ACTA ICHTHYOLOGICA ET PISCATORIA
Vol. XV Fasc. 2 Szczecin 1985

Włodzimierz ZAŁACHOWSKI

AMOUNT AND COMPOSITION OF FOOD OF COD (*GADUS MORHUA*) IN THE SOUTHERN BALTIC IN 1977–1982

ILOŚĆ I SKŁAD POKARMU DORSZY (*GADUS MORHUA*) W POŁUDNIOWYM BAŁTYKU W LATACH 1977–1982

Institute of Ichthyology,
Szczecin

Based on total and partial daily coefficient values, the amount and composition of cod food was determined for six consecutive years, from 1977 through 1982. The range and nature of differences between different years with respect to a long-term mean were examined. An attempt is made to find a possible correlation between weight and composition of the food consumed.

INTRODUCTION

Feeding of cod in the Baltic Sea was studied in the fifties (Reimann, 1955; Strzyżewska, 1959, 1962; Chrzan, 1962) and seventies (Uzars, 1975; Załachowski, 1977). The results agree in pointing out to the same organisms dominating in the food. However, the studies listed differ in their evaluation of various dominants and in assessing food uptake. The differences might have been caused by two kinds of reasons. Firstly, they might have resulted from different methods used by various authors (earlier studies were based on coefficients calculated from the actual weight of stomach content, while the more recent ones attempt to assess the daily food consumption), or, secondly, from changes in conditions of cod feeding. The changes might have been occurring continuously with time or irregularly from year to year. In the first case, the changes would be associated with long-term processes occurring in the environment (e.g. eutrophication); in the second case, they would depend on some unpredictable factors such as short-term climatic changes or oceanic inflows.

In 1977, systematic studies were began in the Southern Baltic, the studies aiming at the characterisation of cod feeding during the consecutive calendar years of the project. The overall summary of the results disregards detailed regional and seasonal analyses and other ecological conditions possibly operative. Such analyses will be presented elsewhere. Here, the attention is focused on ranges of variation in indices describing the amount and composition of food in various years relative to the long-term mean. An attempt is also made to find out whether the changes observed had been continuous or irregular. Additionally, a question is addressed if there is any relationship between the amount and composition of food, both in its total mass and within separate groups of components.

A six-year period is too short to form a basis from which to draw final conclusions. Correlations in particular require an enlarged set of basic data. Therefore the results presented can be treated only as preliminary grasp of the problem. More precise analyses of the observations presented here will be performed gradually, with accumulation of further data.

MATERIALS AND METHODS

Over the 6-yr period, a total of 11,098 stomachs of cod caught in the statistical areas 25 and 26 were examined. The location of sampling sites is shown in Fig. 1. Most data were collected from the Gdańsk Bay in the east and the Kołobrzeg-Darłowo fishing grounds in the west. Smaller samples were obtained from the central part of the study area: the Słupsk Trough and Ustka-Łeba fishing grounds. Table 1 shows the sizes of samples collected in various years and the length distribution in the samples. In 1977–1981, the cod were assigned to 7 length classes, at 10-cm intervals in the first six classes. In 1982, according to the recommendations for the international project (Anon., 1981), the number of length classes was increased to 10, with 5-cm intervals for juvenile cod. The table shows the length range of 26–45 cm to be most abundantly represented; the cod of this size is also most abundant in commercial catches. However, the materials were collected mostly by research vessels. A point was made to take, on fixed stations, at short time intervals, hauls at various depths within 20–100 m. Such hauls were repeated in different seasons. Detailed sample size distributions by seasons and by depths will be described in forthcoming papers dealing, i.a., with seasonal variability in cod feeding.

The amount and composition of food consumed were determined by means of total and partial daily coefficients, i.e., the daily food uptake as pro-decimille of fish body weight. Daily coefficients were calculated using Bajkov's formula (Bajkov, 1935) as described in detail by Załachowski (1985). Separate coefficients were calculated for the

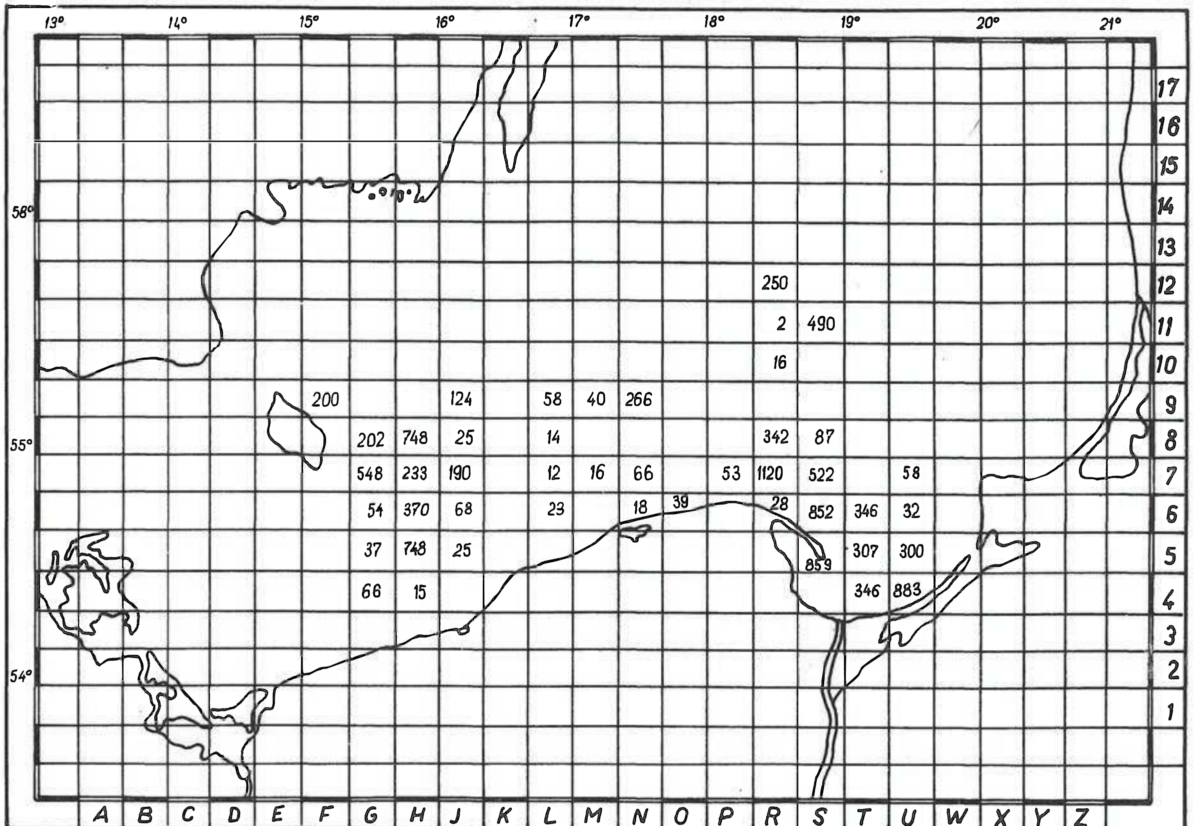

Fig. 1. Number and distribution of samples

Table 1

Number of cod individuals examined in various years (by length classes)

