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REPORT OF THE AD HOC WORKING GROUP ON MULTISPECIES ASSESSMENTS IN THE BALTIC

Copenhagen, 25 - 28 May 1982

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REPORT OF THE AD HOC WORKING GROUP ON MULTISPECIES ASSESSMENTS IN THE BALTIC

ICES Headquarters, 25-28 May 1982

1. PARTICIPANTS

O. Bagge	Denmark
R. Chevalier	France
H. Lassen (Chairman)	Denmark
J. Modin	Sweden
S. Munch-Petersen	Denmark
A. Müller	Federal Republic of Germany
R. Parmanne	Finland
W. Załachowski	Poland

The participation of Dr Załachowski was supported under the Cultural Agreement between Denmark and Poland.

Mr K. Hoydal partcipated in his capacity as ICES Statistician.

2. TERMS OF REFERENCE

2.1 The Working Group met under Recommendation 1981/2:27:14 :

"It was decided that :

the *ad hoc* Working Group on Multispecies Assessments in the Baltic (Chairman: Mr H. Lassen) should meet 25 to 28 May in Gdynia*to continue assesssments of species interaction between the three main stocks in the Baltic and to advise on data deficiencies."

Also C. Res. 1981/4:9 is relevant :

"It was decided that :

in order to facilitate multispecies assessment of fish stocks in the Baltic in the near future,a data base should be created in Copenhagen, in which the relevant data existing within national laboratories refer to :

(i) commercial catch (age and length compositions),

(ii) stomach contents

(iii) growth (mean length and weight at age).

The level of aggregation of all data should be by Sub-divisions and quarters of years.

The data on fish stomach contents should be arranged in the same way as described in the "Draft Manual for Stomach Sampling" dealing with the North Sea. Length groups of predators and prey should be specified by correspondence by a group of workers dealing with stomach sampling. Dr O. Bagge should be appointed coordinator of this Group, and he should report to the Working Group on Multispecies Assessments of the Baltic."

At the previous meeting (see C.M. 1981/J:34) the calculation of daily rations was recognised as a specific problem area and research on this problem is required.

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*Subsequently the meeting was held at ICES Headquarters.

2.2 The Working Group recognised that nothing on the data bank problem could be achieved during this meeting due to the absence of major potential contributions to this data bank.

2.3 The Working Group disucssed its terms of reference recognising "Proposal for a new strategy in the management of Baltic Fish stocks" submitted to the Meeting of IBSFC in September 1981 by the Polish Delegation. This proposal is attached as Appendix I.

After reviewing material presented to this meeting (see Section 3), and taking material previously presented into account, the Working Group decided to make an investigation of the data available and attempt a multispecies assessment. The various data which are necessary for such exercises show significant disagreements (see Section 3), and it was not possible during this meeting to resolve these discrepancies. As the data base necessary for multispecies assessment of the Baltic fish stocks is at present not consistent, any calculations based on whatever model must be considered to be of interest primarily to the scientific community and cannot form the basis of sound scientific managerial advice to IBSFC.

2.4 However, while quantitative multispecies assessments of the Baltic fish stocks are not feasible before these data base inconsistencies have been resolved, quantitative statements of the biological independencies between the fish stocks, the relative strength of these interrelations may be possible.

2.5 The Working Group furthermore decided to address the framework of scientific advice of fishery management based on multispecies assessments. The considerations are reported in Section 5.

3. MEAN STOCK SIZE OF HERRING, SPRAT AND COD AND THE YEARLY CONSUMPTION BY COD

In order to estimate the effects of cod stocks as predator on herring, sprat and young cod, the Working Group made use of biomass estimates from the 1982 Assessment Working Group reports (Anon. 1982a and 1982b), and Polish data on yearly consumption by cod 1977-81. The Polish stomach samples were collected from Sub-divisions 25 and 26, and the Working Group, therefore, decided to restrict itself only to the eastern cod stock (Sub-divisions 25-32). As the herring and sprat stock assessments do not cover the same Sub-divisions, the Group excluded the herring stock in Sub-divisions 22-24, and subtracted from the herring stocks in Sub-divisions 29N-31 the Gulf of Bothnia stock (Sub-divisions 30-31) in relation to landings. All three stocks of sprat were combined for the purpose of comparison.

The mean annual biomass of herring, sprat and cod were estimated by multiplyin[g] the biomass at the beginning of the year by

$$\frac{1 - e^{-Z}}{Z}$$

The F and M values were taken as unweighted means from the VPA in the 1982 Working Group reports (Anon. 1982a and 1982b).

Fs for cod were unweighted means of ages 3-7 to estimate the mean biomass of cod predating on *Mesidothea*, sprat and herring and of ages 4-7 to estimate the mean biomass predating on cod and "other fish", except *Gobiidae*.

The Polish estimates of yearly consumptions were adjusted accordingly. The estimated biomass and the yearly consumptions are shown in Tables 3.1. and 3.2, together with the natural mortalities M estimated from these data by solving the equation

$$C = Be^{-Z}(1-e^{-Z})\frac{M}{Z}$$

where C is the yearly consumption, B the mean biomass of the prey and F was taken to be the weighted mean of Fs for all age groups from VPA. It appears that the yearly consumption of herring by cod varies from 20-51% of the mean biomass and that the consumption of sprat in 1980 and 1981 exceeds the mean biomass. On the average, over 1977-81, 94% of the sprat stock is consumed by cod indicating inconsistency of data which prevent the use of these in any multispecies model.

This obvious bias is possibly due to the uncertainties in the single-species assessments, in which the same M values were used for all age groups, resulting in a too small stock size in younger age groups. This is indicated by the M values given in Table 3.2. This also applies to cod assessments. The acoustic surveys presented in Anon. 1982a could not remedy this, as 0- and possibly 1-group of herring and sprat are not well represented by these surveys.

