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**COD OFF THE COAST OF FINLAND IN 1974—82**

by

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Abstract

The increase in the cod catch in the northern Baltic (Sub-divisions 29-32) has been due to an increase in the stock. The abundance of cod was highest off the Finnish coast in 1978 and the biomass was highest in 1980. The catch reached a peak in 1982 (8126 t) in Finland. Smaller catches are predicted for 1983 and 1984. The total instantaneous mortality rate for 1974-82, calculated from the age distribution, was  $Z = 1.15$  in age groups 3-10, and the instantaneous emigration rate for adult cod was  $E = 0.40$ . From the tagging data it could be concluded that only 25 % of the recaptures are reported. Of the reported recaptures, about 47 % have been made outside the Finnish fishing zone.

Résumé

L'accroissement des prises de morue dans la Baltique septentrionale (sous-division 29-32) est dû à une augmentation du stock. L'abondance de la morue était maximale au large de la côte finlandaise en 1978 et la biomasse était à son plus haut point en 1980. Les prises atteignirent un pic en Finlande en 1982 (8126 t). De plus petites prises sont prédites pour 1983 et 1984. Le taux de mortalité instantanée total pour les années 1974-1982, calculé à partir de la distribution d'âge, était de  $Z = 1.15$  dans les groupes d'âge 3-10 et le taux d'émigration instantanée pour la morue adulte était de  $E = 0.40$ . À partir des données de marquages on a pu conclure que seulement 25 % des recaptures sont signalées. Environ 47 % des recaptures signalées ont été prises en dehors des zones de pêche finlandaises.

## Introduction

The abundance of cod in the northern Baltic increased in the late 1970's and at the beginning of the 1980's. Earlier, the total catches in sub-divisions 29-32 were insignificant, but at present they are at the same level as the catches in sub-divisions 22 and 24 in the southern Baltic (Anon. 1983), having reached a peak in 1980 (about 26 000 tonnes, Table 1). The increased catches off the coast of Finland in the late 1970's and at the beginning of the 1980's were largely caused by the very abundant year classes 1976, 1977 and 1980. In 1980 the total catch of cod in Finland was about fifty times that in 1974. The higher catches were due to the higher recruitment of cod larvae and immature cod from the central and southern Baltic to the fishable stock in the northern Baltic. At maturation these cod start to migrate to the spawning grounds in the central and southern Baltic, which also causes fluctuations in the abundance of cod in the northern Baltic. Estimates of the cod stock off the coast of Finland could be used for assessing the number of recruits joining the exploitable stock in the central and southern Baltic, for predicting the short-term yield off the coast of Finland and for assessing the effects of the cod stock on the Baltic herring and sprat populations.

## Material and methods

In all, 11 617 cod were sampled from pelagic and bottom trawl by-catches, salmon long lines and commercial gillnet catches in Finland in 1974-82. The majority of the samples were taken in the autumn. The cod were measured and weighed, and their age determined from the otoliths. The total instantaneous mortality rate in age groups 3-10 was estimated from the age distribution by the method presented by ROBSON & CHAPMAN (1961). To estimate the emigration rate from the northern Baltic to the central and southern Baltic, a total of 6425 cod were tagged in the Åland Islands and in the western part of the Gulf of Finland in 1974-78. A more detailed description of the taggings is given by SJÖBLOM et al. (1980). The total instantaneous mortality rates were estimated from taggings, the annual survival and mortality rates being assumed to be independent of the year (PAULIK 1962). The reciprocal of the slope of the regression of force of total mortality on force of reported fishing mortality was used to estimate the percentage of tags returned from tagged fish which are caught (YOUNGS 1974). For the VPA all