<table>
<tr><th rowspan="2">Year</th><th colspan="14">Length class (cm)</th><th rowspan="2">Total</th></tr>
<tr><th>5–10</th><th>11–15</th><th>16–20</th><th>21–25</th><th>26–30</th><th>31–35</th><th>36–40</th><th>41–45</th><th>46–50</th><th>51–55</th><th>56–60</th><th>61–65</th><th>66–70</th><th>> 70</th></tr>
<tr><td>1977</td><td colspan="2">417</td><td colspan="2">309</td><td colspan="2">328</td><td colspan="2">465</td><td colspan="2">352</td><td colspan="2">123</td><td colspan="2">31</td><td>2025</td></tr>
<tr><td>1978</td><td colspan="2">234</td><td colspan="2">299</td><td colspan="2">561</td><td colspan="2">459</td><td colspan="2">174</td><td colspan="2">72</td><td colspan="2">29</td><td>1828</td></tr>
<tr><td>1979</td><td colspan="2">115</td><td colspan="2">92</td><td colspan="2">563</td><td colspan="2">588</td><td colspan="2">169</td><td colspan="2">48</td><td colspan="2">9</td><td>1584</td></tr>
<tr><td>1980</td><td colspan="2">111</td><td colspan="2">33</td><td colspan="2">208</td><td colspan="2">770</td><td colspan="2">258</td><td colspan="2">61</td><td colspan="2">18</td><td>1459</td></tr>
<tr><td>1981</td><td colspan="2">197</td><td colspan="2">99</td><td colspan="2">498</td><td colspan="2">550</td><td colspan="2">394</td><td colspan="2">167</td><td colspan="2">101</td><td>2006</td></tr>
<tr><td>1982</td><td>95</td><td>268</td><td>175</td><td>124</td><td>172</td><td colspan="2">495</td><td colspan="2">475</td><td colspan="2">253</td><td colspan="2">109</td><td>30</td><td>2196</td></tr>
</table>

length classes listed in Table 1. Mean coefficients to characterise a given year were calculated from seasonal values. However, the mean daily coefficients presented are related to age groups rather than to length classes. The conversion was made on the assumption of each age group having its length range, and it was this range (when different from that given in Table 1) that the mean coefficient was related to (calculated from two or more classes). Length ranges corresponding to age groups were determined for various calendar years from data on mean individual weight, given in reports of the ICES Working Group on Assessment of Demersal Stocks in the Baltic and from the available length-weight relationships.

RESULTS

Over the six years of study, the cod food was found to include 40 items (21 invertebrate taxa and 17 fish species) listed in Table 2. Six-year mean partial daily coefficients given in the table show the importance of various items; the dominants in particular tend to change with fish age. The importance of most invertebrate components tends to decrease, while the fish items gain in importance. The total daily coefficient of age group I is twice that recorded for group II. The coefficient decreases gradually, but slowly, in the next age groups, so that the difference between groups II and VIII amounts to about 30% of the lowest value.

The above relationships are illustrated in Fig. 2 showing, apart from long-term means, also what the relationships looked like in various years. Each year there is a similar trend for the daily coefficient decrease with fish age, with a simultaneous increase in fish contribution to the food. Differences, however, are seen in the range of changes covered by the trend. Fig. 2 shows the strongest oscillations to be typical of the age group I daily coefficient values. In the subsequent years the differences, although still existent (cf. the extremely distant curves representing 1978 and 1980), are not so extensive. This finding is confirmed by the coefficient of variation analysis, presented in Table 3, for three different age groups of cod. If an arbitrary significance level of 8–10% is accepted for the coefficients of variation, the differences for the fish in age groups II–VI can be considered as bordering on the significance, significant in group I, and non-significant in groups VII and VIII.

The invertebrates: fish ratio in the food changes from year to year more strongly than does the daily coefficient. Fig. 2 shows that, in the long-term mean, the daily ration of cod food in the first three age groups is dominated by invertebrates, a gradually increasing domination of fish beginning in age group IV. Similar patterns are observed in 1978, 1979, and 1981 only. In 1977, the fish begin dominating as eraly as in group II, their domination indices in the subsequent groups being much higher than the mean values. Opposite was the picture in 1980, when invertebrates still prevailed in cod food as late as age group V; in the three subsequent groups they made up more or less half of the daily ration.

Table 2

Mean daily consumption ($^{0}/_{000}$ body weight) of food items eaten by cod of various age within 1977–1982