A source of bias could be that the consumption by cod may be over-estimated due to extrapolation of results obtained in the southern part of Sub-divisions 25 and 26 to Sub-divisions 25-32.

This is supported by Danish results from an attempt (November 1981 and March 1982) to make observations on stomach contents of cod in different locations in the Baltic within a few days. In the Midsjö Bank area *Mysis mixta* played a dominating role as food item for cod less than 55 cm in contrast to the areas east of Gotland, off Liepaja, Słupsk Furrow, just east of Bornholm and northwest of Kriegers Flak. In Finnish waters (Axell, 1979) it is indicated that the diet of cod to a higher degree consists of herring and sprat than in the southern areas.

Uzars (1975) found that the consumption of Mysidae was 30% of the total which, compared to the 5-10% obtained from Polish data (1977-81) (Załachowski *et al.*, not published). Possibly, due to the use of another method for estimation of daily rations (Winberg, 1956), the yearly consumption is found to be about 10 times the biomass of cod which, compared to the Polish results (4.5-5 times), is very high.

The estimation of daily ration, here based on Bajkov (1935) could be one further source of bias. In Anon. 1981 a factor of 2 between two methods was found (Jones and Daan, see Section 4.1). The Bajkov method gives results which lie in between the results from these two methods.

4. ASSESSMENTS

4.1 Multispecies VPA

The approach applied is that of Sparre (1980). This approach was presented in Anon.(1981) and except for catch figures for 1981 no new input data were available to the multispecies VPA.

To compare with the Horbowy model, simulations (Section 4.2), two multispecies VPAs were carried out using the F(1981) array used by the Baltic Working Groups in 1982. The trends in the estimated stock biomass appear from

from Table 4.1. It appears that the stock sizes of the predator (cod) and prey (herring and sprat) follow the same pattern as that of estimates from Horbowy's model.

The two options given represent likely levels of total food consumption by cod (e.g., levels of the same magnitude as those given by Jones (1978) and Daan (1975)). The annual food consumption is given by

$$R = h \times w^{2/3}$$

where R = annual consumption, w = body weight and h the optional parameter.

It was to be kept in mind that in this model a reduction in the total consumption of the predator reduces the estimated stock size of the prey.

Table 4.2 shows the estimated predation mortalities on the two youngest age groups of cod, herring and sprat, corresponding to the stock estimates given in Table 4.1. The reason for selecting the youngest age groups of the prey species is that these are subject to a much higher predation pressure than the older ones, cf., the figures for sprat given in Table 4.3. Even if this pattern of predation mortality is also a product of the model, it is likely that especially the younger age groups of sprat are subject to heavy predation by cod in the Baltic. It is noted that the estimated predation mortalities increase with increasing cod stock.

From Table 4.3 it is apparent that the assumption of a constant natural mortality over neither time nor age is not justified. It appears that irrespective of the input values chosen, the natural mortality of the two youngest age groups for sprat is about 1.5 to 2 times that of the older fish. The ratio seems to vary with the predation pressure.

4.2 Andersen-Ursin Model Assessment

Horbowy and Kuptel (1980) presented a multispecies assessment of the Central Baltic fish stocks (cod, herring and sprat) based upon the model of Andersen and Ursin (1977).

The Working Group reviewed this approach and attempted to pursue the calculations. Dr Horbowy had made some preliminary runs from his program available to the Working Group. His program was transcribed onto the ICES computer system, but it was not possible to reproduce Dr Horbowy's results. The Working Group was unable, due to the limited time, to find the causes of these differences. Dr Horbowy had stated that his runs were not finalized so they could not form the basis for an actual asessment.

Dr Horbowy submitted estimates of the size preference parameters based upon the method of Ursin (1973) applied to data from the Polish cod stomach investigations in a working document. Preliminary calculations applying these parameter values indicate a very much lower consumption of fish by cod than estimated otherwise (see Table 4.4.) The Working Group could not resolve this conflict, but the estimated width of the size preference curve and optimal size ratio appears to be low compared to estimates obtained elsewhere (see Text Table below).

Food size preference parameters estimated for cod

	Ursin (1973)	Horbowy (pers. comm.) Sprat	Herring	Young Cod
Optimal size ratio (weight ratio)	1:164	1:90	1:90	1:50
Width of size preference curve	1	0.6	0.7	0.7

These differences may be related to the estimates of available food to the cod which, in Dr Horbowy's calculations, are based upon the ICES stock assessments. The stock areas do not match with the stomach sampling areas.

5. FRAMEWORK OF BIOLOGICAL ADVICE ON FISHERY MANAGEMENT UNDER A MULTISPECIES (BIOLOGICAL INTERACTIONS) ASSESSMENT REGIME

5.1 The scientific advice problem on management of the Baltic fisheries is similar to other general planning problems encountered and dealt with by social science disciplines. As in analogous situations, the interest is focussed on the output from the system, not the system's internal behaviour as such, i.e., in relation to fisheries management, the actual size of stocks is of no particular interest, but it is the consequence for the yield (or economic returns to the fleets, land-based production facilities, investments, labour, geographical sectors, etc.) which matter.

5.2 A general way to describe such planning systems could be as follows :

We have a system which includes 3 types of variables :

	Symbol
Target variables	T
Decision variables (controlled variables)	X
Uncontrolled variables	Y

Generally, $T = g\ (f\ (X,Y))$ where g

is man's activities, while f represents the biological system.

5.3 Target Variables

Applying this to the present problems, the target variables are the management objectives set by managers, i.e., the Commission, for the fishery. At present, this is done only in very general terms. This may be illustrated by the text of the IBSFC Convention which is headed :

"The States Parties to this Convention

- bearing in mind that maximum and stable productivity of the living resources of the Baltic Sea and the Belts is of great importance to the States of the Baltic Sea basin,

- recognising their joint responsibility for the conservation of the living resources and their rational exploitation,
- being convinced that the conservation of the living resources of the Baltic Sea and the Belts calls for closer and more expanded cooperation in this region".

