+Average		730	1 046
1960	9	19	13	Poor		473	699
1961	2	2	2	Poor		339	528
1962	7	4	6	Poor		779	1 166
1963	21	120	76	Rich		1 585	2 263
1964	49	45	46	Rich		1 300	1 843
1965	<1	<1	<1	Very poor	6	165	245
1966	2	<1	1	Very poor	<1	112	174
1967	1	<1	1	Very poor	34	203	311
1968	7	1	5	Poor	25	437	647
1969	11	6	9	Poor	93	1 160	1 655
1970	74	86	76	Rich	606	2 069	2 758
1971	37	24	32	+Average	157	(621)	(820)
1972	53	17	40	+Average	140	(1 048)	(1 367)
1973	(51)	(5)	(31)	+Average	684	(810)	(1 200)
1974	(11)	(1)	(6)	Poor	51	(470)	(700)
1975					343		

( ) = estimated.

* USSR Murman cod included for 1974 and 1975.

umber per hour trawling for
is for 2 year old fish.

s	Virtual Population No. of 3-year-olds x 10^{-6} *
	241
	110
	240
	276
	316
	99
	236
	287
	17
	16
	157
	92
	924
	(242)
	(67)
	(108)
	(150)
	(275)

Table 18. Estimates of the spawning stock and the year class strength for COD. Estimates from VPA.

M = 0.2			
Year	Spawning stock biomass tons x 10^{-3}	Year class	Year class strength at 3 years old Millions
		1947	705
		1948	1 097
		1949	1 192
1950	1 458	1950	1 593
1951	1 385	1951	645
1952	1 155	1952	273
1953	903	1953	441
1954	827	1954	805
1955	869	1955	498
1956	993	1956	685
1957	929	1957	791
1958	1 019	1958	919
1959	837	1959	730
1960	600	1960	473
1961	514	1961	339
1962	474	1962	779
1963	377	1963	1 584
1964	243	1964	1 300
1965	213	1965	165
1966	338	1966	112
1967	458	1967	203
1968	437	1968	437
1969	470	1969	1 160
1970	469	1970	(2 069)
1971	684	1971	(621)
1972	695	1972	(1 048)
1973	402	1973	(810)
1974	239	1974	(470)
1975	233		
1976	(309)		
1977	(637)		
1978	(1 040)		

M = 0.3			
Year	Spawning stock biomass tons x 10^{-3}	Year class	Year class strength at 3 years old Millions
		1947	1 070
		1948	1 666
		1949	1 773
1950	1 731	1950	2 333
1951	1 645	1951	958
1952	1 359	1952	411
1953	1 079	1953	649
1954	979	1954	1 133
1955	1 012	1955	697
1956	1 161	1956	932
1957	1 098	1957	1 060
1958	1 212	1958	1 251
1959	1 014	1959	1 046
1960	698	1960	699
1961	587	1961	528
1962	542	1962	1 166
1963	427	1963	2 263
1964	280	1964	1 843
1965	250	1965	245
1966	395	1966	174
1967	527	1967	311
1968	502	1968	647
1969	527	1969	1 655
1970	532	1970	(2 758)
1971	775	1971	(820)
1972	797	1972	(1 367)
1973	467	1973	(1 200)
1974	288	1974	(700)
1975	276		
1976	(362)		
1977	(709)		
1978	(1 101)		

( ) = provisional figures.

Table 19. Estimates of the spawning stock and the year class strength for HADDOCK. Estimated from VPA for M = 0.20.

Year	Spawning stock biomass tons x 10^{-3}	Year class	Year class strength at 3 years old Millions
		1947	67
		1948	552
		1949	63
1950	270	1950	1 029
1951	151	1951	127
1952	95	1952	52
1953	66	1953	169
1954	179	1954	53
1955	156	1955	69
1956	474	1956	325
1957	324	1957	241
1958	202	1958	110
1959	160	1959	240
1960	129	1960	276
1961	105	1961	316
1962	147	1962	99
1963	106	1963	236
1964	67	1964	287
1965	76	1965	17
1966	140	1966	16
1967	190	1967	157
1968	161	1968	92
1969	165	1969	924
1970	201	1970	(242)
1971	143	1971	(67)
1972	106	1972	(108)
1973	79	1973	(150)
1974	72	1974	(275)
1975	186		
1976	(143)		
1977	(91)		
1978	(78)		

( ) = provisional figures.

