

This paper not to be cited without prior reference to the author

International Council for
the Exploration of the Sea

C.M. 1975/ P: 14
Baltic Fish Committee
Ref. Demersal Fish /N/
C -tee

Biomass and fishing mortality coefficients of Baltic Cod
evaluated by use of Virtual Population Analysis.

/MURPH-y computer program/

by

x/

Maria Kosior

Catches of Baltic cod are mainly concentrated in the southern and western Baltic. Thus the most frequently exploited regions are: 25; 26; 22 and 24. The Polish fleet operates in regions 25 and 26, where the commercial catch composition of the species is under constant investigation. The results of total cod catches from the two regions and the age composition of Polish catches, determined from the age of cod taken in commercial catches, were applied in considerations. Table 1 gives the data for 1960-1964 elaborated on the basis of annual studies, whereas those for 1965-1973 were based on material collected in the first quarters of these years. The change was due to difficulties in obtaining homogeneous material for study, over the period of a year. Mention should be made of the fact that during the years in question, catches from the I quarter comprised an average of 50% of the annual total,

x/ Sea Fisheries Institute
Gdynia /Poland/

the fish being taken by means of similar gear. another factor is that the subject of catches is cod, which forms pre-spawning and partially spawning concentrations at that time.

Table 2 gives the number of cod caught in the southern Baltic, according to age groups. The mean cod weights in the age groups, calculated from biological analyses were applied here - Table 3. This table also gives the mean weights in age groups calculated from the length-weight ratio, employing:

$$W = 0.0142 L^{2.91}$$

The equation was calculated for cod with II-VI stage gonads according to Maier's scale.

Total mortality

Data concerning the catch yield and effort from the grounds most highly exploited by Polish fishery: 26 and 25, were used to calculate Z. Table 4 gives the amount of cod of particular age groups caught per cutter/day.

The total mortality was calculated from a comparison of the number of cod from the same age group caught per cutter/day in consecutive years /Table 5/. This was expressed by the mortality coefficient from the formula:

$$Z = \ln \frac{N_t}{N_{t+1}}$$

where:

Z = coefficient of total mortality,

N_t = the number of t generation fish per cutter/day in the previous year,

N_{t+1} = the number of t generation fish per cutter/day in following year.

Fishing mortality

The fishing mortality coefficients were calculated by the Virtual population method, assuming that the natural mortality is 0.20, 0.30, 0.40 consecutive.

The results are presented in Table 6. The mean annual mortality given in this table, was calculated from individuals from age group III and upward.

The stock size and biomass of the cod stock exploited

Table 7 gives the stock size of the south Baltic cod stocks /regions 25, 26/ in 1960-1973. Depending upon the natural mortality assumed, the stock size fluctuated from 210.4 to 359.6 million with $M = 0.20$; from 238.9 to 411.6 million with $M = 0.30$ and from 275.5 to 479.5 million with $M = 0.40$.

The stock biomass corresponds to this. Thus at $M = 0.20$ the biomass is between 173.9 and 274.8 thousand tons at $M = 0.30$ - from 195.9 to 315.4 thousand tons, and at $M = 0.40$ - from 223.8 to 369.6 thousand tons. It should be remembered that these figures refer to the size of the exploitable stock. In this case, calculations were based on cod of the III to $x+$ age group.

References

1. Abramson N.J. 1971 - Computer Programs for Fish Stock Assessment. FAO Fisheries Technical Paper No. 101. Rome.
2. Gulland A.J. 1969 - Manual of Methods for Fish Stock Assessment. Part 1. Fish Population Analysis. FAO Fisheries Technical Papers No. 40, Rome.
3. Kosior M. 1969 - Dorsz południowego Bałtyku w latach 1965-1967. Prace MIR, Gdynia, T. 16, Seria A.
4. Kosior M. - Dorsz południowego Bałtyku w latach 1968-1972. Prace MIR, Gdynia., T.18/A /in print/.
5. Kosior M. 1969 - Total Mortality of Cod from the Southern Baltic in 1965-1969. CM. 1969/F 10 Demersal Fish /Northern/ Committee.