5.4 Decision Variables

In the present case this is only the input of fishing effort ~ fishing mortality. Eventually translated, if possible, to the corresponding yield (the TAC). To interpret this decision variable in terms of actual components of the fishing industry, the whole problem of technical interaction arises.

5.5 Uncontrolled Variables

Uncontrolled variables are in this case the variables of the biological system. These are the parent stock size

growth (mean weight)

recruitment

biological interaction (from zero and upwards)

Only when, and if, we are able to model these variables with a precision, which allows as a first step projections and as a second predictions inside some probable limits the planning becomes meaningful. The biological interaction is, in effect, to change from a model with constant M to a model, where M in one stock is correlated to another stock.

5.6 Objectives

As a first step it might be possible rather than finding optimal levels to establish some lower "safe limits" above which a number of solutions are possible.

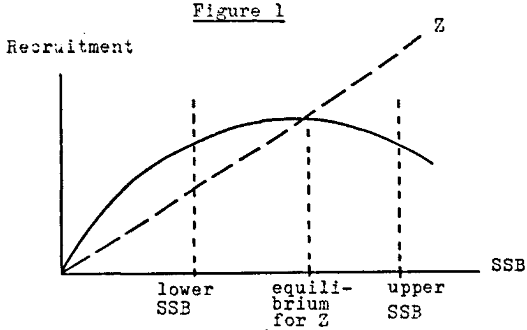
5.6.1 Safe biological limits

ACFM operates at present with the concept of "safe biological limits". This could be interpreted as follows :

Single species assessments

Let the stock/recruitment relationshipt for, say, a herring stock be as sketched below :

Figure 1



Then, "safe biological limits" could be interpreted as keeping the spawning stock biomass (SSB) within some interval, i.e., the target variable is the spawning stock biomass and the situation aimed for is an interval rather than a single number. To each point of stock/recruitment curve corresponds a total mortality Z active in this stock and, provided the natural mortality M is constant in time, we may control Z through the fishing mortality F ($Z = F + M$). F is thus (through e.g., effort regulation) the decision variable in single-species assessments, and the decision problem is to find such Fs which meet both the biological objective of safe biological limits and socio-economic criteria. This may, in single-species assessments, be done for a series of fish stocks independently of one another as illustrated above.

Multispecies (biological interaction) assessment

If, however, we consider biological interactions in the stock complex, then for, say, herring we get

$$Z(\text{herring}) = F_{\text{herring}} + M1 + M2$$

where M2 is a predation term (e.g., herring eaten by cod) and M1 is other mortality (also other predation mortality).

M2 is a function of the cod stock, i.e., is a function of the decision and uncontrolled variables of the cod stock. The stock/recruitment relationship may still be valid if a non-predation mechanism, e.g., starvation, is the controlling factor of this relationship. In this simple situation we have $Z_{low} < Z_{herring} < Z_{high}$, but this is now in terms of fishing mortality

$$Z_{low} - M^{(1)} - M^{(2)} < F < Z_{high} - M^{(1)} - M^{(2)}$$

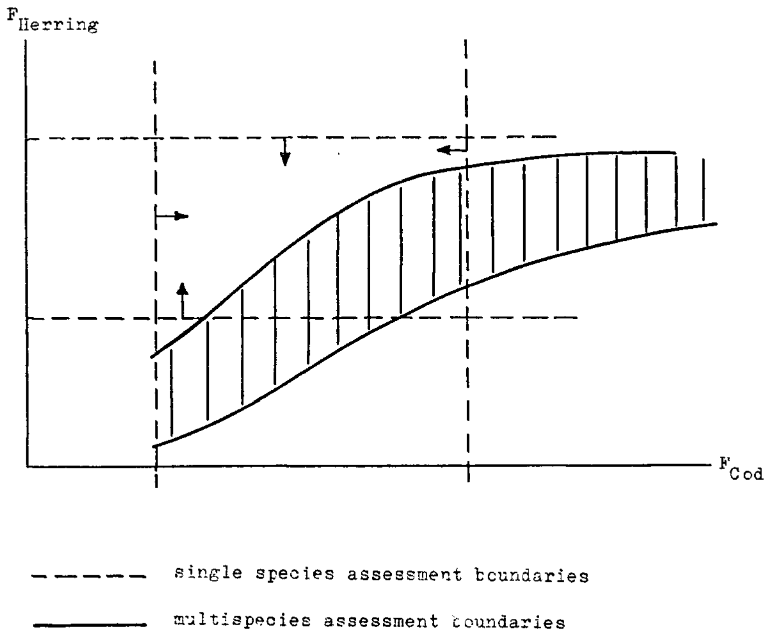
and the boundaries in Figure 2 will be as illustrated, and only the shaded area in Figure 2 is within safe biological limits.

5.7 In the simple analysis above it is assumed that only a single stock shows changes and all other factors remain equal. Relaxing this assumption will make the appealing simple graphical representation impossible, but it will still be possible, involving all decision variables, to delineate a volume of possible sets of fishing mortalities within which "safe biological limits" can be obtained. These sets of mortalities will be interrelated in a complex way.

5.8 A simplifying assumption made above is that the stock/recruitment relationship is not affected by the biological interactions, here mainly predation. Andersen and Ursin (1977) showed that it is possible to model the stock/recruitment through predation considerations. Again, relaxing the assumption of unaffected stock/recruitment relationship will complicate the graph, but the concept would still apply, as for every given situation a minimum spawning stock biomass could be defined and the corresponding Fs be inferred.