the catches in the years 1974-82 were divided according to the age distribution of the samples, using the mean weights at age in each year. The instantaneous natural mortality rate was taken as  $M = 0.30$ , the value adopted by the Working Group on Assessment of Demersal Stocks in the Baltic for sub-divisions 25-32 (Anon. 1983). The instantaneous emigration rate  $E = 0.40$ , based on reported recoveries of Finnish taggings, was used for maturing and mature cod (age groups 3 and older) in the VPA. The rate of immigration of adult cod into sub-divisions 29-32 was considered to be negligible and disregarded. On the basis of the mean total instantaneous mortality rate estimated from the age distribution in 1974-82,  $Z = 1.15$  (age groups 3-10), and the given  $M$  and  $E$  values, the final  $F = 0.40$  was selected for the years 1974-82. For catch predictions for the years 1983 and 1984, the year class 1982 was considered to be below average (Anon. 1983) and the 1983 year class average. For 1983 the predicted value of  $35\,000 \times 10^3$  one-year-old cod was used and for 1984 the average value from the years 1974-80,  $45\,600 \times 10^3$ . The fishing mortalities for 1983 and 1984 were assumed to be at the same level as that selected for the VPA in 1982. The mean weights at age for the years 1974-82 were used for the predictions.

## Results

The main part, about 75 %, of the Finnish cod catches in 1974-82 consisted of the age groups 2-4 (Table 7). In 1982 the total catch increased by about 40 % from that in 1981 (Table 1). In 1981 about 67 % was taken in commercial fishing. About 44 % of the commercial catch was taken as by-catches in herring trawls and trapnets, 29 % as mixed catches with gillnets and 13 % as by-catches on salmon long lines and 14 % in hook and line fishing. Catch and effort statistics on Finnish cod fishing in 1981 are given in Table 2.

The estimated survival rates varied between 0.16 and 0.63 in age groups 3-10. The lowest survival rate was observed in 1979 and the highest value in 1982. The corresponding instantaneous mortality rates indicate that, depending on the year, 34 % to 84 % of the specimens in age groups 3-10 die, emigrate or are removed from the stock off the coast of Finland (Table 3). According to taggings the mean annual survival rate was  $S = 0.41$  in 1974-78 and the total instantaneous mortality rate  $Z = 0.88$  (Table 4). The probability of tagged cod being recaptured and reported varied from 0.071 to 0.118. The regression of force of total mortality on reported force of fishing mortality is described by the equation  $Z = 4.023 R + 0.618$  and the reciprocal

of the slope of this equation shows that about 25 % of the recoveries are reported (Table 5). Of the total reported recaptures, approximately 47 % were made outside the Finnish fishing zone (Table 6). In the first year after tagging, the proportion of tagged individuals emigrating from the Finnish zone is about 34 %. The probability of recapture in the different sub-divisions of the Baltic in the five years following the first three months after tagging is:

Sub-div.	25	26	27	28	29	30	31	32
1st year	0.23	0.06	0.10	0.18	0.37	0.01	0.00	0.06
2nd year	0.36	0.07	0.20	0.21	0.14	0.00	0.00	0.02
3rd year	0.31	0.05	0.16	0.18	0.16	0.04	0.00	0.09
4th year	0.30	-	0.17	0.26	0.13	0.13	0.00	0.00
5th year	0.20	0.20	0.40	0.20	0.00	0.00	0.00	0.00
For the total period	0.27	0.06	0.14	0.19	0.27	0.01	0.00	0.05

According to the VPA, the unweighted mean total instantaneous fishing mortality rate for age groups 3-8 in 1974-81 was  $F = 0.10$  in sub-divisions 29-32 (Table 8). The VPA indicates that the size of the cod stock off the Finnish coast increased about five-fold from 1974 to 1978, and the biomass about eighteen-fold from 1974 to 1980 (Table 9). In 1981 the size of the stock decreased by about 38 % from that in 1980 due to the emigration of the strong year classes 1976 and 1977 and to the two weak year classes 1978 and 1979 in the northern Baltic.

Catch predictions for 1983 and 1984 are shown in Table 10. With the present exploitation pattern, the cod catch in Finland is expected to decrease by about 37 % in 1983 from the catch in 1982. In 1984 the total catch is predicted to decrease by approximately 55 % from the catch in 1982. In 1983 and 1984 the size of the stock will be about one and a half times that in 1982. The biomass of the stock is predicted to decrease by 28 % in 1983 and by 34 % in 1984 from that in 1982. The immigration from the northern Baltic (sub-divisions 29-32) to the main stock (sub-divisions 25-28) is estimated at  $4200 \times 10^3$  3-year-old and older cod in 1983 and  $2300 \times 10^3$  in 1984.

