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Stock Size of Cod at West Greenland by the Beginning of 1984
and Projections of Yield and Stock Size 1984-87

by

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INTRODUCTION

In the assessment of cod in Subarea 1 in years prior to 1983, virtual population analyses (VPA) were carried out on the basis of catch-by-age figures and estimates of last year's fishery mortality (terminal F), the latter generally estimated on the basis of catch curves and trends in catch per unit effort. In the analyses carried out in 1983 the Scientific Council did, however, base its VPA and projections on stock estimates (minimum trawlable biomass) from a trawl survey carried out by the Federal Republic of Germany in November-December 1982 since the stock estimate from this survey was regarded a better starting point for the VPA than a very uncertain terminal-F value.

Again in November-December 1983, the Federal Republic of Germany carried out an extensive trawl survey off West Greenland. The conduct of the two surveys as to area coverage, timing, vessel and fishing gear was the same in the two years. Details and results of the survey are given in (SCR Doc. 84/VI/93).

Comparison between survey results in 1982 and 1983

Comparison between the two surveys indicates a substantial reduction during 1983 of the estimated minimum trawlable biomass by about 45% from about 180,000 tons to about 99,000 tons. In terms of stock numbers the decline was from 109 million fish to 59 million. The reduction for year-classes prior to 1979 was especially pronounced, from 71 to 21 million fish.

The information of catch rate from the commercial fishery in 1983 (NAFO SCR Doc. 84/VI/78) seems to confirm a decline of the stock biomass throughout 1983 of about the same magnitude (38%) as found by the trawl survey. The age composition of the catches likewise confirm that the decline is mainly on older fish.

The decline in stock as observed by the surveys is not fully explained by the numbers by age fished during 1983 and by losses due to natural mortality and emigration when the latter is calculated by an instantaneous coefficient $E = 0.05$ as in previous years.

It should be recalled that stock estimates based on survey results have a wide confidence interval. The 95% confidence interval for the biomass estimates for the two surveys is $\pm 37\%$ and $\pm 28\%$, respectively.

It could also not be excluded that due to the unusual hydrographic situations in 1983 (NAFO SCR Doc. 84/VI/59) the distribution of cod in Greenland waters might have changed, especially in the last part of the year, compared to the previous year.

In previous assessments it was indicated that migration from West to East Greenland and Iceland may vary between years and year-classes. A quantification of the emigration from West Greenland during 1983 may be made on the basis of the two surveys mentioned and on the analyses carried out for the East Greenland cod stock.

Table 1 shows the analyses for age-group 5 and older fish when for these age groups it is supposed that the difference between the two survey biomass estimates is fully explained by the catch at West Greenland during 1983, a natural mortality of $M = 0.20$ and emigration. Referring to the columns in the table, the following figures were obtained:

A. Stock numbers at the beginning of 1983 from the November-December 1982 survey.....	71.3 million
E. Catch numbers 1983	22.5 "
F. Losses due to natural mortality	8.1 "
H. Calculated losses due to emigration (difference between survey stock - (E+F))	19.6 "
B. The resultant stock by the end of 1983 (= stock from the 1983 survey)	21.1 "

The number of emigrants found through this assumption corresponds to an instantaneous emigration coefficient of 0.47 (Column G) from West to East Greenland from age 5 and onwards.

From the assessments carried out for East Greenland cod by the ICES Working Group on cod stocks at East Greenland (ICES C.M. 1984/Assess:5) it was estimated that during 1983 an immigration from West Greenland of 6.4 million cod of age 6 and older could have taken place, see Table 2, last column. If that number is taken as the true figure then there remains an explanation for about 13.1 million cod in the difference between the two survey stocks. If that number did not emigrate one would have to adopt either a higher natural mortality than $M = 0.20$ or to accept either that the 1982 survey stock was overestimated or that of 1983 underestimated (or any combination of these possibilities).

Taking the stock estimate from last survey as basis for the projections of catch and stock size, lower and upper estimates of the stock by the beginning of the year were taken as the observed survey stock (59 million fish) and the same stock with the addition of the 13.1 million fish, respectively. The latter assumption would incorporate adoption of an emigration rate of E about 0.14 (Table 1, last line), which is close to the value of 0.15 previously used for Div. 1E-1F cod separately. Projections were also carried out for a value of $E = 0.30$ (the level found by the ICES North Western Working Group for Div. 1E-1F and East Greenland combined).