Food item	Age group							
	I	II	III	IV	V	VI	VII	VIII
Annelida:								
Halicryptus spinulosus	0.01	0.02	0.03	0.01	–	–	–	–
Priapulus caudatus	0.29	0.28	0.18	0.07	0.03	–	–	–
Nereis diversicolor	14.53	2.54	1.20	0.20	0.02	0.00	–	–
Antinoella sarsi	85.87	26.88	22.11	10.47	9.79	2.73	0.05	0.02
Scoloplos armiger	0.02	–	–	0.00	0.00	–	–	–
Nemertini	0.07	–	–	–	–	–		–
Crustacea:								
Entomostraca	1.40	–	–	–	–	–		–
Mysis mixta	65.99	15.57	10.30	2.62	1.86	0.49	0.42	0.36
Neomysis vulgaris	8.91	0.22	0.14	0.01	0.00	0.00	0.01	0.01
Pontoporeia affinis	19.69	3.25	1.80	0.30	0.13	0.01	–	–
Pontoporeia femorata	3.05	5.31	4.61	1.87	1.82	0.34	–	–
Caliopius rathkei	–	–	0.00	–	–	–	–	–
Gammarus sp.	16.64	3.25	1.59	0.42	0.19	0.05	0.03	0.02
Corophium sp.	3.95	0.29	0.14	0.03	0.01	0.00	–	–
Hyperia galba	0.13	0.06	0.04	0.02	0.02	0.02	0.01	0.01
Diastylis rathkei	3.45	0.81	0.73	0.33	0.32	0.07	–	–
Jaera sp.	0.00	0.00	0.00	0.00	0.00	–	–	–
Idotea sp.	0.02	–	–	0.00	0.00	–	–	–
Mesidotea entomon	10.75	32.53	32.76	30.17	30.60	27.90	24.22	19.27
Crangon crangon	9.55	3.49	2.60	0.94	0.78	0.37	0.07	0.06
Bivalvia:	0.02	0.12	0.07	0.02	0.02	0.03	0.01	0.01
Pisces:								
Gobiidae	13.78	3.10	2.37	1.49	1.44	0.46	0.34	0.31
Sprattus sprattus	0.47	8.73	12.54	14.54	13.19	11.57	8.99	5.08
Clupea harengus	–	6.13	9.01	20.52	24.22	44.02	36.50	39.82
Clupeidae indeterm.	2.89	14.65	17.19	15.42	14.32	6.11	4.05	5.08
Osmerus eperlanus	–	–	0.06	0.19	0.18	–	–	–
Gasterosteus aculeatus	–	0.04	0.33	0.47	0.47	0.11	0.02	0.02
Syngnathus typhle	–	–	0.00	0.02	0.02	–	0.00	0.00
Belone belone	–	–	0.17	–	–	–	0.01	0.01
Ammodytidae	0.08	0.40	0.67	0.69	0.55	1.75	0.62	0.69
Rutilus rutilus	–	–	–	–	–	–	1.35	1.35
Pholis gunnelus	–	0.23	0.12	0.00	–	–	–	–
Lumpenus lampretaeformis	–	0.14	0.07	–	–	–	–	–
Zoarces viviparus	–	–	–	0.22	0.22	–	–	–
Agonus cataphractus	–	–	0.01	0.01	–	–	–	–
Platichthys flesus	0.18	0.01	0.02	0.02	0.01	0.92	0.93	2.02
Enchelyopus cimbrius	–	–	0.90	2.97	3.05	8.18	11.45	10.57
Gadus morhua	0.24	0.78	1.01	8.99	9.54	8.41	14.00	14.26
indeterminata	0.58	3.69	3.73	3.08	2.78	3.19	2.67	2.43
ova	–	0.12	0.06	–	–	–	–	–
Daily coefficient	262.56	132.64	126.56	116.11	115.58	116.73	105.75	101.40

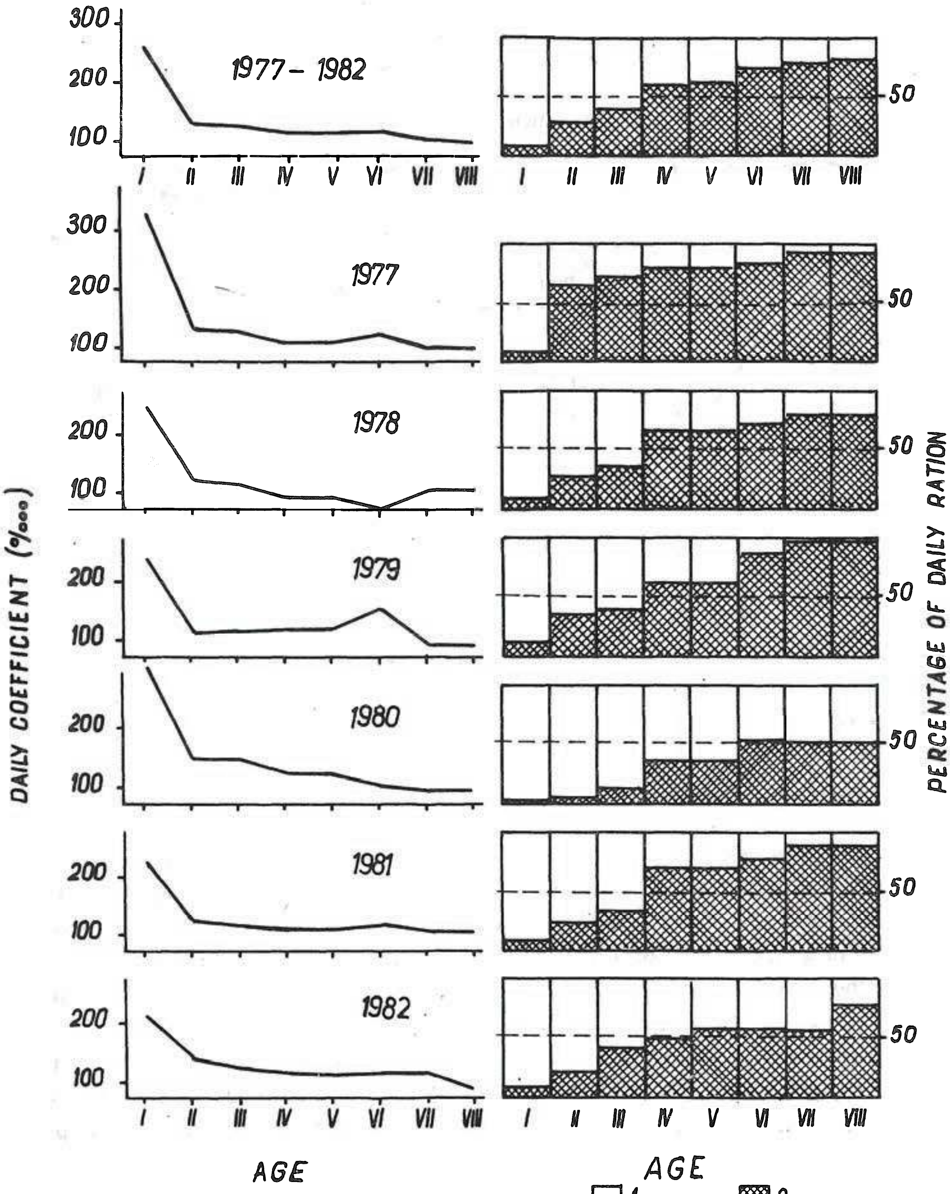

Fig. 2. Amount of food (to the left) and fish: invertebrates ratio in food of cod of various age groups (1 = invertebrates; 2 = fish)

Table 3

Relationship between amount of food eaten by cod of various age and contribution of fish and invertebrates to food ration, and variability of these characters in various years within 1977–1982 ($\bar{x}$ = long -term mean; S = standard deviation; v = coefficient of variation; r = correlation coefficient)

Cod age group		Daily coefficient $^0/_{000}$	Contribution to daily ration	
			Pisces %	Invertebrata %
I	$\bar{x}$	262.09	7.15	92.85
	S	47.24	3.76	3.76
	v	18.02	52.60	4.05
	r		−0.6631	0.6631
II–IV	$\bar{x}$	121.50	52.35	47.65
	S	11.33	15.86	15.86
	v	9.33	30.29	33.28
	r		−0.4655	0.4655
VII–VIII	$\bar{x}$	103.55	78.87	21.13
	S	5.34	17.50	17.50
	v	5.16	22.18	82.81

If the ratio discussed is measured by the per cent contribution of fish to the daily ration, the coefficient of variation will indicate significant differences (occurring in various calendar years) in all three age categories distinguished (Table 3). The contribution of fish in age group I is, however, so small, that no biological significance can be involved, the more so that the same standard deviation referred to the invertebrate percentage yields the coefficient of variation amouting to 4.05 only.