Table 1

Age composition of Polish cod catches in the southern Baltic in 1-st quarters /in number %/

Region	Years	A g e g r o u p s									
		I	II	III	IV	V	VI	VII	VIII	IX	X+
26	1960	1,4	24,6	42,8	17,2	10,1	2,3	0,8	0,4	0,4	
	1961	1,5	30,4	29,1	28,0	8,2	2,5	0,2	0,1		
	1962	1,6	30,2	35,7	17,4	12,3	2,3	0,4	0,1		
	1963	0,1	17,0	37,0	27,3	14,5	3,4	0,3	0,1	0,1	
	1964	0,4	15,2	41,8	23,4	14,1	3,8	0,7	0,3	0,3	
	1965	-	15,3	47,0	27,8	7,5	1,9	0,3	-	0,1	0,1
	1966	0,1	12,5	46,0	25,9	11,9	2,8	0,8	-	-	-
	1967	-	12,4	66,2	15,5	3,8	1,3	0,3	0,4	0,1	-
	1968	-	6,5	42,0	34,6	14,1	2,0	0,7	0,1	-	-
	1969	-	4,9	58,7	24,1	9,4	2,3	0,4	0,2	-	-
	1970	-	3,5	49,6	32,1	12,0	2,0	0,5	0,2	0,1	-
	1971	-	0,6	19,1	36,8	35,2	7,0	1,2	0,1	-	-
	1972	-	0,9	49,8	30,8	14,0	3,2	0,9	0,3	-	0,1
1973	-	1,3	24,6	39,6	25,0	6,0	1,6	1,3	0,5	0,1	
25	1960	0,3	35,9	37,0	18,6	6,2	1,6	0,4	-	-	-
	1961	2,7	32,9	24,1	20,6	15,4	3,6	0,6	0,1	-	-
	1962	2,0	29,1	33,4	19,7	12,1	3,2	0,4	0,1	-	-
	1963	2,5	28,0	33,3	17,8	12,9	3,6	0,7	0,1	0,1	-
	1964	6,6	23,0	32,8	19,4	12,7	4,0	0,6	0,2	0,7	-
	1965	0,2	14,3	38,3	27,6	14,2	4,6	0,4	0,2	0,2	-
	1966	-	9,9	58,6	21,9	7,8	1,4	0,2	0,2	-	-
	1967	-	16,2	56,9	17,4	6,4	2,3	0,4	0,2	0,1	0,1
	1968	-	17,9	54,1	18,1	8,8	1,0	0,1	-	-	-
	1969	-	17,9	52,2	20,2	8,5	1,0	0,2	-	-	-
	1970	0,2	9,7	49,2	28,0	10,7	1,8	0,2	0,1	-	-
	1971	-	4,7	34,3	34,4	22,5	3,4	0,5	0,1	0,1	-
	1972	-	0,9	44,9	33,3	15,7	4,1	0,8	0,2	0,1	-
1973	-	1,9	42,1	33,6	16,5	4,5	0,6	0,5	0,2	0,1	

Table 2

Number of fish each year-classes caught in Southern Baltic
in 1960-1973
/in thousand units/

Year of catch	Age groups									
	I	II	III	IV	V	VI	VII	VIII	IX	X
	<u>Region 26</u>									
1960	1 542	27 554	49 226	16 661	9 746	2 044	287	129	26	
1961	1 035	22 742	23 302	15 796	6 664	1 610	97	44	-	
1962	1 132	24 625	29 170	12 714	8 283	1 574	377	95	-	
1963	417	26 440	30 338	18 692	6 499	2 123	334	53	78	
1964	306	11 285	25 568	13 517	6 704	1 053	111	48	-	
1965	-	8 977	25 356	13 743	4 017	1 020	142	-	-	
1966	-	8 836	33 918	17 816	8 326	2 040	551	-	-	
1967	-	14 286	61 708	14 343	3 452	1 309	236	470	108	
1968	-	4 755	28 946	22 405	9 566	1 330	458	64	-	
1969	-	5 061	49 962	18 738	7 475	1 896	273	171	-	
1970	-	2 527	37 680	22 304	8 471	1 441	417	286	-	
1971	-	574	7 058	12 920	11 975	2 352	476	186	-	
1972	-	759	34 435	17 793	7 556	2 090	611	74	-	56
1973	-	517	8 785	12 797	7 652	1 822	535	386	145	28
	<u>Region 25</u>									
1960	211	16 816	22 078	10 117	3 424	746	138	6	-	
1961	1 714	22 035	20 835	18 080	8 298	2 431	419	61	-	
1962	1 304	21 736	29 358	13 857	7 531	1 967	268	19	-	
1963	1 857	24 892	33 008	13 433	8 316	2 556	616	100	25	
1964	3 329	26 806	41 273	13 088	4 717	980	233	60	-	
1965	354	10 021	26 159	18 238	9 475	2 915	138	84	-	
1966	-	9 115	48 566	18 206	6 307	1 140	146	144	-	
1967	-	17 056	48 439	14 876	5 813	2 175	526	240	92	139
1968	-	24 264	66 616	21 389	10 472	1 127	112	-	-	
1969	-	23 712	58 277	21 612	9 118	1 072	206	-	-	
1970	472	10 306	51 573	26 969	9 444	1 612	268	113	-	
1971	-	3 886	24 336	24 778	16 067	2 556	285	143	-	
1972	-	827	43 039	27 575	12 422	3 203	626	133	68	
1973	-	2 219	41 886	28 850	14 814	4 098	570	610	455	