## Discussion

The main reason for the increase of cod catches in the northern Baltic in the 1970's and at the beginning of 1980's is the increase of stock size due to the strong year classes 1976, 1977 and 1980. The Finnish cod catch is mainly taken as a by-catch in the Baltic herring fishery and mixed fisheries for other species (SJOBLUM & PETTERSSON 1978, SJOBLUM & ARO 1979, 1980, ARO & SJOBLUM 1981, 1982a, 1982b, 1983). Although the total number of days on which cod were caught with the various types of gear has increased, this may be evidence of increasing stock size rather than increasing effort, because the total amount of fishing gear was already in operation before the cod stock started to increase. Cpue values also show that the cod has extended its distribution in the northern Baltic (ARO & SJOBLUM 1982c).

The total instantaneous mortality rates estimated from the age distribution data show great variation from year to year. The main reason for this is the fluctuation of year class abundance and the variation in the catch at age data (Table 7). However, the estimated mean total instantaneous mortality rate for the years 1974-82 agrees quite well with the figures obtained by BERNER & BORRMANN (1980),  $Z = 1.13$  for 1970-76, and by the Working Group on Assessment of Demersal Stocks in the Baltic (Anon. 1983),  $Z = 0.98$  for 1974-82.

The mean total instantaneous mortality rate estimated from our tagging data agrees very well with the figures estimated by the Working Group. Our mean total instantaneous mortality rate for age groups 3-8 (i.e. length groups from 30 cm to 85 cm) was  $Z = 0.88$  in 1974-78 and the estimate of the Working Group was  $Z = 0.90$  (Anon. 1983).

The unweighted mean instantaneous fishing mortality rate obtained by VPA,  $F = 0.10$  for age groups 3-8 in 1974-80, is evidence of very low exploitation of the cod stock off the coast of Finland. However, the estimates of  $F$  are strongly dependent on the rates of natural mortality and emigration. The changes in the size of the cod stock in sub-divisions 29-32 agree with the estimates for the main stock. In sub-divisions 25-32 the stock size in numbers was biggest in 1978 and the biomass in 1980, as in sub-divisions 29-32. The size of the stock has decreased since 1978 and the biomass since 1980. In the northern Baltic the relative decrease in size and biomass has been even greater.

The occurrence of cod in the northern Baltic seems to be connected with events in the Bornholm Basin and the Gotland Deep. The stock in the northern Baltic is evidently mainly recruited from spawning in the Bornholm Basin

and the southern part of the Gotland Deep during high inflow of sea water into the basins. Recruitment from spawning in the northern Baltic is unlikely or very weak because of the low salinity in sub-divisions 29-32. Emigration of adult cod from the northern Baltic to the central and southern Baltic has been clearly demonstrated (OTTERLIND 1962, KONDRATOVICH 1980, SJÖBLOM et al. 1980). Immigration of adult cod into sub-divisions 29-32 from the central and southern Baltic has not been observed (OTTERLIND 1962, 1966) or has been insignificant. OTTERLIND (1966) also attributes increased abundance of cod in the Åland Sea, Bothnian Sea and Gulf of Finland to the oxygen conditions in the Gotland Deep region, claiming that oxygen deficiency leads to large-scale northward migration of mainly young cod. If this is the case, there should have been northward migration in 1968-72 from the region of the Gotland Deep, because of the lack of oxygen in that area (ANDERSIN et al. 1979). Such migration was not noted and was not indicated by the cod catches in sub-divisions 29-32 (Anon. 1978). The immature cod are usually segregated from the adults, living nearer to the coast in order to avoid cannibalism (RILEY & PARNELL 1983). This segregation was also observed in March 1983 in the Baltic (O. BAGGE, pers. comm.).

From the dependence of the cod stock in the northern Baltic on events in the central and southern Baltic, we can conclude that if recruitment from the central and southern Baltic fails, the cod stock in sub-divisions 29-32 will decrease to one third of its original size within three years.