Neither the daily coefficient nor the fish: invertebrates ratio shows (Fig. 2) a definite trend of changes within the period of study (1977–1982). The differences described above appear rather irregularly. However, it would be worthwile to find a relationship, if any, between the two indices, i.e., if a higher proportion of fish (or invertebrates) in a given year would affect the value of daily coefficients. Correlation coefficients given in Table 3 do not allow to accept this hypothesis. Although there is an inverse relationship between daily coefficient and fish percentage in food in groups I and II–VI, the relationship, particularly in older fish, is not clear enough to be classified as significant. The relationship was not examined in groups VII and VIII because the daily coefficient variability was too low.

Table 4

Relationship between amounts and composition of fish and invertebrates eaten by cod of various age, and variability of these characters in various calendar years of 1977–1982 ($\bar{x}$, S, v, r as in Table 3)

Cod age group		Pisces		Invertebrata			
		Partial daily coefficient ‱	*Clupeidae*	Partial daily coefficient ‱	*Polychaeta* %	Small crustaceans %	Large crustaceans %
I	$\bar{x}$	17.77	12.68	244.33	39.62	51.47	8.80
	S	8.63	16.63	51.58	11.90	7.80	4.20
	v	48.57	131.13	21.11	30.03	15.15	47.73
	r		0.5528		0.7780	–0.7588	–0.7942
II–VI	$\bar{x}$	61.92	74.64	59.58	18.56	15.15	66.28
	S	19.43	10.28	24.13	15.00	7.50	16.80
	v	31.38	13.77	40.50	80.82	49.50	25.34
	r		0.1345		0.7909	0.2368	–0.8128
VII–VIII	$\bar{x}$	81.27	61.55	22.28			
	S	17.50	17.77	18.16			
	v	21.56	28.87	81.53			
	r		–0.1007				

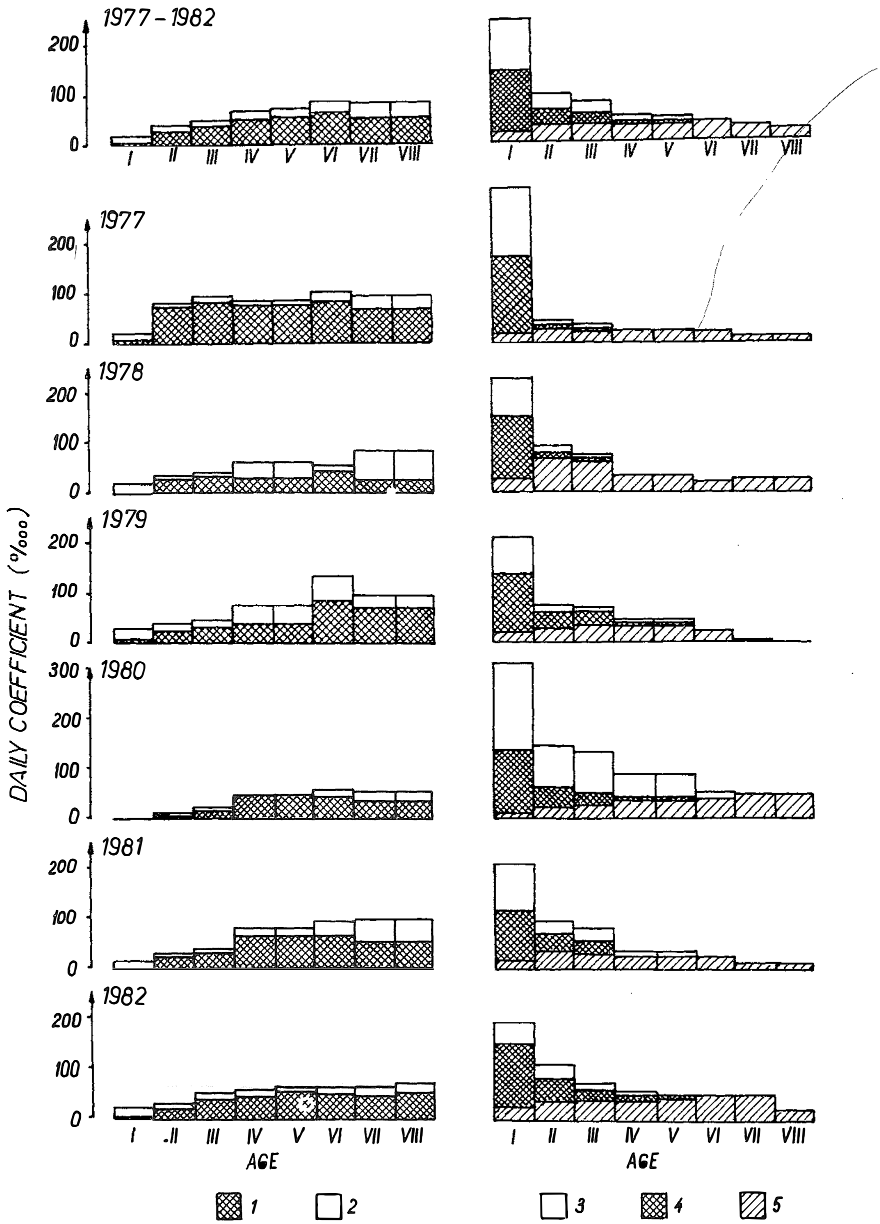

Fig. 3. Amount and composition of fish (to the left) and invertebrates (to the right) eaten by cod of various age groups (1 = *Clupeidae;* 2 = various fish; 3 = *Polychaeta;* 4 = small *Crustacea;* 5 = large *Crustacea*)

The two groups of items discussed above are examined separately in Fig. 3 and Table 4. In the case of fishes, the amount of clupeids relative to other species is considered. As for the invertebrates, three groups are looked at: polychaetes, small crustaceans, and large crustaceans. Fig. 3 shows age-related changes, while Table 4 presents differences between age categories identical as those in Table 3.