Table 3

Mean lengths and weights of cod in age groups,
for the Gdańsk Deep Region

	Age groups							
	III	IV	V	VI	VII	VIII	IX	X
Mean lengths observed /cm/	38,6	44,3	51,8	60,1	67,5	69,0		
Mean weights observed /g/	571	959	1518	2352	3609	4604	8536	11127
Mean weights calculated	591	883	1392	2145	3007	3204	5527	8272

Table 4

The number of cod in age groups caught during
1 cutter day /in 1965-1973/

Year of catch	A g e g r o u p s										
	I	II	III	IV	V	VI	VII	VIII	IX	X+	
	<u>Region 26</u>										
1965	-	293	901	533	144	36	6	-	2	2	1 917
1966	-	301	1106	623	286	67	19	-	-	-	2 402
1967	-	484	2588	605	148	51	12	16	4	-	3 908
1968	-	126	816	672	274	39	14	2	-	-	1 943
1969	-	145	1731	711	278	68	12	6	-	-	2 951
1970	-	134	1854	1189	452	75	22	11	-	-	3 737
1971	-	9	288	555	531	105	18	2	-	-	1 508
1972	-	27	1469	909	413	94	27	9	-	3	2 951
1973	-	17	315	506	320	77	21	17	6	1	1 280
	<u>Region 25</u>										
1965	-	-	-	-	-	-	-	-	-	-	-
1966	-	75	444	166	59	11	2	2	-	-	759
1967	-	139	487	149	55	20	3	1	1	1	856
1968	-	214	648	217	105	12	2	-	-	-	1 198
1969	-	134	390	151	64	7	2	-	-	-	748
1970	-	113	593	322	119	20	4	1	-	-	1 175
1971	-	23	167	167	109	17	2	1	1	-	487
1972	-	5	262	194	92	24	5	1	-	-	583
1973	-	9	205	164	81	22	3	2	1	-	487

Table 5

The coefficient of total cod mortality

Years	Age groups				Z ⁺	Z ^x
	III/IV	IV/V	V/VI	VI/VII	III/VII	III/X
<u>Region 26</u>						
1965/66	0,37	0,62	0,76	0,64	0,60	0,49
1966/67	0,60	1,44	1,72	1,72	1,37	0,91
1967/68	1,35	0,79	1,33	1,29	1,19	1,23
1968/69	0,13	0,88	1,39	1,18	0,90	0,52
1969/70	0,37	0,46	1,31	1,13	0,82	0,47
1970/71	1,21	0,81	1,46	1,43	1,22	1,07
1971/72	-	0,29	1,73	1,36	1,13	0,03
1972/73	1,06	1,04	1,68	1,49	1,34	1,13
1965/73	0,38	0,84	1,51	1,42	<u>1,04</u>	<u>0,71</u>
<u>Region 25</u>						
1965/66	-	-	-	-	-	-
1966/67	1,09	1,10	1,08	1,30	1,61	1,07
1967/68	0,81	0,35	1,52	2,30	0,77	0,75
1968/69	1,46	1,22	2,71	1,79	1,79	1,46
1969/70	0,19	0,24	1,16	0,56	0,54	0,27
1970/71	1,27	1,08	1,95	2,30	1,65	1,27
1971/72	-	0,60	1,51	1,22	1,11	0,38
1972/73	0,47	0,87	1,43	2,07	1,21	0,75
1966/73	0,67	0,81	1,91	1,45	<u>1,21</u>	<u>0,82</u>