When adding the 13.1 million fish to those observed in the survey it was found that although Table 1 allows for addition in each age-group individually, a better approach was to upgrade the age-groups by the same proportion considering the most recent information on the age composition of the stock.

Weight-by-age. Figures used are those given in NAFO SCR Doc. 84/VI/78, and are shown in Table 3.

Partial-F values were taken as in last year's assessment and are shown in Table 3.

Natural mortality is taken as previously to be $M = 0.20$ except for age-group 3 for which a figure of 0.30 is used to take possible discarding of small fish into account.

Figures for recruitment are found in Table 3. In relation to figures estimated last year, the figures for year-class 1982 has been reduced from 200 million fish at age 3 to 150 million. This is a precautionary step taken due to the extreme winters after the year-class was born and due to the fact that the year-class still has to be confirmed as a strong year-class. Year-classes 1983 and 1984 are both taken as poor year-classes (20 million fish at age 3).

Request for advice by the EEC (NAFO SCS Doc. 84/VI/3)

The EEC has requested projections of catches up to and including 1987 (1988 for the spawning stock) for a number of specified management options and has informed that the agreed TAC for 1984 is 68,500 tons. The projections are, therefore, generally given on the assumption that the catch in 1984 amounts to the TAC. The analyses shows, that such a catch can be obtained only if F -values are well above the $F_{0.1}$ on the yield per recruit curve (Fig. 1). By an emigration rate of $E = 0.15$, the F value to achieve the TAC also exceeds the F_{max} . However, amongst the options requested is a constant catch from 1985 and onwards equal to that in 1984 if the stock were fished at $F_{0.1}$ in 1984. The analyses indicate $F_{0.1} = 0.27$ by $E = 0.15$ and $F_{0.1} = 0.39$ by $E = 0.30$. In addition to the options requested also projections for a steady $F_{0.1}$ level from 1984 and onwards are given.

In addition to the TAC management options the EEC has requested advice of the affects of increasing the mesh size from the existing regulations 130 mm to 140 mm, 150 mm and 160 mm respectively, indicating that from September 1984 Greenland fishermen will use 140 mm mesh size.

RESULTS

The parameters used in the forecasts are set up in Table 3. The results for the various options are presented in Table 4 with direct survey stock, and Table 5 with adjusted survey stock. In both tables the results are given with $E(6+) = 0.15$ and 0.30 .

The results are illustrated graphically in Figure 2a and 2b.

The following remarks are made: The spawning stock biomass by January 1984 as estimated from the 1983 survey is between 60 and 92 thousand tons, and only a complete stop of the fishery from 1985 and onwards brings it close to the 175 thousand tons (by 1988) used as reference by the EEC as one of the options.

Maintaining the $F_{0.1}$ level from 1985, allowing for a catch of 68,500 tons in 1984, shows a catch range for 1985 of 22-37 thousand tons and a spawning stock by 1988 of 65-106 thousand tons.

If the TAC of 68,500 tons for 1984 is not taken, the projected figures will be somewhat improved. The estimates of catches in 1984 corresponding to the $F_{0.1}$ level range between 29 and 49 thousand tons. Revisions of recruitment estimates will, of course, also influence the projections.

Remarks regarding VPA

The possibility of comparing minimum trawlable biomass estimates in two consecutive years offers the possibility of estimating emigration rates compared with a standard emigration rate, as was done in this paper. This does however, to some extent, restrict the usefulness of VPA's based on a standard emigration coefficient to indicate trends in stock size and fishing mortality only in a more general way. Therefore, a VPA starting with the 1983 catches has not been prepared, and the VPA in the assessments carried out last year (NAFO SCR Doc. 83/VI/60 revised) might still describe the trends in the stock with the restrictions mentioned above.

For future reference, however, the catch-at-age matrix for the years 1965-83 is given in Table 6.

References

- GALLAGHER, E. MS 1984. EEC request for scientific advice on management in 1985 of certain stocks in NAFO Subareas 0 and 1. NAFO SCS Doc. 84/VI/3, Serial No. N782, 1 p.
- HORSTED, Sv. Aa. MS 1984. Subarea 1 cod: fisheries and stock composition, 1983. NAFO SCR Doc. 84/VI/78, Serial No. N867, 14 p.
- HORSTED, Sv. Aa., J. MESSTORFF, and A. SCHUMACHER. MS 1983. Status of Subarea 1 cod and estimates of stock and yield for 1983-85. NAFO SCR Doc. 83/VI/60, Serial No. N719, 43 p.
- MESSTORFF, J., and H. P. CORUNG. MS 1984. Subarea 1 cod: results of research vessel survey conducted off West Greenland in 1982 and 1983. NAFO SCR Doc. 84/VI/93, Serial No. N884, 13 p.
- STEIN, M., and E. BUCH. MS 1984. 1983: an unusual year off West Greenland. NAFO SCR Doc. 84/VI/59, Serial No. N847, 18 p.