5.9 One further assumption inherent in the analysis is that it should be possible through knowlege of the biological interaction system F and of the socio-economic system g by regulating the decision variable X. to obtain some specified target value $T = g(f(X,Y))$.

Figure 2. Decision variables, fishing mortalities on herring and cod, and the sets of Fs within safe biological limits.



It has been demonstrated, e.g., Schopka (1980) and May *et al.* (1980), that it is possible to regulate cod and haddock stocks through the fishing mortality on those stocks. However, it remains to be demonstrated for small pelagic fish stocks (in the Baltic herring and sprat) that regulating fishing mortalities is a tool sufficiently strong for guiding the system towards an aimed target value. The experiences from cod and haddock stocks may not be directly applicable to herring and sprat stocks,due to the different trophical level of these stocks, and the larger influence of predation on the stock size.

The uncontrolled variables will show fluctuations in time; these fluctuations may be of a magnitude which cannot be counteracted by appropriate actions through the decision variables. A classic discussion in this respect is whether some observed rapid decline in recruitment may be caused by small spawning stock biomasses due to heavy fishing, or whether the stock/recruitment relationship has changed due to changes in the uncontrolled variables. Recently, this discussion arose around recruitment failures in the sprat stocks of the Baltic proper. Here, a breakdown of these stocks have previously been observed even under very light fishing.

5.10 The conclusions from the above discussions seem to be that the concept of "safe biological limits" is applicable even under a multispecies assessment regime, but also that the tuning of the system required for using these multispecies assessments could be quite complicated and that it may, or may not, be possible through the classical control of the fishing activities to guide the system toward the desired target value, thus involving regulation of fishing mortality on stocks other than the one in question.

6. FUTURE WORK

The discrepancies observed between the yearly consumption of food by cod in relation to the total stock as estimated by different methods and the varied preference of prey in different areas of the Baltic (Section 3) should stress the need for international cooperation in the Baltic in the following fields.

1. Digestion time according to :
   a) prey size
   b) prey type
   c) predator size
   d) total stomach content
   e) temperature
   f) time of day
2. Simultaneous sampling in different areas and seasons combined with estimates of the actual density of cod, sprat and herring.
3. Cod stomach contents especially in relation to the oxygen regime.

4. Stomachs from the following length groups should be sampled for the data bank: (cm)

   10-15, 16-20, 21-25, 26-30, 31-40, 41-50, 51-60, 61-70, >70.

These tasks should be coordinated so that comparative methods, both experimentally and in raising data, are employed.

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Table 3.1 Sub-divisions 25-32. Yearly Consumption by cod in 10^3 tonnes and biomass of cod by year.

	1977	1978	1979	1980	1981
Mesidothea	277	846	589	974	499
Herring	524	326	816	477	610
Sprat	482	221	98	251	400
Mean Biomass of Cod Age 3+	268	339	536	543	440
Cod	63	208	238	25	60
Mean Biomass of Cod Age 1-2	226	270	165	65	75
Other Fish	57	92	258	95	220

Table 3.2 Mean Biomass of Herring, Sprat, and Cod and the Yearly Consumption by Cod.

	1977	1978	1979	1980	1981	Mean 1977-81
Mean Biomass Herring	1 811	1 632	1 588	1 584	1 563	1 636
Yearly Consumption by Cod	524	326	816	477	610	551
Consumption/Biomass	0.29	0.20	0.51	0.30	0.39	0.34
M. (Herring)	0.37	0.24	0.79	0.38	0.54	0.44
Mean Biomass Sprat	518	349	239	214	219	308
Yearly Consumption by Cod	482	221	98	251	400	290
Consumption/Biomass	0.93	0.63	0.41	1.17	1.83	0.94
M. (Sprat)	4.03	1.23	0.59	?	?	4.14
Mean Biomass Cod Ages 1+2	226	270	165	65	75	160
Yearly Consumption by Cod	63	208	238	25	60	119
Consumption/Biomass	0.28	0.77	1.44	0.38	0.80	0.74
M. (Cod ages 1+2)	0.34	1.61	?	0.58	2.05	1.16
Mean Biomass of Cod age 3+	268	339	536	543	440	425

Table 4.1 Stock biomasses in 10^3 tonnes from multispecies VPA. Option A is with a high COD food consumption option B is with a low COD food consumption. (see Section 4.1)

	1974		1975		1976		1977		1978		1979		1980	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Cod 25-32	361	361	410	410	431	430	437	435	526	524	677	676	798	795
Herring 25-27	1 340	1 255	1 315	1 221	1 275	1 182	1 250	1 161	1 194	1 107	1 128	1 046	1 056	990
Herring 28-29S	255	232	296	260	280	248	264	232	261	228	269	230	228	206
Herring 29N-30	116	102	138	113	132	109	116	94	106	83	97	78	69	60
Herring (Riga)	466	451	499	480	503	485	512	493	496	478	482	465	468	458
Herring 32	247	242	230	224	231	226	213	207	190	184	188	181	191	186
Sprat 22-25	146	113	158	119	123	96	116	91	93	65	117	78	85	69
Sprat 26+28	495	390	523	380	442	328	363	279	283	211	161	120	147	122
Sprat 27-29 32	624	469	651	451	661	463	472	340	311	223	196	147	127	107

Table 4.2 Estimated annual predation mortalities on the two youngest age groups from multispecies VPA. Option A is with high cod food consumption, Option B is with low food consumtion, sess tect Section 4.1.