Table 20. Parameters used in the catch prediction.

Age	COD			HADDOCK		
	Stock size beginning of 1977 (millions of fish)*	Proportion of F (adult) 1976 and 1977	Mean weight per age (kgs)	Stock size beginning of 1977 (millions of fish)**	Proportion of F (adult) 1975-77	Mean weight per age (kgs)
3	700.0 470.0	0.20	0.65	275.0	0.14	0.41
4	820.6 604.5	0.30	1.00	111.1	0.53	0.62
5	639.5 581.0	0.66	1.55	44.6	0.93	0.97
6	191.8 175.6	0.90	2.35	10.6	1.00	1.59
7	263.0 229.8	0.90	3.45	11.6	1.00	2.33
8	102.5 92.5	1.00	4.70	15.1	1.00	2.72
9	21.7 19.3	1.00	6.17	0.6	1.00	3.56
10	5.9 5.2	1.00	7.70	0.4	1.00	4.41
11	1.7 1.5	1.00	9.25	0.03	1.00	5.40
12	0.8 0.8	1.00	10.85	0.04	1.00	6.70
13	1.2 1.0	1.00	12.50	0.1	1.00	7.40
14	0.58 0.54	1.00	13.90	0.04	1.00	8.00

* Upper figure: for M = 0.3
Lower figure: for M = 0.2

** For F = 0.7 in 1976.

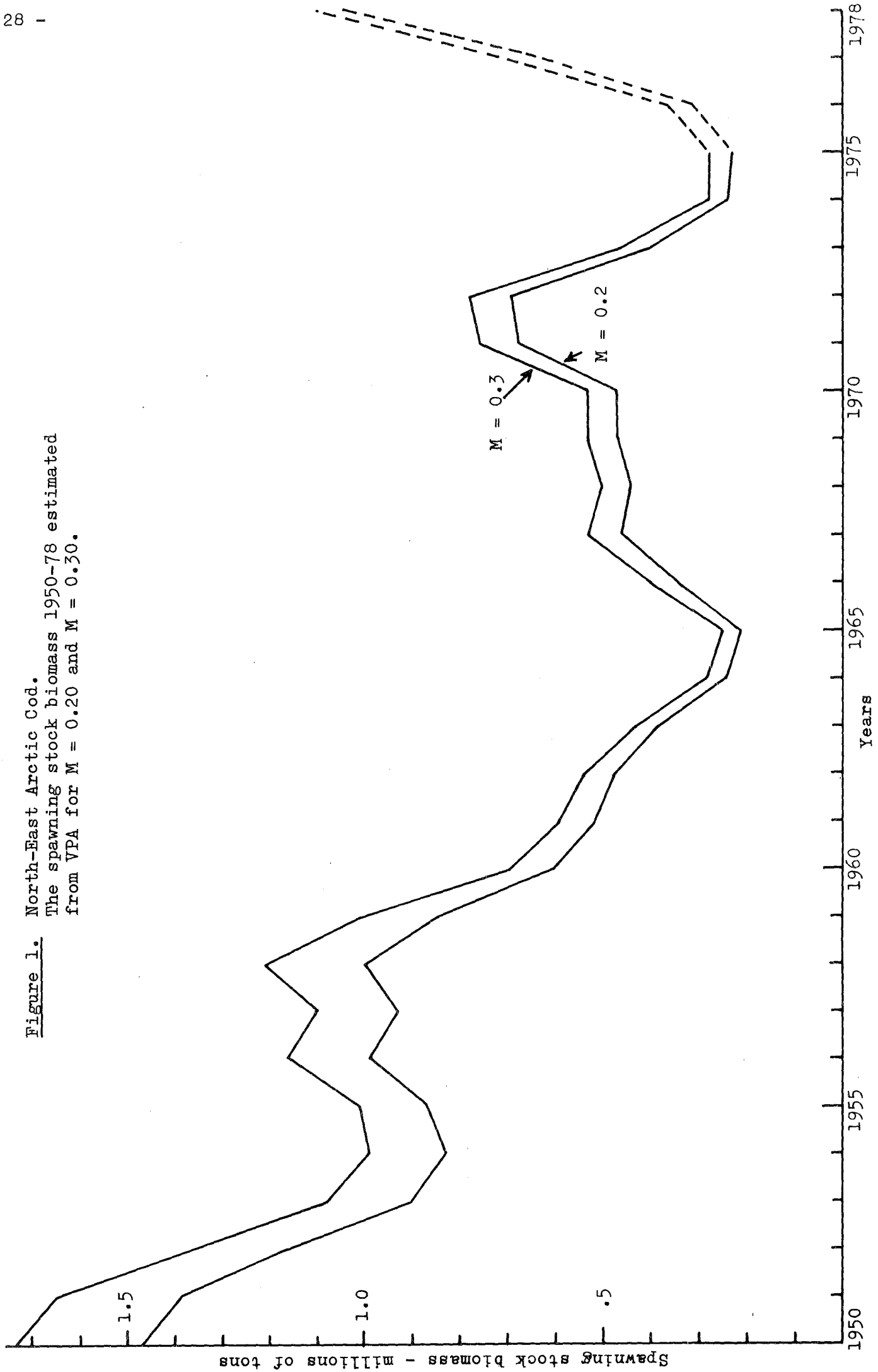


Figure 1. North-East Arctic Cod.
The spawning stock biomass 1950-78 estimated from VPA for M = 0.20 and M = 0.30.

Figure 2. Haddock.
The spawning stock biomass 1950-78 estimated from VPA for M = 0.20.

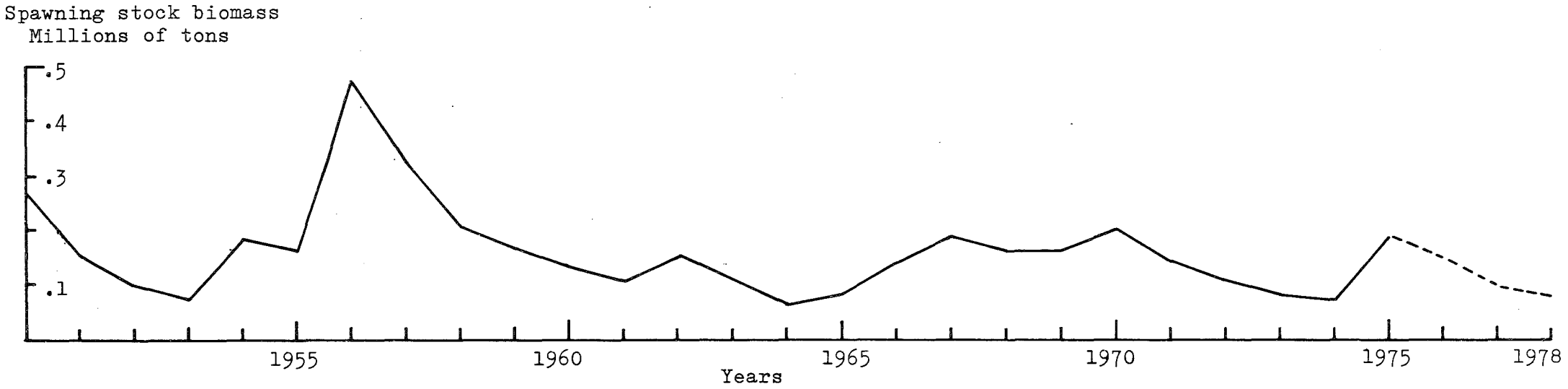


Figure 3. North-East Arctic Cod.
Curves of yield and spawning stock biomass for present exploitation pattern.