Table 1. West Greenland cod (NAFO Subarea 1).

Age (yr)	Year-class	Stock size (000)		1983		1983 catch (000)	1983		1983 losses (000) due to		Gains from E.G. ¹	Net loss of immigrants
		1 Jan 1983	31 Dec 1983	Z	F		M	E	M	E		
5	1978	10,821	4,895	0.793	0.269	2,011	0.2	0.325	1,494	2,428	-	2,428
6	1977	38,789	12,413	1.139	0.744	17,228	0.2	0.195	4,631	4,515	3,256	1,259
7	1976	13,618	1,996	1.920	0.261	1,581	0.2	1.460	1,210	8,837	1,818	7,019
8	1975	4,754	1,121	1.445	0.396	995	0.2	0.850	530	2,137	600	1,537
9	1974	1,047	359	1.070	0.534	344	0.2	0.330	129	212	404	-192
10	1973	2,006	226	2.183	0.420	343	0.2	1.560	163	1,272	313	959
11+	≤1972	224	28	2.079	0.486	46	0.2	1.580	19	149	13	136
Total		71,259	21,038	1.220	0.546	22,548	0.2	0.474	8,149	19,550	6,404	13,146
Total (6+)		60,438	16,443	1.302	0.601	20,537	0.2	0.501	6,655	17,122	6,404	10,718
Total (6+) ²		60,438	27,161	0.800	0.457	20,537	0.2	0.143	6,336	6,404	6,404	-

¹ Estimated emigrants from East Greenland assessment.

² Corrected for underestimate.

Table 2. East Greenland cod (from ICES C.M. 1984/Assess:5, table 9). (Stock size and catch numbers in thousands of fish.)

Year-class	Age (yrs)	1982		Age (yrs)	1983			1984 calc. stock 1 Jan ² (B)	(B)-(A)
		Survey results Sep-Oct	Catch Nov-Dec		Calc. stock 1 Jan ¹ (A)	Survey results Sep-Oct	Catch Jan-Oct		
1979	3	495	-	4	479	846	93	1,101	622
1978	4	1,029	-	5	996	997	571	1,795	799
1977	5	1,295	4	6	1,249	1,784	2,230	4,505	3,256
1976	6	913	25	7	859	1,080	879	2,677	1,818
1975	7	279	137	8	126	254	289	726	600
1974	8	105	51	9	48	222	98	452	404
1973	9	1,462	566	10	806	590	192	1,119	313
1972	10	142	49	11	84	58	8	97	13
1971	11	73	2	12+	110	47	3	74	-
1970	12+	48	-						
<age 7		M = 0.033			M = 0.167				
≥age 7		E&M = 0.082			E&M = 0.408				

¹ From 1982 survey results.

² From 1983 survey results.

Table 3. Subarea 1 cod: parameters used in catch projections, with $M = 0.2$ and recruitment at age 3 as listed below¹.

Age (yr)	Stock size 1 Jan 1984 direct ² (000)	Stock size 1 Jan 1984 adjusted ³ (000)	Relative natural mortality (M) for		Mean weight at age (kg)	Percent maturity	Relative fishing mortality (F)
			E=0.15	E=0.30			
3	20,000	20,000	1.50	1.50	0.78	1	0.039
4	54,407	54,407	1.00	1.00	0.98	3	0.520
5	33,245	33,245	1.00	1.00	1.38	15	1.000
6	4,895	7,954	1.75	2.50	2.08	48	1.000
7	12,412	20,170	1.75	2.50	2.95	83	1.000
8	1,996	3,243	1.75	2.50	3.85	96	1.000
9	1,121	1,821	1.75	2.50	4.78	99	1.000
10	359	583	1.75	2.50	5.58	100	1.000
11	226	367	1.75	2.50	6.00	100	1.000
12	1	2	1.75	2.50	6.70	100	1.000
13	6	10	1.75	2.50	7.30	100	1.000
14	16	26	1.75	2.50	7.70	100	1.000
15+	5	7	1.75	2.50	8.00	100	1.000

¹ Recruitment at age 3: 150 million fish in 1985, and 20 million fish in both 1986 and 1987.