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Table 1. Total catch of cod in the northern Baltic (sub-divisions 29-32) in 1974-82 (tonnes) (Anon. 1983).

Sub-div.	Y e a r								
	1974	1975	1976	1977	1978	1979	1980	1981	1982
29	1086	1985	301	326	833	2923	7528	7481	8552
30	49	14	29	62	378	663	1396	1184	3037
31	1	1	1	1	6	22	49	19	80
32	75	180	195	165	1170	4492	17016	9512	11655
Total	1211	2180	526	554	2387	8100	25989	18196	23324
Finland	160	298	287	310	1437	2938	5962	5681	8126
Sweden	41	103	120	142	473	792	1310	1220	2394
U S S R	1010	1779	119	102	477	4370	18717	11295	12804

Table 2. Finnish cod fishing in 1981.

	Archipelago Sea, Åland Sea and northern Baltic proper (29)	Bothnian Sea (30)	Bothnian Bay (31)	Gulf of Finland (32)	Sub-division 29 - 32
Commercial fishing					
Gillnet (mixed fishing)					
Total number of fishing days .....	33494	22510	1839	14661	72504
Mean number of nets per fishermen .....	34.6	40.6	41.6	21.7	35.0
Total catch (t) .....	742	187	1	183	1113
Average daily catch per 10 nets in kg .....	6.7	2.4	0.1	5.9	4.9
Long line (by-catch)					
Total number of fishing days .....	2367	570	-	1265	4202
Mean number of hooks per fisherman .....	813	631	-	798	808
Total catch (t) .....	370	18	-	87	475
Average daily catch per 1000 hooks in kg ..	190	30	-	220	170
Hook and line					
Total catch (t) .....	436	6	-	106	548
Average daily catch in kg .....	135	74	-	263	147
Trapnet (by-catch)					
Number of nets .....	70	664	7	174	915
Total catch (t) .....	6	109	1	19	135
Herring bottom trawl (by-catch)					
Total catch (t) .....	853	75	2	358	1288
Average daily catch in kg .....	605	625	22	724	651
Pelagic herring trawl (by-catch)					
Total catch (t) .....	182	-	2	46	230
Average daily catch in kg .....	406	-	20	43	286
Total commercial catch (t) .....	2589	395	6	799	3789
Non-commercial catch (t) .....	447	289	5	1151	1892
Total catch (t) .....	3036	684	11	1950	5681

Table 3. The survival ( $\hat{S}$ ) and the total instantaneous mortality ( $\hat{Z}$ ) rates of cod in Finland in 1974-82 calculated from the age distribution (age groups 3-10).

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982
$\hat{S}$	0.30	0.52	0.49	0.38	0.21	0.16	0.24	0.57	0.63
95 % conf. interval of $\hat{S}$	0.26- 0.33	0.49- 0.54	0.45- 0.53	0.33- 0.42	0.18- 0.24	0.14- 0.18	0.22- 0.26	0.55- 0.58	0.62- 0.64
$\hat{Z}$	1.21	0.66	0.72	0.98	1.56	1.85	1.42	0.57	0.46
95 % conf. interval of $\hat{Z}$	1.09- 1.33	0.61- 0.71	0.64- 0.80	0.86- 1.10	1.40- 1.72	1.71- 1.98	1.34- 1.50	0.55- 0.60	0.44- 0.48
$\hat{Z}$ interval from $\hat{S}$	1.10- 1.34	0.61- 0.71	0.64- 0.81	0.87- 1.11	1.42- 1.74	1.73- 1.99	1.35- 1.50	0.54- 0.60	0.44- 0.48

Table 4. The survival ( $\hat{S}$ ) and total instantaneous mortality ( $\hat{Z}$ ) rates of cod calculated from the taggings made in Finland in 1974-78.