Z⁺ - arithmetical meanZ^x - " weighted

Table 6

Fishing mortality of cod in region 25 +26

Year	Year class																	Average F _{xx}	
	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969		1970
	<u>M = 0,20</u>																		
1960	1,03	1,23	1,12	0,72	0,67	0,30	0,01	-											0,73
1961	0,80 ^x	0,80	1,47	1,24	0,80	0,55	0,25	0,01	0,01										0,73
1962		0,41	1,06	1,24	1,19	0,77	0,62	0,27	0,01										0,74
1963		0,80 ^x	0,80 ^x	1,59	1,72	1,59	0,85	0,72	0,27	0,01									0,86
1964				0,80 ^x	0,54	0,98	0,87	0,78	0,68	0,24	0,01								0,73
1965					0,24	0,33	0,88	1,28	0,83	0,59	0,10								0,73
1966					0,80 ^x	0,28	0,37	1,36	1,27	1,14	0,75	0,07							0,89
1967					0,80 ^x	0,80 ^x	0,80 ^x	1,84	1,38	1,09	0,67	0,80	0,13						0,85
1968								0,80 ^x	0,92	1,03	1,52	0,91	0,71	0,10					0,84
1969										0,56	1,06	1,15	0,76	0,66	0,12				0,72
1970										1,43	0,77	0,66	0,96	0,73	0,66	0,07			0,71
1971										0,80 ^x	1,12	0,34	0,77	1,37	0,66	0,24	0,02		0,53
1972											0,74	0,15	0,45	1,15	0,92	0,65	0,61	0,01	0,66
1973											0,80 ^x	0,80 ^x	0,80 ^x	0,80 ^x	0,80 ^x	0,80 ^x	0,80 ^x	0,80 ^x	0,80
	<u>M = 0,30</u>																		
1960	0,92	1,08	1,03	0,65	0,59	0,25	0,01												0,65
1961	0,70 ^x	0,68	1,34	1,14	0,72	0,48	0,21	0,01	0,01										0,65
1962		0,35	0,94	1,14	1,09	0,70	0,54	0,23	0,01										0,65
1963		0,70 ^x	0,70 ^x	1,44	1,51	1,37	0,74	0,64	0,23	0,01									0,76
1964				0,70 ^x	0,44	0,81	0,76	0,70	0,60	0,20	0,01								0,64
1965					0,20	0,27	0,75	1,18	0,75	0,52	0,08								0,65
1966					0,70 ^x	0,24	0,31	1,26	1,17	1,03	0,66	0,06							0,79
1967					0,70 ^x	0,70 ^x	0,70 ^x	1,67	1,25	0,98	0,60	0,71	0,11						0,71
1968								0,70 ^x	0,81	0,91	1,39	0,80	0,62	0,08					0,73
1969									0,50	0,94	0,97	0,66	0,58	0,10					0,63
1970									1,29	0,68	0,53	0,83	0,66	0,57	0,05				0,62
1971										0,99	0,27	0,66	1,25	0,58	0,20	0,02			0,45
1972										0,70 ^x	0,64	0,12	0,38	1,02	0,81	0,56	0,53	0,01	0,58
1973											0,70 ^x	0,70 ^x	0,70 ^x	0,70 ^x	0,70 ^x	0,70 ^x	0,70 ^x	0,70 ^x	0,70
	<u>M = 0,40</u>																		
1960	0,79	0,93	0,93	0,58	0,51	0,21	0,00												0,57
1961	0,60 ^x	0,56	1,20	1,04	0,64	0,41	0,17	0,01	0,01										0,56
1962		0,29	0,82	1,04	0,98	0,62	0,46	0,19	0,01										0,56
1963		0,60 ^x	0,60 ^x	1,28	1,29	1,19	0,64	0,56	0,19	0,01									0,66
1964				0,60 ^x	0,35	0,65	0,64	0,63	0,53	0,17	0,01								0,56
1965					0,17	0,21	0,62	1,08	0,68	0,46	0,07	0,01							0,58
1966					0,60 ^x	0,20	0,26	1,16	1,06	0,92	0,58	0,05							0,70
1967					0,60 ^x	0,60 ^x	0,60 ^x	1,50	1,11	0,87	0,54	0,61	0,09						0,62
1968								0,60 ^x	0,69	0,80	1,26	0,70	0,52	0,07					0,63
1969									0,60 ^x	0,44	0,89	0,79	0,60	0,51	0,08				0,56
1970										1,14	0,59	0,41	0,70	0,59	0,48	0,04			0,53
1971										0,86	0,21	0,54	1,12	0,50	0,16	0,01			0,37
1972										0,60 ^x	0,55	0,10	0,32	0,89	0,70	0,48	0,45	0,10	0,49
1973											0,60 ^x	0,60 ^x	0,60 ^x	0,60 ^x	0,60 ^x	0,60 ^x	0,60 ^x	0,60 ^x	0,60