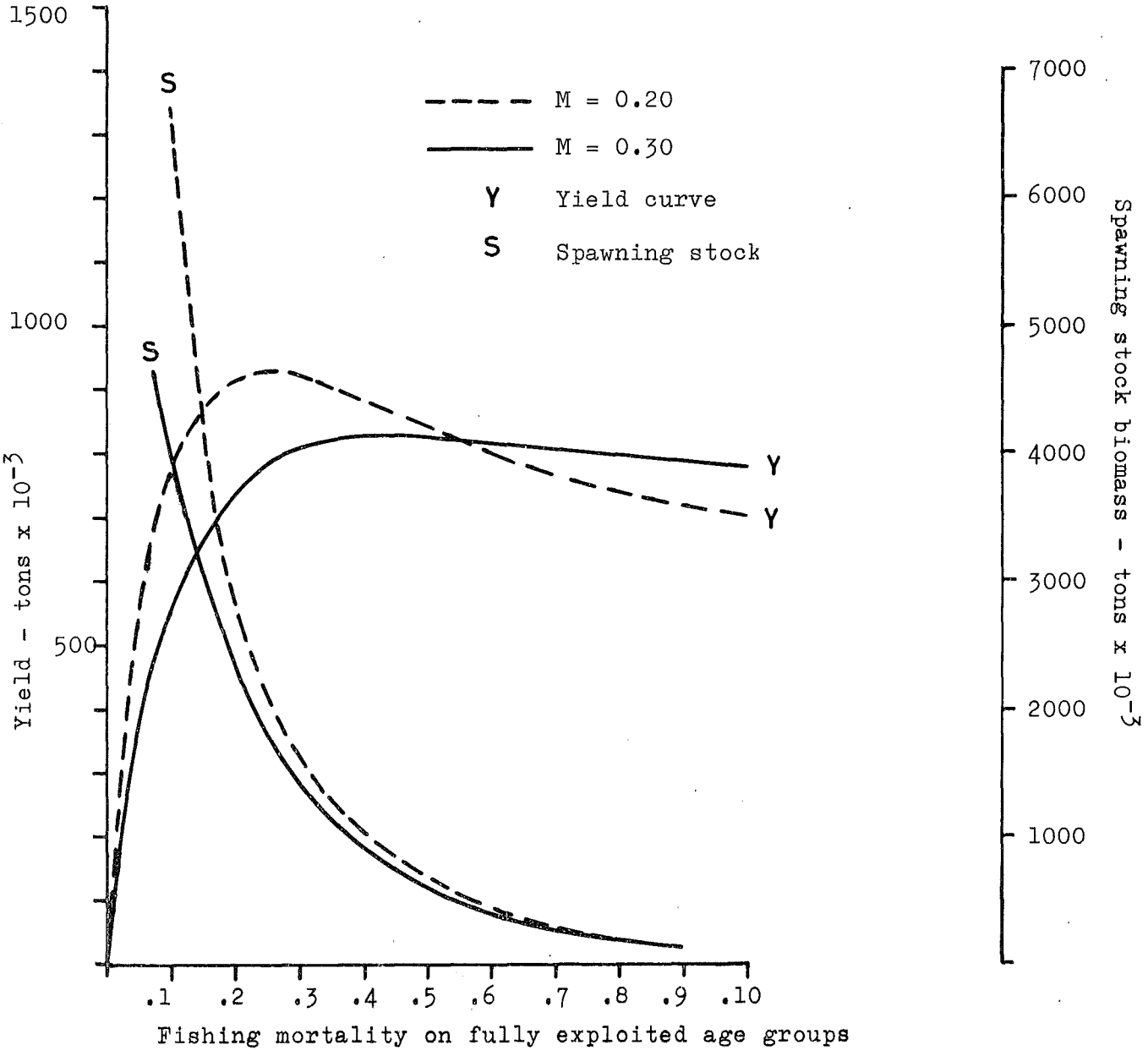