² Direct estimates from 1983 survey.

³ Adjusted estimates from 1983 survey.

Table 4. Subarea 1 cod: projections of spawning stock biomass (SSB) at the beginning of each year and catch during the year for various management strategies. Population numbers at the beginning of 1984 are based on direct results of 1983 survey.

Management options	F(1985-87) = F _{0.1}		F(1985-87) = F _{max}		F(1985-87) = F(1982)		SSB> 175,000 t		Catch(85-87) = 68,500 t		Catch(85-87) at F _{0.1} (84)1		F(84-87) = F _{0.1} (84-87)	
	0.15	0.30	0.15	0.30	0.15	0.30	0.15	0.30	0.15	0.30	0.15	0.30	0.15	0.30
1984 SSB ²	60	60	60	60	60	60	60	60	60	60	60	60	60	60
F	0.772	0.800	0.772	0.800	0.772	0.800	0.772	0.800	0.772	0.800	0.772	0.800	0.273	0.392
Catch ²	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	29.4	39.2
1985 SSB	46	41	46	41	46	41	46	41	46	41	46	41	72	59
F	0.273	0.392	0.642	1.000	0.340	0.340	0	0	1.010	1.145	1.172	1.335	0.273	0.392
Catch	22.4	28.2	45.5	57.4	27.2	25.0	0	0	62.5	62.5	68.5	68.5	32.1	37.4
1986 SSB	58	45	41	26	54	47	75	64	30	23	26	20	85	61
F	0.273	0.392	0.642	1.000	0.340	0.340	0	0	0.950	1.087	1.179	1.353	0.273	0.392
Catch	31.6	37.6	54.3	61.8	37.0	34.1	0	0	62.5	62.5	68.5	68.5	38.9	43.1
1987 SSB	72	50	41	22	64	54	113	93	26	19	20	15	95	61
F	0.273	0.392	0.642	1.000	0.340	0.340	0	0	1.124	1.418	1.180	2.650	0.273	0.392
Catch	39.0	43.8	55.7	54.8	44.2	40.7	0	0	62.5	62.5	68.5	68.5	44.1	46.8
1988 SSB	95	65	45	21	82	72	174	145	21	14	10	4	111	70

¹ Catch in 1985-87 = hypothetical catch at F_{0.1} in 1984.

² SSB and catch values in thousands of tons.

Table 5. Subarea 1 cod: projections of spawning stock biomass (SSB) at the beginning of each year and catch during the year for various management strategies. Population numbers at the beginning of 1984 are based on adjusted results of 1983 survey.

Management options	F(1985-87) = F _{0.1}		F(1985-87) = F _{max}		F(1985-87) = F(1982)		SSB ² 175,000 t		Catch(85-87) = Catch (83)		Catch(85-87) = 68,500 t		Catch(85-87) at F _{0.1} (84)		F(84-87) = F _{0.1} (84-87)	
	0.15	0.30	0.15	0.30	0.15	0.30	0.15	0.30	0.15	0.30	0.15	0.30	0.15	0.30	0.15	0.30
1984 SSB ²	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
F	0.561	0.586	0.561	0.586	0.561	0.586	0.561	0.586	0.561	0.586	0.561	0.586	0.561	0.586	0.273	0.392
Catch ²	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	37.5	49.4
1985 SSB	75	66	75	66	75	66	75	66	75	66	75	66	75	66	98	79
F	0.273	0.392	0.642	1.000	0.340	0.340	0	0	0.665	0.763	0.752	0.870	0.350	0.555	0.273	0.392
Catch	30.2	37.1	61.0	75.1	36.6	32.9	0	0	62.5	62.5	68.5	68.5	37.5	49.4	37.7	42.8
1986 SSB	81	61	57	35	76	64	105	88	56	43	52	39	76	52	103	71
F	0.273	0.392	0.642	1.000	0.340	0.340	0	0	0.660	0.790	0.790	0.955	0.291	0.516	0.273	0.392
Catch	37.1	42.5	61.8	67.2	43.2	38.7	0	0	62.5	62.5	68.5	68.5	37.5	49.4	42.6	45.9
1987 SSB	89	59	49	25	79	64	142	113	47	33	40	28	82	48	106	66
F	0.273	0.392	0.642	1.000	0.340	0.340	0.1	0	0.710	0.914	0.950	1.290	0.248	0.491	0.273	0.392
Catch	42.6	46.3	59.2	56.3	48.0	43.2	23.2	0	62.5	62.5	68.5	68.5	37.5	49.4	46.4	48.1
1988 SSB	106	69	48	22	91	77	180	160	44	29	31	18	103	56	118	73