	1974		1975		1976		1977		1978		1979		1980	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Cod 25–32	0.02	0.01	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.05	0.03	0.08	0.05
Herring 25–27	0.19	0.12	0.23	0.14	0.21	0.14	0.22	0.14	0.30	0.19	0.42	0.27	0.46	0.29
Herring 28–29S	0.22	0.14	0.25	0.16	0.24	0.15	0.24	0.15	0.34	0.21	0.48	0.30	0.53	0.33
Herring 29N–30	0.29	0.18	0.31	0.20	0.28	0.18	0.31	0.19	0.44	0.28	0.58	0.37	0.58	0.73
Herring (Riga)	0.06	0.04	0.07	0.04	0.06	0.04	0.06	0.04	0.09	0.06	0.12	0.08	0.12	0.08
Herring 32	0.06	0.04	0.06	0.04	0.06	0.04	0.06	0.04	0.09	0.06	0.012	0.07	0.11	0.07
Sprat 22–25	0.57	0.37	0.55	0.36	0.49	0.32	0.55	0.36	0.72	0.47	0.81	0.52	0.79	0.47
Sprat 26+28	0.41	0.27	0.41	0.27	0.37	0.25	0.43	0.28	0.60	0.38	0.71	0.45	0.64	0.41
Sprat 27–29 32	0.33	0.21	0.33	0.21	0.30	0.19	0.34	0.22	0.49	0.31	0.62	0.39	0.59	0.37

Table 4.3 Estimated annual predation mortalities on Sprat by age and year

Option A (h = 4.7) - see text section 4.1 for description of option

Sprat Sub-divisions 22-25

Age	1974	1975	1976	1977	1978	1979	1980
0	0.5650	0.5545	0.4904	0.5516	0.7230	0.8105	0.7198
1	0.5651	0.5546	0.4909	0.5525	0.7236	0.8116	0.7200
2	0.3016	0.3501	0.3122	0.2952	0.4077	0.5553	0.5923
3	0.2773	0.3260	0.2942	0.2749	0.3753	0.5177	0.5639
4	0.2560	0.3043	0.2777	0.2568	0.3471	0.4837	0.5366
5	0.2560	0.3043	0.2778	0.2568	0.3471	0.4838	0.5367
6	0.2464	0.2943	0.2699	0.2485	0.3344	0.4681	0.5235
7	0.2375	0.2849	0.2628	0.2409	0.3226	0.4536	0.5108

Sprat Sub-divisions 26+28

Age	1974	1975	1976	1977	1978	1979	1980
0	0.4481	0.4351	0.3988	0.4717	0.6397	0.7322	0.6441
1	0.3766	0.3838	0.3489	0.3954	0.5534	0.6835	0.6393
2	0.2883	0.3162	0.2912	0.3084	0.4351	0.5830	0.5961
3	0.2511	0.2833	0.2597	0.2625	0.3798	0.5323	0.5602
4	0.2378	0.2720	0.2506	0.2516	0.3623	0.5120	0.5470
5	0.2252	0.2604	0.2416	0.2407	0.3453	0.4924	0.5330
6	0.2059	0.2421	0.2274	0.2239	0.3171	0.4579	0.5074
7	0.1973	0.2337	0.2208	0.2161	0.3045	0.4423	0.4946
8	0.1817	0.2182	0.2085	0.2022	0.2819	0.4133	0.4710
9	0.1747	0.2111	0.2029	0.1959	0.2718	0.4002	0.4597

Sprat Sub-divisions 27, 29-32

Age	1974	1975	1976	1977	1978	1979	1980
0	0.3952	0.3805	0.3461	0.4224	0.5931	0.6879	0.604[illegible]
1	0.2594	0.2898	0.2628	0.2682	0.3935	0.5478	0.5680
2	0.2357	0.2695	0.2481	0.2490	0.3598	0.5095	0.5443
3	0.2250	0.2599	0.2410	0.2401	0.3445	0.4915	0.5320
4	0.2250	0.2599	0.2410	0.2401	0.3445	0.4915	0.5320
5	0.2250	0.2599	0.2411	0.2401	0.3445	0.4916	0.5319
6	0.2151	0.2508	0.2340	0.2316	0.3303	0.4743	0.5195
7	0.2151	0.2507	0.2341	0.2316	0.3303	0.4743	0.5195
8	0.2151	0.2508	0.2341	0.2316	0.3303	0.4742	0.5195
9	0.2151	0.2508	0.2341	0.2316	0.3303	0.4742	0.5194
10	0.2152	0.2509	0.2344	0.2319	0.3305	0.4749	0.5202

continued ....../

Table 4.3, Continued ....

Option B (h = 3.0)

Sprat Sub-divisions 22-25

1974	1975	1976	1977	1978	1979	1980
0.3685	0.3612	0.3228	0.3600	0.4651	0.5236	0.4700
0.3686	0.3613	0.3229	0.3602	0.4653	0.5243	0.4701
0.1880	0.2183	0.1967	0.1859	0.2553	0.3485	0.3734
0.1729	0.2032	0.1853	0.1731	0.2349	0.3248	0.3553
0.1596	0.1896	0.1748	0.1617	0.2174	0.3035	0.3380
0.1596	0.1896	0.1748	0.1617	0.2174	0.3035	0.3380
0.1537	0.1833	0.1699	0.1565	0.2095	0.2937	0.3297
0.1481	0.1775	0.1653	0.1517	0.2021	0.2846	0.3217

Sprat Sub-divisions 26+28

1974	1975	1976	1977	1978	1979	1980
0.2961	0.2895	0.2669	0.3106	0.4138	0.4741	0.4205
0.2427	0.2491	0.2275	0.2547	0.3520	0.4352	0.4092
0.1832	0.2022	0.1871	0.1964	0.2744	0.3679	0.3775
0.1594	0.1809	0.1670	0.1674	0.2396	0.3356	0.3543
0.1506	0.1734	0.1607	0.1603	0.2284	0.3225	0.3456
0.1422	0.1656	0.1546	0.1529	0.2173	0.3098	0.3363
0.1301	0.1539	0.1454	0.1422	0.1995	0.2880	0.3200
0.1247	0.1485	0.1413	0.1373	0.1917	0.2782	0.3119
0.1149	0.1387	0.1334	0.1285	0.1776	0.2601	0.2970
0.1105	0.1342	0.1298	0.1245	0.1712	0.2518	0.2898