x Fishing mortality coefficient assumed

xx weighted by stock size

Table 7

Size of Cod stock in 1960 - 1973

Year of catch	Years class																	Total d/ /in thousand fish/	
	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969		1970
1960	714	4262	21179	57008	159562														242.727
1961	207	1018	5660	22773	66929	113861				<u>M = 0.20</u>									210.451
1962		373	1069	5396	24591	53714	138449												223.594
1963		203	302	1282	6123	20273	61016	134647											223.849
1964				213	898	3539	21344	53689	148205	126493									227.890
1965					428	1090	7306	20226	61618	126493									217.163
1966						641	2479	4619	57475	57475	169995								257.163
1967					274	395	1404	971	5021	15109	65585	217376							306.139
1968								126	1032	4149	27586	79771	205060						317.727
1969									338	1214	4920	26340	82567	244203					359.585
1970										565	1393	6853	31594	103217	201381				345.004
1971										529	2883	9938	40521	85117	161227				300.217
1972										110	141	1677	3760	8401	36009	103770	185224		339.096
1973										55	1186	1969	2185	11706	44426		82357	100202	244.089
1960	801	4748	23162	63919	182343														274.976
1961	237	1187	6144	24761	74807	131756				<u>M = 0.30</u>									238.894
1962		445	1196	5864	26875	60202	160615												255.198
1963		232	345	1391	6704	22203	69465	152950											253.294
1964				244	1096	4155	24413	59831	168762										258.503
1965					520	1369	8476	21898	68563	144245									245.073
1966						775	2966	4979	23876	63267	193301								289.166
1967							1604	1043	5490	16741	73612	247277							346.535
1968					314	452		144	1168	4647	29842	90394	236516						362.713
1969									386	1382	5486	30144	94518	279635					411.554
1970										618	1578	8439	35983	115671	234168				396.460
1971										-	591	3668	11607	44117	97993	198567			356.544
1972										126	162	2068	4456	9348	40721	120321	215555		392.761
1973										63	1355	2250	2497	13377	50768	94113	114505		278.932
1960	915	5407	25576	72384	211359														315.644
1961	276	1423	6751	27158	84680	155212													275.503
1962		542	1363	6439	29781	68648	190619												297.394
1963		271	403	1531	7505	24845	80880	175744											291.182
1964				284	1379	5055	28628	67219	194743										297.311
1965					648	1770	10096	23872	77099	166740									280.227
1966						960	3631	5407	26244	70489	222743								329.477
1967					366	527	1872	1133	6091	18814	83497	288117							400.419
1968								168	1348	5287	32626	105334	279075						423.841
1969									450	1597	6219	35778	110690	324791					479.527
1970										686	1819	10832	41989	131122	278305				464.757
1971										-	673	4811	13910	48600	115097	250565			433.659
1972										147	191	2610	5403	10585	46979	142549	256469		464.938
1973										73	1582	2626	2913	15610	59242	109821	133617		325.488

Table 8

Biomass of southern Baltic cod
/in tons/

Year of catch	R e g i o n 25 + 26		
	M = 0,20	M = 0,30	M = 0,40
1960	185.413	209.044	238.784
1961	173.960	195.902	223.875
1962	179.472	203.095	234.379
1963	180.761	203.599	233.364
1964	175.688	199.546	230.204
1965	177.644	200.240	228.909
1966	201.194	225.428	256.013
1967	230.066	259.589	303.864
1968	242.441	275.085	319.297
1969	269.188	307.851	359.083
1970	274.832	315.452	369.617
1971	256.535	302.715	363.830
1972	287.624	332.349	392.440
1973	238.792	279.878	318.423