1 Catch in 1985-87 = hypothetical catch at F_{0.1} in 1984.

2 SSB and catch values in thousands of tons.

Table 6. Subarea 1 cod: catch-at-age, 1965-83

Age	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
3	14,163	1,530	1,727	3,764	662	49	272	15	131	334
4	56,928	7,872	15,091	7,976	12,399	2,768	2,519	10,039	2,302	1,079
5	52,451	62,130	30,457	36,670	8,709	10,342	10,172	9,786	16,378	2,384
6	9,055	39,941	61,848	29,824	27,433	6,465	9,283	12,020	3,065	6,938
7	9,890	5,915	24,562	34,591	14,664	13,985	5,237	4,081	2,605	1,135
8	15,395	4,955	2,700	10,005	12,411	4,365	9,158	2,550	1,406	1,806
9	2,849	6,912	1,996	1,725	4,784	2,810	2,077	2,660	1,203	800
10	566	1,289	5,237	833	513	1,280	1,841	624	552	194
11	488	283	352	2,348	237	149	953	954	165	177
12	1,911	130	93	187	704	85	78	709	237	152
13	75	981	166	37	41	201	51	130	93	272
14	37	139	453	42	62	27	134	57	37	147
15+	276	247	85	303	8	41	56	122	44	11
	164,084	132,324	144,767	128,305	82,627	42,567	41,831	43,747	28,218	15,438

Age	1975	1975	1977	1978	1979	1980	1981	1982	1983
3	275	10,760	634	287	286	2,999	12	1,204	77
4	3,595	4,026	46,649	5,494	10,656	4,513	16,864	1,210	12,356
5	2,677	2,243	6,053	30,039	12,505	4,580	6,374	17,960	2,011
6	1,803	1,216	1,515	1,004	18,970	1,978	2,391	2,965	17,228
7	5,855	302	618	509	709	8,014	1,053	2,078	1,581
8	1,388	1,594	425	83	400	125	3,382	807	995
9	619	139	446	41	78	60	45	610	344
10	291	148	168	13	52	24	65	45	343
11	84	53	79	7	55	1	1	88	3
12	38	27	88	7	80	16	1	9	22
13	9	17	22	7	5	3	0	4	0
14	12	14	1	1	5	1	0	1	2
15+	10	26	1	1	16	2	7	13	19
	16,656	20,565	56,699	37,493	43,817	22,316	30,195	26,994	34,981