The long-term means point to the *Clupeidae* as dominants among the fish food items, beginning at age group II, their predominance in the food of the oldest cod (groups VII and VIII) being, however, less conspicuous. Considerable variation, both in the amounts of fish consumed and in clupeid contribution, was recorded over the years of study. The two variables are not mutually correlated. This is shown in Fig. 3 demonstrating the highest contribution of clupeids to be recorded in 1977 and 1980, i.e., the years of the highest and smallest fish consumption, respectively. Very low correlation coefficients within the age group range of II–VIII confirm this observation. A slightly higher correlation coefficient in group I is of no significant importance in view of very low indices of fish contribution to the food and clupeid percentage.

To consider the importance of herring and sprat, as members of the *Clupeidae,* in the food of cod, is rendered difficult by the fact of most individuals found in stomachs remaining unidentified because of strong digestion. Fig. 4 (to the left) shows the long-term data to demonstrate a tendency of a gradual decrease in the sprat contribution and an increase in the herring contribution among the clupeids consumed by older and older cod. The contribution of unidentified clupeids decreases clearly, too, which results from an increased size of individuals eaten by older cod. The uncertainty as to the classification of fish found in stomachs as sprat or herring concerns those individuals only that do not exceed the maximum sprat size.

In various calendar years the sprat: herring ratio fluctuates considerably; in this case, however, the fluctuations are time-dependent, as opposed to variability in factors considered previously. The sprat contribution decreased gradually from 1977 down to the minimum in 1979 and increases gradually thereafter again. The herring contribution showed an inverse pattern, while unidentified clupeids varied the least from year to year. The changes are presented in Fig. 5 for age groups II–VI; for these cod the clupeids are the most important food items and the herring:sprat ratio is most even. The same figure presents the total uptake of clupeids (as measured with partial daily coefficients). In this case, if the exceptionally high value in 1977 is disregarded, no regular tendency of changes with time is evident. That means that there is no relation between the amount of clupeids taken up and their composition. Very low correlation coefficients for sprat and herring (Table 5) confirm this conclusion. The high (negative) correlation coefficient obtained (in spite of a narrow range of variation) for unidentified clupeids can be somewhat surprising in this context. It means that there is a close inverse relationship between the amount of clupeids consumed and the amount of unidentified individuals among them. This relationship can be easily accounted for because the strongest-digested individuals (i.e., difficult to identify) occur primarily in poorly-filled stomachs, that is in periods of less intensive feeding.

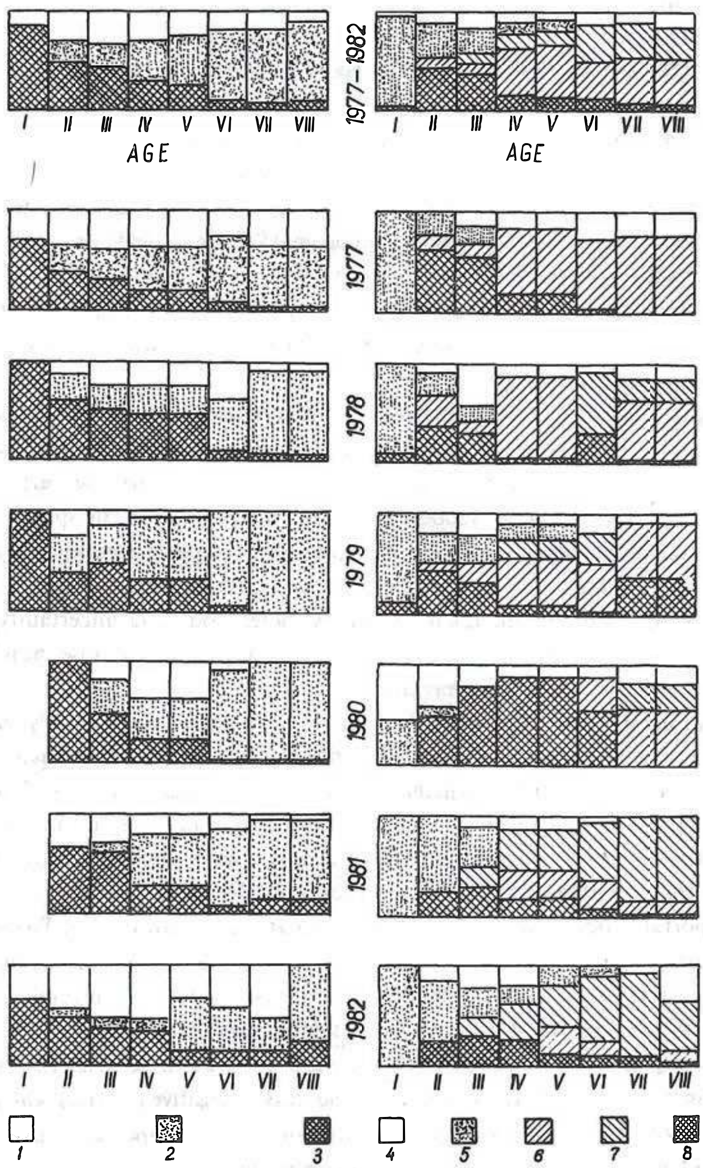

Fig. 4. Composition of *Clupeidae* (to the left) and other fish (to the right) eaten by cod of various age groups (1 = *Sprattus sprattus;* 2 = *Clupea harengus;* 3 = non-determined clupeids; 4 = various other species; 5 = *Gobiidae;* 6 = *Gadus morhua;* 7 = *Enchelyopus cimbrius;* 8 = non-identified species)