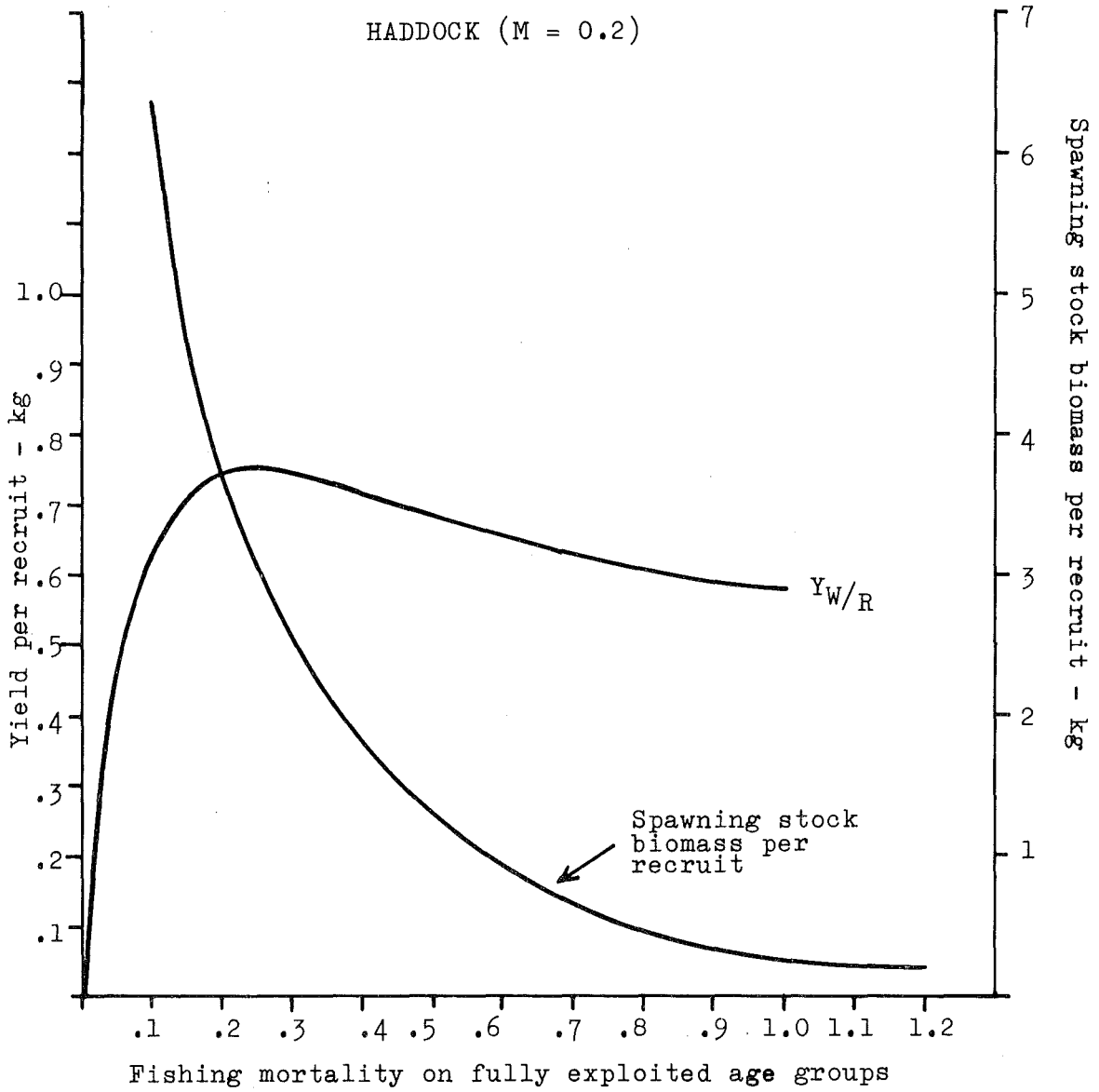