Sprat Sub-divisions 27, 29-32

1974	1975	1976	1977	1978	1979	1980
0.2494	0.2425	0.2206	0.2664	0.3720	0.4334	0.3830
0.1635	0.1840	0.1679	0.1699	0.2471	0.3442	0.3580
0.1487	0.1712	0.1586	0.1579	0.2261	0.3202	0.3431
0.1420	0.1651	0.1541	0.1523	0.2166	0.3090	0.3354
0.1420	0.1651	0.1541	0.1523	0.2166	0.3090	0.3354
0.1420	0.1651	0.1541	0.1523	0.2166	0.3090	0.3354
0.1358	0.1593	0.1497	0.1470	0.2077	0.2982	0.3275
0.1358	0.1593	0.1497	0.1470	0.2077	0.2982	0.3275
0.1359	0.1593	0.1497	0.1470	0.2077	0.2982	0.3275
0.1359	0.1593	0.1497	0.1470	0.2077	0.2981	0.3275
0.1359	0.1594	0.1497	0.1471	0.2079	0.2986	0.3279

Table 4.4 Annual consumption by COD in the central Baltic (1 000 tonnes) as estimated by three approaches.

Prey Species	Working Group estimate Sub-divisions 25-29 Mean 1977-1981	Multispecies VPA Sub-division 25-32 Range in 1980		Horbowy 1982 Sub-divisions 25-29S Mean 1974-1980
		Option A	Option B	
Cod	119	5	3	5
Herring	551	271	162	79
Sprat	290	139	74	76

APPENDIX 1

INTERNATIONAL BALTIC SEA FISHERY COMMISSION

Seventh Session

Warsaw, 21-30 September, 1981

PROPOSALS FOR A NEW STRATEGY IN THE MANAGEMENT OF BALTIC FISH STOCKS

SUBMITTED BY POLISH DELEGATION

1. The Present Biological and Exploitational Situation in the Eastern Part of the Baltic

The situation in the Baltic /east of Bornholm/, can be outlined as follows, basing on the data contained in the reports of ICES Advisory Committee on Fishery Management of July 1981 and results of investigations on the feeding of Baltic fish /carried out by a research group directed by Dr. Załachowski/.

1.1. After a period of 9 years stabilization. the biomass of cod spawning stocks increased substantially in the years 1975 - 1980, from slightly over 450,000 to almost 900,000 tons. Simultaneously, the biomass of herring in sub-divisions 25 + 26 + 27 dropped from 1,370,000 to 940,000 tons. The drop in the sprat biomass in sub-divisions 26 + 28 was much greater, from 612,000 to 230,000 tons. As regards catches, that of cod in 1980, was 177 % higher in 1980, than in 1975.
Over the whole 5-year period, herring catches remained at more or less the same level. Sprat catches, on the other hand, dropped drastically - by 70 % /Fig. 1/. During the same period, there was a rapid drop in the biomass of herring and sprat spawning stocks and a significant deterioration of recruitment in these species /Fig. 2/.

1.2. Investigations on the food taken up by the cod and estimates of the weight of organisms eaten over the period of one year by the total stock, showed that:

a/ the clupeids constitute the basic component in the diet of adult cod of over 40 cm. in length /Table 2/,

b/ the mass of clupeids eaten by the east-Baltic cod stocks in one year fluctuates between 700,000 and 1.4 million tons, depending upon the biomass of the cod and that of its prey /Table 1/,

c/ the basic part of this biomass /about 60 %/ constitute clupeids less than 15 cm. in length; thus, the sprat total stock constitutes the prey of the cod /from the youngest to the oldest generations of the stock/, as does part of the herring stock which constitutes the recruitment group /Table 3/,

d/ cod, from the 56-cm. length class. practice cannibalism on their own juveniles, to a substantial degree.

1.3. The species composition of the cod food changes from year to year, depending upon the age of the cod, the biomass of the stock and that of the fish which constitute its prey.
During its whole life, the Baltic cod is not only omnivorous. but also shows considerable flexibility as regards its food intake /Table 1/. It can be concluded that, in the conditions existing in the Baltic, sufficient food can be found to maintain even the greatest biomass of cod. It would thus seem that the factor limiting the development of the cod biomass of the eastern Baltic is not the abundance of food available, but the reproductive conditions of the environment /chemism of the near-bottom waters in the Baltic deeps/.

Dorich arrange
N 1 bring limits
all Recruitment
limited

2. Conclusions

2.1. The overstepping of the biomass of 450,000 tons by the east-Baltic spawning stock caused a sudden drop in the biomass of the stocks of the clupeids /herring and sprat/ and permanent deterioration of the recruitment in these species.

2.2. The fact that cod is an omnivorous species, showing very high flexibility as regards food, and that there is sufficient food in the eastern Baltic to maintain even the greatest cod biomass prove that there is no natural system of regulating its stock by exhaustion of the food resources.

3. Proposed Principles for the New Strategy in the Management of the East-Baltic Fish Stocks

3.1. The TAC of cod, herring and sprat in the eastern Baltic should be fixed by taking into account the trophic dependencies between these three species, and mainly the effect of cod predation on the development of the spawning stocks of herring and sprat, as well as the recruitment in these two species.

3.2. For the reasons given in 2.2. and the situation where the biomass of cod stock exceeds 400 - 450,000 tons, fishery should assume the regulating role of the adult cod stock biomass, to protect the herrings against predation by the cod.