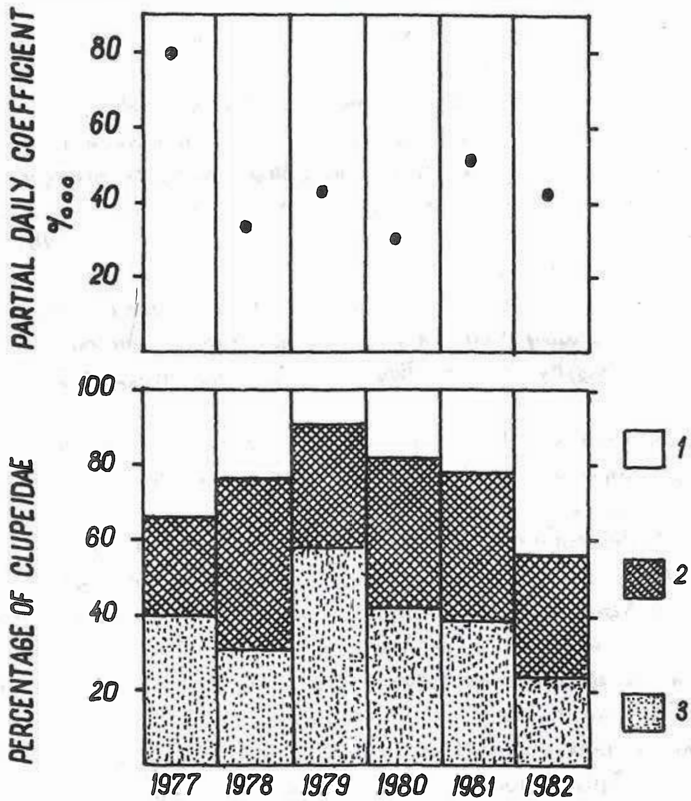

Fig. 5. Amount and composition of *Clupeidae* eaten by cod of age groups II–VI (1 = *Sprattus sprattus;* 2 = non-identified *Clupeidae;* 3 = *Clupea harengus*)

Table 5

Relationship between amount and composition of *Clupeidae* eaten by cod of various age, and variability of these characters in various calendar years of 1977–1982 ($\bar{x}$, S, v, r as in Table 3)

	Partial daily coefficient $^0/_{000}$	*Sprattus sprattus* %	*Clupea harengus* %	*Clupeidae indeterm.* %
$\bar{x}$	46.43	24.96	39.02	36.02
S	17.98	12.30	11.41	7.18
v	38.73	49.28	29.25	19.93
r		0.3554	0.1018	–0.7899

The composition of non-clupeid fish food items is presented in Fig. 4 (to the right). In age group I, it is almost exclusively the *Gobiidae.* Although the "other" made up about a half in 1980, it was in that year that the lowest percentage of fish (1%) in the food of the smallest cod was recorded. Gobiids gradually loose their importance in older age groups, the importance of two large-sized species increasing, namely *Enchelyopus cimbrius* and *Gadus morhua* itself. The two species are the most important items, apart from clupeids, in food rations from age group VI on. In some years (1978, 1979, 1981; Fig. 3) these species reach – and even exceed – 50% of the total fish weight consumed. There is additionally a tendency to shift the importance of the two species in time: the cod play a markedly greater role until 1980, while in 1981 and 1982 *E. cimbrius* seems to be more important. The category "unidentified" concerns the strongest-digested specimens retained in stomachs as skeletal fragments. One can suppose that some of them belonged to the clupeids. Their contribution to the total food weight is less than 3%. In 1980, a relatively high proportion of "unidentified" among non-clupeids resulted from cod feeding mostly on clupeids in that year (Fig. 3).

The invertebrates consumed by cod are divided into 3 groups: polychaetes, large crustaceans (*Mesidotea* and *Crangon*), and small crustaceans (remaining taxa). It was only the *Priapulidae, Nemertini,* and *Bivalvia* that were omitted; their amounts consumed, however, were so low (Table 2) that they can be disregarded completely. Variations in importance of the three above-mentioned groups as food of cod of various age are presented in Fig. 3 (to the right). In age group I, polychaetes and small crustaceans taken together make up more than 90% of the mean daily ration; in group II, however, large crustaceans are of equal importance. The consumption of large crustaceans by the older cod (as measured by the partial daily coefficient value) is maintained at a more or less even level, while the uptake of polychaetes and small crustaceans drops rapidly; from group VI onwards they hardly play any role in the food. The pattern described is repeated from one year to the next, the numerical proportions, however, varying considerably. Fig. 3 shows, for example, the year 1980 to be exceptional in terms of the amount of polychaetes consumed (their role being still considerable in age group VI), while the year 1978 showed a particularly high contribution of large crustaceans. The variability of invertebrate composition is related to the magnitude of consumption of this group as indicated by data in Table 4: there is a positive correlation between the amount of invertebrates taken up and the percentage of polychaetes, the correlation being negative with the percentage of large crustaceans. This observation concerns both age group I and groups II–VI. The correlation coefficients, oscillating around 0.8, indicate the significance of the correlation. Additionally, age group I showed a rather close negative correlation with small crustaceans, which did not occur in groups II–VI. This type of relationship for groups VII and VIII is not considered as there is only one invertebrate item present in the food, namely *Mesidotea entomon.*

Table 2 shows both polychaetes and large crustaceans to have a single dominant item: *Antinoella sarsi* among the first and *Mesidotea entomon* among the other. It is only in the youngest cod food that another polychaete, *Nereis diversicolor,* was of some importance,

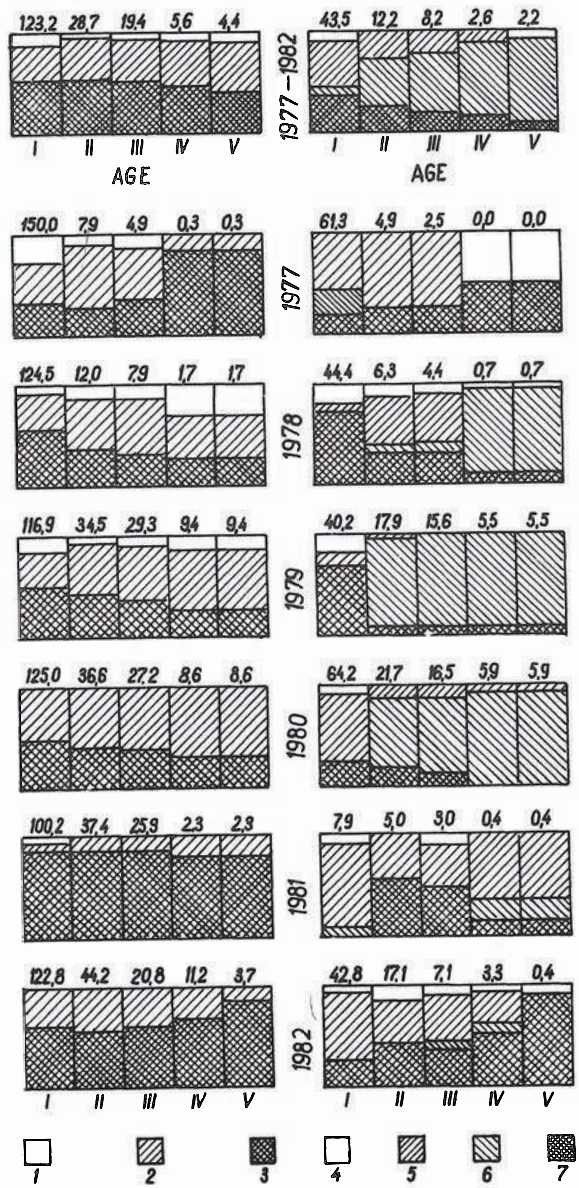

Fig. 6. Amount and composition of small *Crustacea* (to the left) and *Amphipoda* (to the right) eaten by cod of various age groups (1 = various taxa; 2 = *Amphipoda;* 3 = *Mysis mixta;* 4 = various taxa; 5 = *Pontoporeia affinis;* 6 = *P. femorata;* 7 = *Gammarus sp.*). Numbers above graphs denote partial daily coefficients