Year of tagging	Number tagged	Number of recaptures (years after tagging)						Total	$\hat{S}$	$\hat{Z}$
		1	2	3	4	5	6			
1974	416	21	12	4	3	-	1	41	0.43	0.83
1975	1214	60	35	9	4	1	-	109	0.39	0.93
1976	1000	53	13	8	1	2	-	77	0.35	1.05
1977	1589	83	22	15	10	2	-	132	0.41	0.89
1978	2206	33	18	19	5	-	-	75	0.49	0.72
Total	6425	250	100	55	23	5	1	434	0.41	0.88

Table 5. Reported expectation of death from fishing ( $\hat{F}$ ), reported force of fishing mortality ( $\hat{R}$ ), survival ( $\hat{S}$ ) and force of total mortality ( $\hat{Z}$ ) for cod tagged in 1974-79.

Year	$\hat{F}$	$\hat{R}$	$\hat{S}$	$\hat{Z}$
1974-75	0.050	0.073	0.426	0.834
1975-76	0.049	0.075	0.390	0.933
1976-77	0.053	0.085	0.345	1.049
1977-78	0.052	0.078	0.407	0.892
1978-79	0.015	0.021	0.485	0.720

$$\hat{Z} = 4.023 R + 0.618 \quad r = 0.854 \quad 24.9 \% \text{ of recaptures reported}$$

Table 6. The recaptures of cod reported in the different years and sub-divisions in 1974-82. Taggings made in subdivisions 29 and 32 in 1974-78. (\* = tagging place)

Year of tagging	Number tagged	Number of reported recaptures										Total
		Sub-div.	1974	1975	1976	1977	1978	1979	1980	1981	1982	
1974	416	32*	4	14	-	-	-	-	-	-	-	18
		30	-	-	-	-	-	-	-	-	-	-
		29	-	-	1	-	-	-	-	-	-	1
		28	-	4	6	1	1	-	-	-	-	12
		27	-	-	-	1	-	-	-	-	-	1
		26	-	-	1	2	-	-	-	-	-	3
		25	-	3	4	-	2	-	1	-	-	10
1975	1214	32*	-	7	-	-	-	-	-	-	-	7
		30	-	-	-	-	-	-	-	-	-	-
		29*	-	27	19	1	1	1	-	-	-	49
		28	-	-	9	6	3	2	-	-	-	20
		27	-	-	6	4	1	1	-	-	-	12
		26	-	-	6	6	-	-	-	-	-	12
		25	-	-	20	18	4	-	1	-	-	43
1976	1000	32	-	-	-	-	-	-	-	-	-	-
		30	-	-	-	1	-	-	1	-	-	2
		29*	-	-	10	19	4	2	-	-	-	35
		28	-	-	-	12	2	2	-	-	-	16
		27	-	-	-	2	4	1	-	1	-	8
		26	-	-	-	5	-	-	-	1	-	6
		25	-	-	-	14	3	3	-	-	-	20
1977	1589	32	-	-	-	-	1	1	2	-	-	4
		30	-	-	-	-	-	-	-	1	-	1
		29*	-	-	-	51	41	6	2	1	-	101
		28	-	-	-	-	12	4	4	2	1	23
		27	-	-	-	1	14	7	3	2	1	28
		26	-	-	-	-	1	-	1	-	-	2
		25	-	-	-	-	14	4	3	4	-	25
1978	2206	32	-	-	-	-	-	-	1	3	-	4
		30	-	-	-	-	-	-	-	2	1	3
		29*	-	-	-	-	81	13	2	4	1	101
		28	-	-	-	-	-	7	3	-	1	11
		27	-	-	-	-	-	4	5	3	1	13
		26	-	-	-	-	-	3	-	-	-	3
		25	-	-	-	-	-	6	7	7	1	21

Table 7. Age distribution in numbers (thousands) of total catch of cod in Finland in 1974-82 (Sub-divisions 29-32).  
Input catch data for VPA.