3.3. The reduction of the excess biomass of <u>adult</u> east-Baltic cod feeding, in the main, on the clupeids, should be under the strict supervision of the International Council for the Exploration of the Sea. At the same time, the Baltic Fishery Commission should tighten protection over juvenile cod in order to maintain recruitment at the maximum level in the hydrobiological conditions existing in a given year.

T a b l e 1

Weight of organisms eaten yearly by cod /total stock/ in southern and eastern Baltic in 1972-1980 according to estimation of Załachowski et al.

/data in thousand metric tons/

	Years	1972--1974 /average/	1977	1978	2979	1980
	Total Stock Biomass of the Cod in the Southern and Eastern Baltic	482	570	625	580	870
Species composition of the food eaten by cod	Invertebrata - total	1267	1084	1483	1447	3274
	included: Antineella sarsi	590	365	170	170	1631
	Mesidotea entomon	362	395	983	606	1030
	Mysis mixta	146	74	120	190	212
	Crangon crangon	71	15	37	98	31
	Gammarus sp.	42	27	44	44	44
	Pontoporeia femorata	21	14	15	196	202
	Pisces - total	913	1715	1126	1664	1214
	included: Sprattus sprattus	291	698	292	86	358
	Clupea harensus	387	776	386	909	678
	Clupeidae together	678	1474	678	995	1036
	Gadus morrhua	38	104	262	258	35
	Gobiidae	107	47	26	119	4
	Enchelyopus cimbrius	3	4	45	92	11
	Ammodytidae	13	4	14	25	14
	Gasterosteus aculeatus	4	.	25	17	5
	Grand Total	2180	2799	2609	3111	4488
Catches	Cod /25-32/	145	165	154	224	345
	Herring /25+26+27/	153	163	174	190	179
	Sprat /26+28/	101	85	73	32	26

Table 2

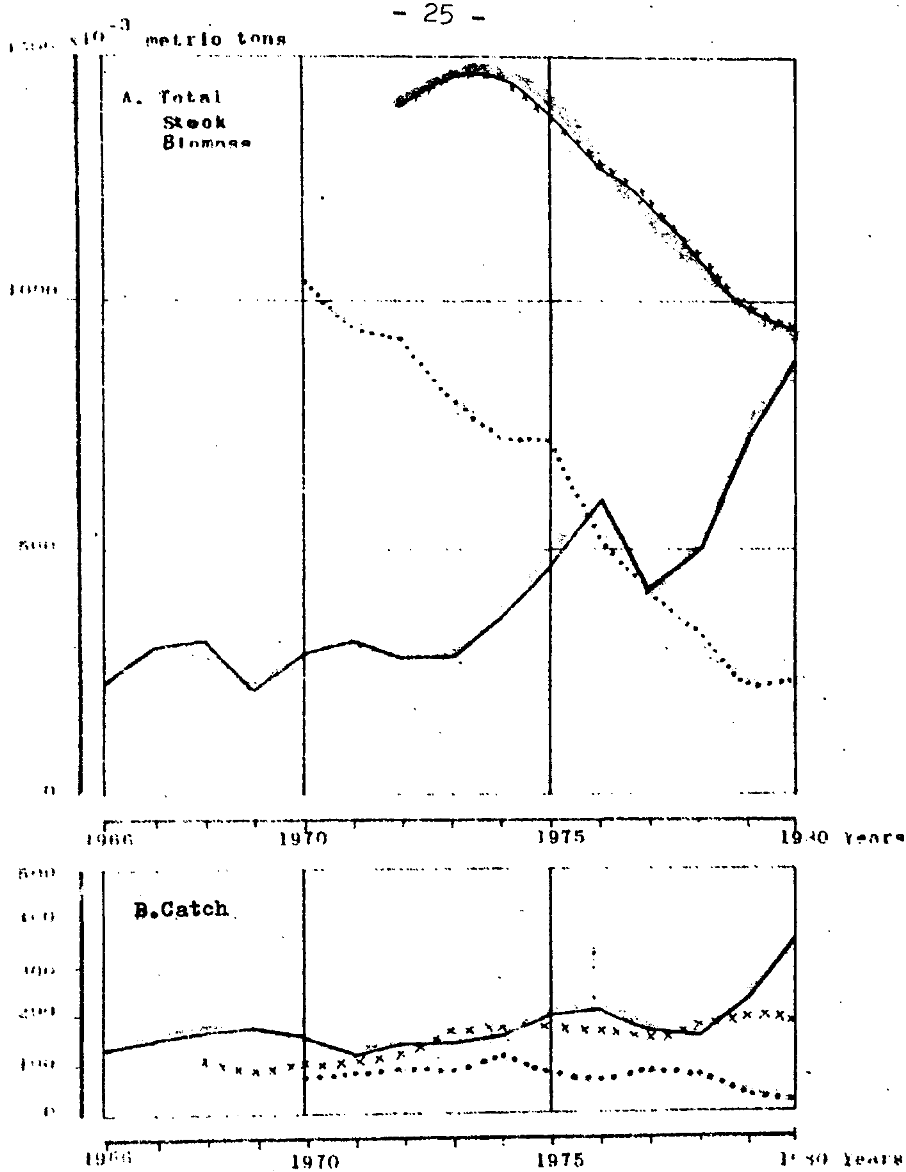
Species composition of the diurnal ratio of the cod
from Southern Baltic in 1972-74
/Załachowski, 1977/ /data in %/