Table 6

Relationship between amount and composition of small *Crustacea* and *Amphipoda* eaten by cod of various age, and variability of these characters in various calendar years within 1977–1982 ($\bar{x}$, S, v, r as in Table 3)

Cod age group		Small *Crustacea*				*Amphipoda*				
		Partial daily coefficient $^0/_{000}$	*Mysis* %	*Amphipoda* %	Other %	Partial daily coefficient $^0/_{000}$	*Pontop. affinis* %	*Pontop. femor.* %	*Gammarus sp.* %	Other %
I	$\bar{x}$	123.23	55.36	34.16	10.48	43.45	47.76	6.63	35.83	9.77
	S	16.07	18.48	14.38	9.90	20.11	32.70	9.61	29.01	8.19
	v	13.04	33.37	42.09	94.44	46.28	68.46	144.94	80.97	83.87
	r		–0.9023	0.7061	0.6583		–0.1937	0.1022	0.2207	–0.1212
II–V	$\bar{x}$	14.50	52.14	40.85	7.01	6.28	31.94	39.39	26.12	2.54
	S	7.83	22.11	18.23	7.98	4.68	26.10	39.00	18.56	3.28
	v	54.00	42.41	44.63	113.86	74.51	81.70	99.01	71.07	129.24
	r		0.0891	0.1479	–0.5708		–0.8524	0.7989	–0.4379	–0.2607

along with *Crangon crangon* among the crustaceans. In older age groups the dominant species make up more than 90% of the polychaetes and crustaceans. It can be thus assumed that the conclusions presented above with regard to polychaetes and large crustaceans are true also with respect to the dominant species. On the other hand, the composition of small crustaceans is more diversified. It is shown in Fig. 6 as related to cod age; the cod older than group V are disregarded due to the small crustaceans' contribution being lower than 1%.

Fig. 6 shows the group of small crustaceans to consist mainly of *Mysis mixta* and *Amphipoda*, the latter being composed primarily of *Pontoporeia affinis*, *P. femorata*, and *Gammarus sp.* Insofar as there is no clear-cut age-dependent variation in the *Mysis: Amphipoda* ratio, the variations of this kind do occur among amphipods and involve a decrease in contributions of *Pontoporeia affinis* and *Gammarus sp.*, and an increase in the *P. femorata* contribution.

Both the *Mysis:Amphipoda* ratio and the contribution of amphipods varied strongly from year to year. The changes were not completely irregular as Fig. 6 shows the *Mysis* contribution to have increased considerably in the last two years of study, while the years 1979 and 1980 were characteristic in their particularly high percentages of *P. femorata.* Table 6 lists indices illustrating the importance of the food items discussed for the food of age group I and groups II–V. Additionally, correlation coefficients are given for the relationship between the amount and composition of a given group of food items. The relationship proved significant in two cases. The first is the age group I cod taking up an amount of small crustaceans inversely proportional to the *Mysis mixta* contribution and proportional to that of amphipods. The amount of small crustaceans varies within rather narrow limits here as evidenced by a relatively low coefficient of variation. No such relationship was found for the older cod. However, among the latter a correlation was found to exist between the amount and composition of amphipods, which did not occur in the age group I cod. The correlation is associated with the contribution of *P. femorata*, negligible in the food of the youngest cod feeding mainly on such amphipods as *P. affinis* and *Gammarus sp.* The older cod, although consuming fewer amphipods, have *P. femorata* as a dominant in their amphipod food. The *P. femorata* domination is visible even in the longterm means although, as seen in Fig. 6, the species in question dominated in 1979 and 1980 only. The amount of amphipods consumed in those years were, however, much higher than when *P. affinis* was prevalent. Thus the correlation coefficients given in Table 6 demonstrate a significant negative correlation between the amount of amphipods consumed and the *P. affinis* contribution, and a positive one in the case of *P. femorata.*

DISCUSSION

It is difficult to discuss the composition and amount of cod food owing to changes occurring with cod size increase. As the fish grow fast and attain considerable size, changes in the amount and composition of food ensue so fast and are of such magnitude that, in order to follow them, individuals from many different length or age classes should be viewed separately. On the one hand, materials examined would be thus divided into numerous subsets, which would affect the reliability of the materials, and on the other, it would be impossible to use population means, which would confound conclusions. The separation of age groups used here showed the amount of food uptake (as measured by daily coefficients) to change relatively slightly within age groups II–VI. Based on that, to determine the food amount-food composition relationship as well as changes in the two variables, mean values for cod of the age limits mentioned were used and given in tables along with data on group I and groups VII–VIII. This is a simplification aimed at perceiving the results in a clear and generalised way. It should, however, be borne in mind that only one variable, viz. the amount of food, is relatively stable. On the other hand, the composition of food is subject to rather regular changes, also within age limits discussed, the changes being particularly well-marked in long-term data. Thus one may conclude that in the future, when a longer period will be covered, the food amount-food composition relationship should be analysed for each age group separately.

Another reservation comes to mind with respect to the data on age group I. They differ considerably from those obtained in group II and the following ones, not only in terms of food composition indices, but also in the food amount. Age group I daily coefficients are, on the average, twice those of group II. This is an evidence of a clearly higher feeding intensity of juvenile cod. On the other hand, analyses for 1982, when the juvenile cod were divided into 5-cm length classes, showed the feeding intensity in group I to change within wide limits, too; the younger (smaller) the fish, the higher the daily coefficient. In this situation, mean values calculated for group I (covering the length range of 5–25 cm) cannot characterise the population adequately as a given calendar year's mean is affected, apart from biological factors, also by the length distribution in the sample. Thus the feeding of juvenile cod should be analysed adequately, the materials being divided into narrow length classes.