Figure 4. Haddock.
Curves of yield per recruit and spawning stock biomass for present exploitation pattern.



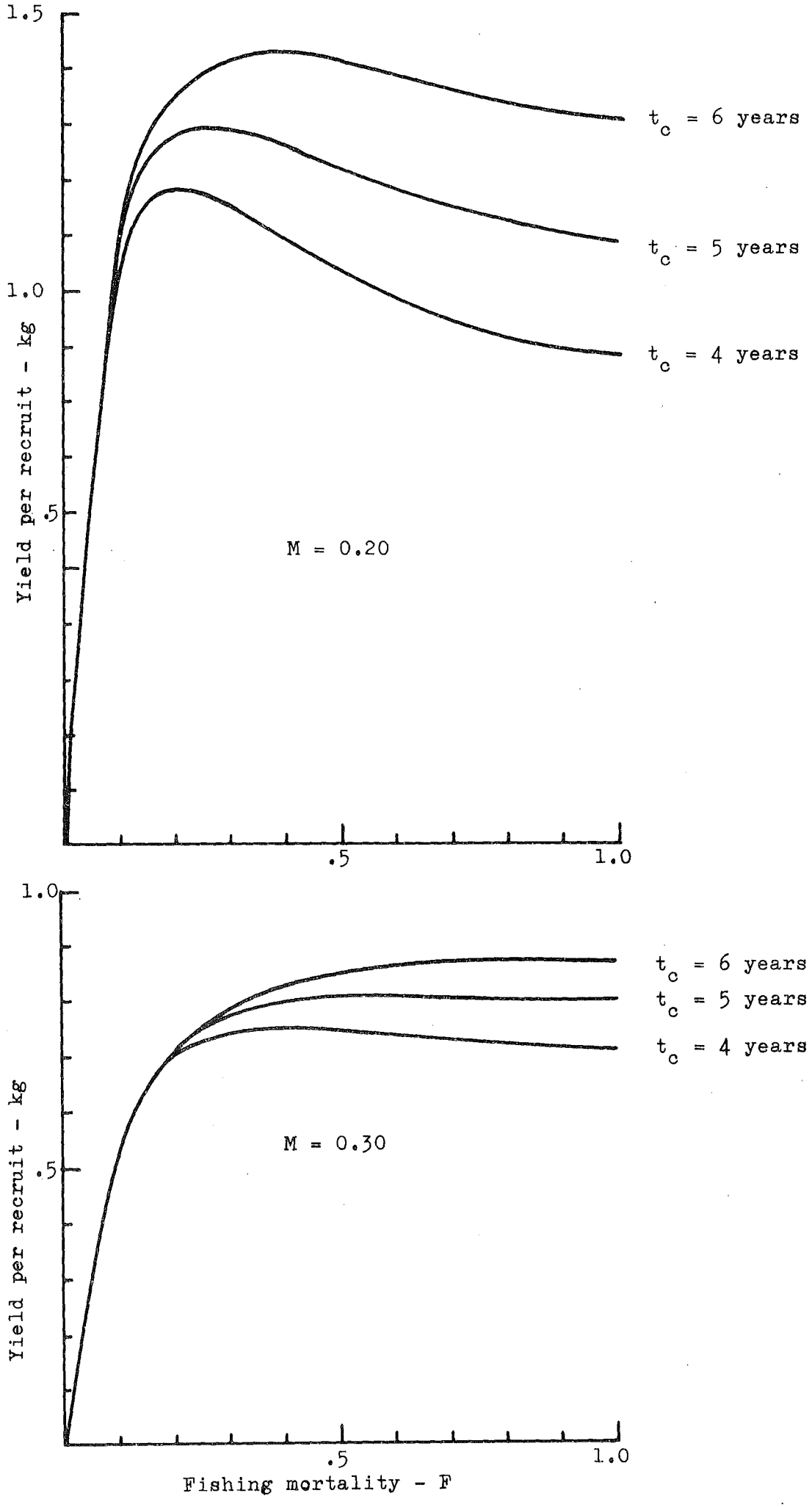


Figure 5. Cod. Yield per recruit curves for different ages at first capture (t_c). Knife-edge selection.

Figure 6. Haddock.
Yield per recruit curves for different ages at first capture (t_c). Knife-edge selection. M = 0.2.