Age group	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	9	3	13	53	585	102	62	524	46
2	311	18	24	81	1876	2579	1095	592	781
3	141	71	114	146	1171	3029	4354	1195	1476
4	32	85	69	86	135	639	1354	1407	1093
5	0	45	37	35	69	25	205	973	1238
6	0	10	19	2	15	0	36	397	986
7	0	3	6	0	10	0	4	143	499
8	0	1	2	3	3	0	11	32	112
9	0	1	0	0	3	0	7	21	32
10	0	0	0	1	0	0	0	5	7
Total	493	237	284	407	3867	6374	7128	5289	6270
Total catch (t)	160	298	287	310	1437	2938	5962	5681	8126

Table 8. Fishing mortalities of cod in Finland in 1974-82 from VPA ( $M = 0.3$ ;  $E = 0.4$  in age groups 3 and older).

Age group	1974	1975	1976	1977	1978	1979	1980	1981	1982	1974-80
1	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.08	0.01	0.04
2	0.04	0.00	0.00	0.00	0.04	0.08	0.10	0.08	0.15	0.04
3	0.07	0.01	0.02	0.01	0.05	0.11	0.26	0.20	0.30	0.08
4	0.09	0.10	0.03	0.03	0.02	0.05	0.11	0.21	0.40	0.06
5	0.00	0.34	0.09	0.03	0.04	0.01	0.04	0.19	0.40	0.08
6	0.00	0.10	0.42	0.01	0.03	0.00	0.03	0.15	0.40	0.08
7	0.00	0.22	0.13	0.00	0.11	0.00	0.01	0.23	0.40	0.07
8	0.00	0.40	0.40	0.15	0.40	0.00	0.08	0.19	0.40	0.21
9	0.00	0.40	0.00	0.00	0.40	0.00	0.40	0.40	0.40	0.17
10	0.00	0.40	0.00	0.00	0.40	0.00	0.40	0.40	0.40	0.17
F (3-8), U	0.03	0.19	0.08	0.04	0.11	0.03	0.09	0.20	0.38	



Table 9. Size of cod stock (thousands) and the biomass (tonnes) in Finland in 1974-82 according to VPA.

Age group	1974	1975	1976	1977	1978	1979	1980	1981	1982	1974-80
1	20329	35850	78246	87882	60409	21356	15177	9333	5350	45607
2	9729	15052	26556	57955	65059	44251	15734	11191	6466	33476
3	4300	6941	11136	19652	42865	46590	30574	10719	7783	23151
4	323	2038	3398	5451	9658	20479	21056	12214	4506	8914
5	149	139	954	1640	2648	4703	9730	9526	5103	2852
6	17	74	39	448	790	1267	2318	4690	4064	708
7	36	9	30	7	221	382	629	1126	2057	188
8	2	18	2	11	3	103	190	310	462	47
9	-	1	8	-	3	-	51	87	132	9
10	-	-	-	4	-	-	-	21	29	1
Total	34885	60122	120369	173050	181656	139131	95459	59217	35952	
Total biomass	4937	17529	27568	56454	60214	67695	89341	54819	35614	

Table 10. Cod in Sub-divisions 29-32 (Finnish fishing zone). Input data and catch predictions for 1983 and 1984.

Age group	Mean weight at age (kg)	F 1982	Stock <sub>1983</sub> ( $\times 10^3$ )	Catch <sub>1983</sub> ( $\times 10^3$ )	Catch <sub>1983</sub> (tonnes)	Stock <sub>1984</sub> ( $\times 10^3$ )	Catch <sub>1984</sub> ( $\times 10^3$ )	Catch <sub>1984</sub> (tonnes)
1	0.104	0.01	35000	350	36	45000	450	47
2	0.284	0.15	3959	478	136	25903	3129	889
3	0.583	0.30	4123	782	456	2525	479	279
4	1.016	0.40	2863	695	706	1517	368	374
5	1.587	0.40	1500	364	577	953	231	367
6	2.397	0.40	1699	412	988	499	121	290
7	3.341	0.40	1353	328	1096	565	137	458
8	4.645	0.40	685	166	772	450	109	507
9	5.827	0.40	154	37	217	228	55	322
10	7.300	0.40	44	11	78	51	12	91
Total ( $10^3$ )			51380	3623		77691	5091	
Total biomass (tonnes)			25446			23441		
Catch (tonnes)					5062			3624