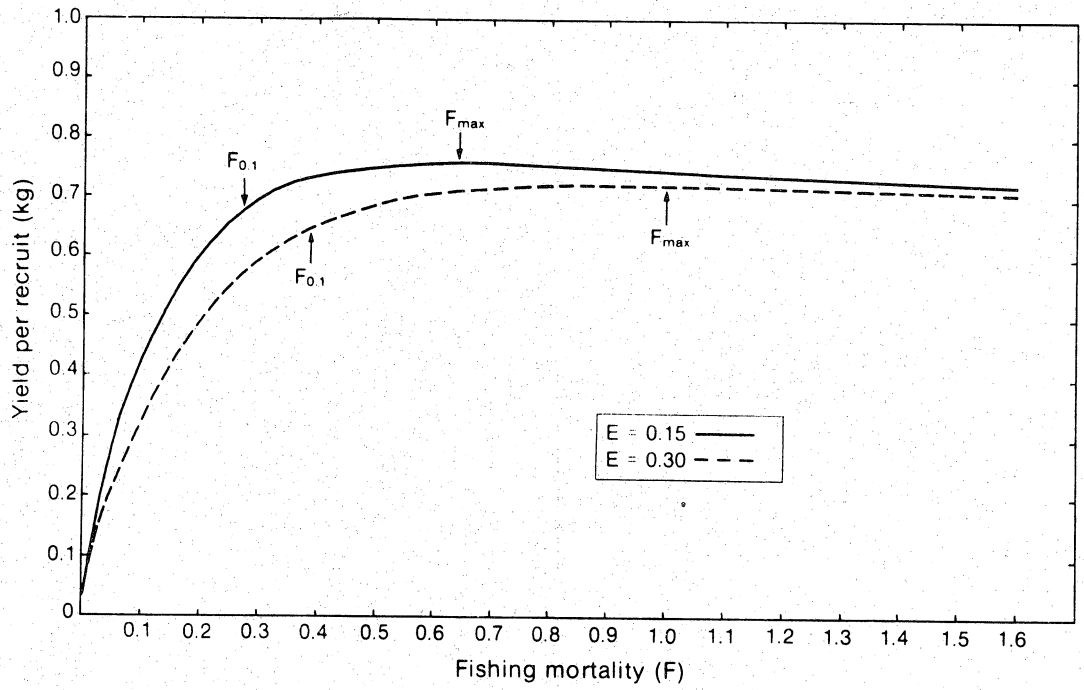


Fig. 1. Subarea 1 cod: yield-per-recruit.

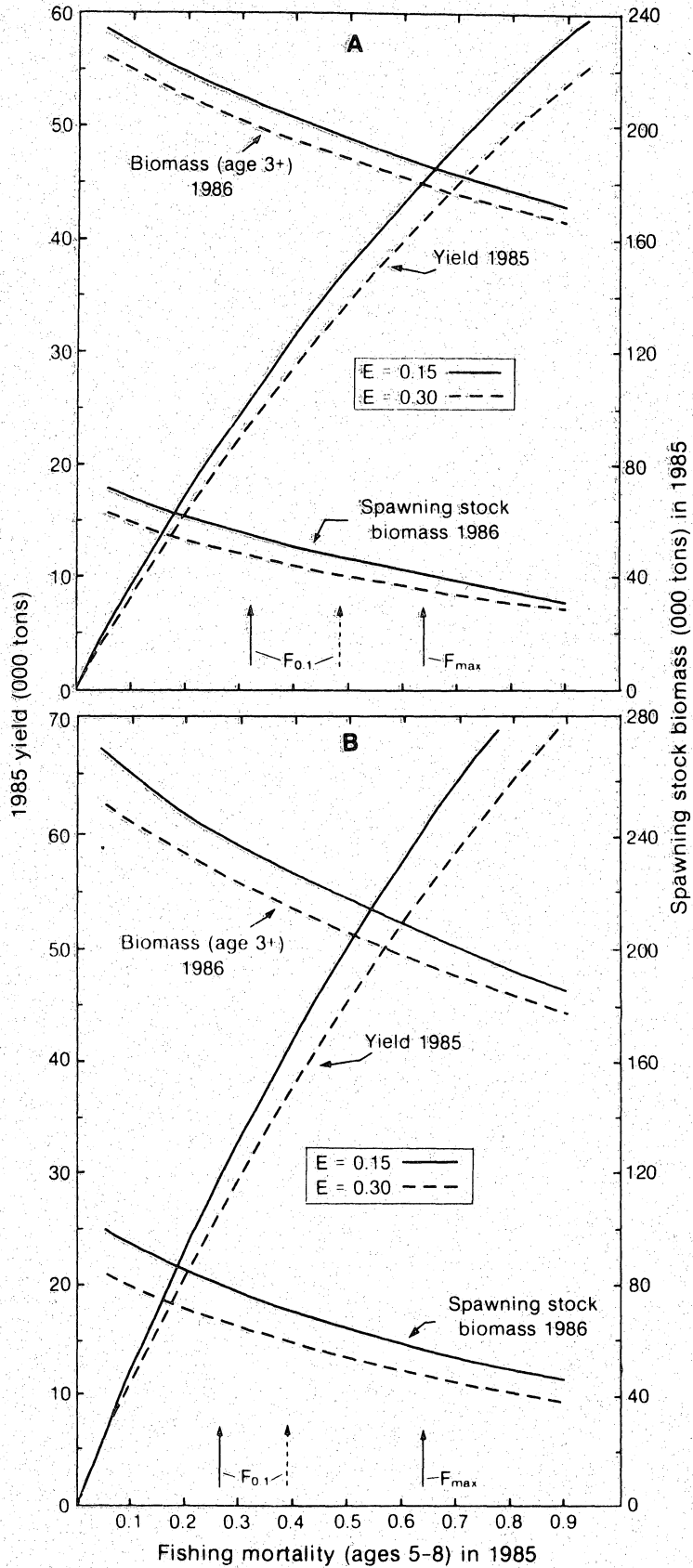


Fig. 2. Subarea 1 cod: estimated yield in 1985, biomass (3+) and resultant spawning stock biomass by January 1986 for various levels of fishing mortality in 1985, assuming the 1984 catch to be 68,500 tons.