Species eaten	Lenght classes of the Cod /in cm/						
	5-15	16-25	26-35	36-45	46-55	56-65	65
Invertebrate - total	89.39	90.52	77.03	59.40	37.89	25.41	18.12
Antinoella sarsi	39.64	39.60	35.05	25.17	12.93	9.28	4.05
Mesidotea entomon	5.90	14.16	23.72	24.19	20.10	15.29	13.92
Mysis mixta	22.00	17.80	7.95	4.83	3.37	0.52	0.07
Crangon crangon	4.41	2.72	5.02	3.59	1.24	0.28	0.06
Gammarus sp.	7.62	7.16	2.85	0.97	0.15	0.02	-
Pontoporeia femorata	2.28	2.42	0.71	0.02	0.00	0.00	-
Pisces - total	10.61	9.48	22.97	40.60	62.11	74.59	81.88
Sprattus sprattus	-	0.51	2.00	7.19	18.30	12.31	6.13
Clupea harengus	-	0.22	3.23	12.36	21.91	30.11	26.50
Clupeidae ind.	-	0.30	8.04	12.16	10.67	11.56	17.72
Clipeidae - together	-	1.03	13.36	31.71	50.88	53.98	50.35
Gadus morrhua	-	-	0.21	0.97	3.55	11.54	22.11
Gobiidae	9.61	7.58	6.68	3.50	1.46	0.36	0.03
Enchelyopus cimbrius	-	-	-	-	0.24	2.00	2.10
Ammodytidae	-	-	0.05	0.69	2.62	1.30	0.48
Gasterosteus aculeatus	-	-	-	0.41	0.03	-	-
Grand total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3

Length composition of the Sprat, Herring and Cod eaten by cod in 1980 /Załachowski et al. 1981/

Species	Length groups /cm/					Total
	0-5	6-10	11-15	16-20	21-25	
A. Weight /in thousand metric tons/						
Sprat	-	26.32	252.92	-	-	279.27
Herring	-	4.16	88.48	396.38	40.38	529.40
Clupeidae indeterminated	0.27	149.74	54.14	24.00	-	228.50
Total Clupeidae	0.27	180.22	395.57	420.38	40.38	1036.82
Cod	-	-	12.30	22.71	-	35.01
B. %						
Sprat	-	9.4	90.6	-	-	100.0
Herring	-	0.8	16.7	74.9	7.6	100.0
Total Clupeidae	0.03	17.38	38.15	40.55	3.89	100.0
Cod	-	-	35.1	64.9	-	100.0



Cod - spawning stock biomass in 25-32 sdvs

x x x x x Herring - total stock biomass in 25-27 sdvs

. . . . . Sprat - total stock biomass in 26-28 sdvs

Fig.1 Fluctuations of the stock biomass and yield of the cod, herring and sprat in the Baltic Sea /eastern part/ in 1966-1980

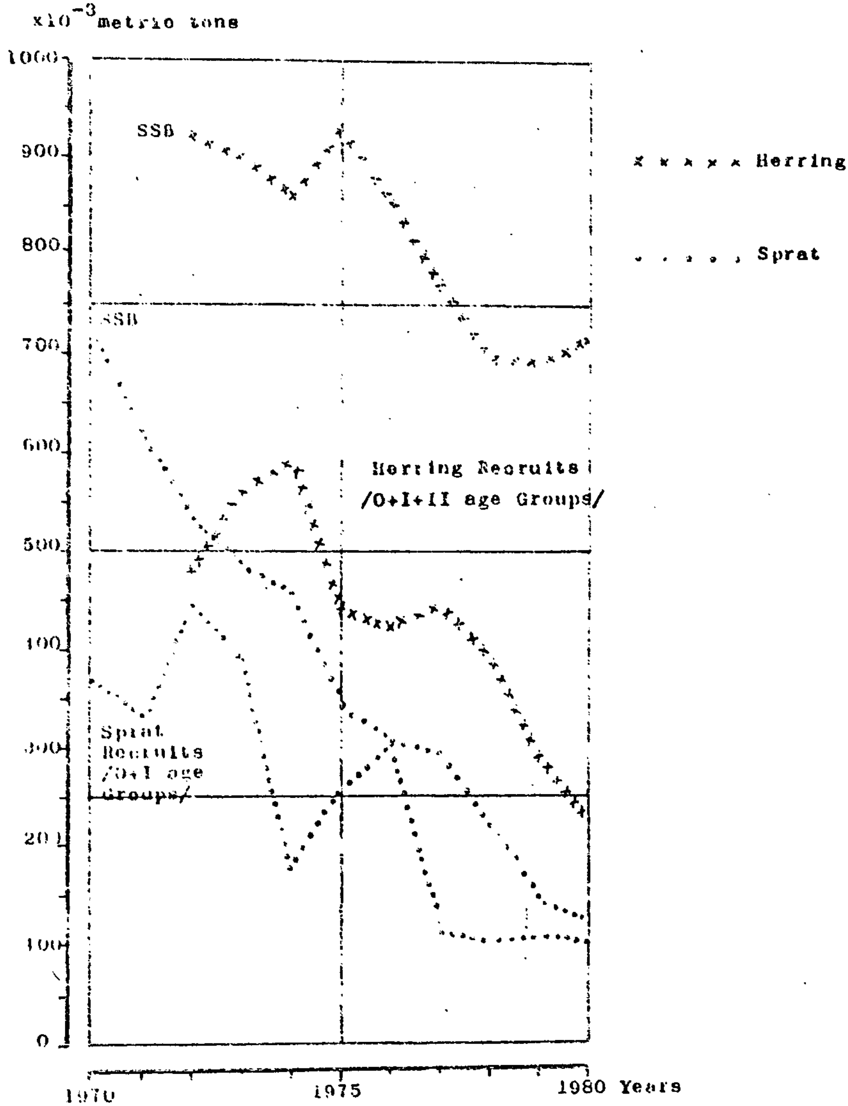


Fig.2 Fluctuations of Spawning Stock Biomass /Herring in subdivisions 25+26+27 and Sprat in subdivisions 26+28/ and Recruits Biomass /Herring 0+I++II age groups and Sprat 0+I age groups/ in Eastern Baltic in 1970-1980