The amount and composition of cod food is affected by seasonality, both in the Baltic (Chrzan, 1962; Strzyżewska, 1962; Uzars, 1975; Załachowski, 1977) and in other seas (Daan, 1973; Stanek, 1973). Thus, to render the mean indices for various calendar years comparable, the seasonal distribution of samples should be similar from one year to the next. The materials for this study were collected with this idea on mind, but some deviations from the sampling programme assumed could not be avoided. They could have resulted in the increased indices of variability, particularly those pertaining to the less important food items. Whenever the dominants such as *Antinoella, Mesidotea,* and the *Clupeidae* were consumed during a year deviating, in a way, from the long-term mean, this was observed usually in every season.

If the mean results for the entire period of study (1977–1982) are compared with earlier data for 1972–1974 (Załachowski, 1977), it is difficult to find differences indicating a clear-cut trend of changes. Daily coefficients in both analyses are of the same order of magnitude and similar dynamics of changes with increasing size of fish. Similar in the two periods are also proportions of fish and invertebrates in a daily ration of cod of the same size as well as the dominants of each of the two food groups. Obviously, there are differences, too. They are noticeable mainly in the importance of various items. One of the differences, a conspicuous one because it concerns the dominants, is the clearly more important role of polychaetes in the earlier period of the two compared. *Mesidotea entomon* occupied a less prominent position in the food. This difference, however, can hardly be regarded as a sign of long-term continuous changes. Considering the analysis of feeding by calendar year, carried out for the second period of the two compared, the years when polychaetes were clearly predominating (also in the food of cod older than 1 yr) are sporadic, but when they do occur, the polychaete domination can be so strong as to affect a long-term mean, e.g. the year 1980.

The food composition in a given year is certainly influenced by environmental conditions. Variations in polychaete contributions to the food exemplify such an influence. Decidedly, the dominant among polychaetes in the Baltic cod food is *Antinoella sarsi*, a species numerous only in stomachs of those cod caught at large depths (80–100 m). At these depths the polychaete is practically the only invertebrate that can be used as food by cod. Consequently, the polychaete's role in food decreases in importance when Baltic deeps are inaccessible due to oxygen deficits, and increases with an improvement in the oxygen regime. Similar relationships can be found with respect to other food items, too. Ipatov and Uzars (1981) noted, for example, that during years with mild winters the resources of *Mysis mixta*, a cold water dweller and a food item for herring, tend to become reduced; the herring do not form dense shoals, becoming thus less available to cod. However, such relationships are not always confirmed in the present paper. Following the mild winters of 1976/1977 and 1977/1978 the *Mysis* consumption by cod was indeed low, but it was related to a low consumption of herring in 1978 only. The severe winter of 1978/1979 induced no increase in consumption of *Mysis*. The increase, on the other hand, occurred after the mild winter of 1980/1981, the high level of this consumption being maintained also the next year, following the severe winter of 1981/1982.

A straightforward relationship between environmental conditions and magnitude of consumption can be observed in a few of the food items only. Most often the relationship is presumably obscured by food selectivity. The problem of selectivity is particularly difficult to study in cod, a euryphagous species consuming food consisting of benthic and pelagic organisms. For example, without any further detailed studies, it is difficult to decide whether the variation in fish vs. invertebrates ratio observed in various years is a result of analogous changes in biomass of the two groups of organisms in the sea or of a cod preference towards some components of the two groups. The lowest, over the long-term period of study, level of fish uptake recorded in 1980, could have resulted from a considerable drop in the herring and, particularly, sprat stocks in the Baltic (Elwertowski, 1982), but it can be also explained by the presence of numerous *Antinoella sarsi*, assuming cod's preference towards this polychaete. A high positive coefficient of correlation between the amounts of invertebrates eaten and the polychaete contribution, accompanied by an equally high but negative correlation for large crustaceans, seems to indicate that *Antinoella* is preferred over *Mesidotea entomon.* It is, however, the only instance of a close correlation between an index of food consumed and a contribution of any of the dominants. Another case of a positive correlation (*Amphipoda* vs. *Pontoporeia femorata*) concerned items of a low overall importance in food.

One of the most significant findings provided by the analysis of cod feeding in various years is a high variability of food composition at a relatively narrow range of variations in the amount of food. This finding does not concern the age group I cod for reasons discussed at the beginning of this chapter. A relative stability of consumption indices accompanied by the diversified composition of a food ration proves the cod to be able to compensate for a deficit in certain type of items by eating increased amounts of other ones. A lower fish consumption is made up by taking up more invertebrates, or vice versa, depending on a preference. A lower consumption of the *Clupeidae* is compensated for by intensified cannibalism and consumption of *Enchelyopus cimbrius.* In view of the reduced sprat resources, the pressure on herring increases, and so on. It should be, however, remembered that this rule is true with respect to the food weight only, while the trophic conditions are described by the amount of energy taken up. The cod food contains items differing both in their energy contents and the energy availability to the consumer. From this point of view, a unit weight of *Mesidotea* is certainly not equal to a unit weight of clupeids. Further studies, therefore, should tackle the problem of estimating energy budgets. A tentative attempt to calculate such budgets was based on a 5-yr period of study (Załachowski, 1985). Similar, but more precise estimates for various calendar years require the knowledge of energy equivalents (and seasonal variability thereof) of all food items.

CONCLUSIONS

1. The studies confirmed the pattern of growth-dependent changes in cod food amount and composition, known from earlier works. At the same time, the amount and composition of food as well as their cod growth-related dynamics were found to deviate considerably in various calendar years from the long-term mean.
2. The above-mentioned deviations are larger with respect to the composition than the amount (weight) of food. This seems to evidence the ability of cod to compensate for deficits in some items by increased consumption of other ones. This ability concerns both the general fish vs. invertebrates relationship and the most important items in the two groups.
3. The food composition changes irregularly from year to year. Changes showing a more long-lasting trend were observed in a few items only, such as *Sprattus sprattus* in particular, and – to a lower extent – *Mysis mixta, Pontoporeia, Enchelyopus cimbrius,* and *Gadus morhua.*

4. Within 1977–1982, the food of cod showed no greater differences in its amount and importance of main dominants from the results obtained in the fifties and early seventies than between various consecutive calendar years. This is an evidence of a lack of any stable and long-lasting trend in changes of principal feeding indices.
5. In two instances only a close relationship between food amount and composition was observed. The amount of invertebrates eaten was directly related to the contribution of Antinoella sarsi and inversely to that of Mesidotea entomon. The amount of amphipods taken up by the cod older than 1 yr was directly related to the contribution of Pontoporeia femorata. On the other hand, no relationship was found between the food amount (weight) and the contribution of fish and between the amount and species composition of the fish eaten.

REFERENCES

Anonim, 1981: Draft manual for the stomach sampling project – Neth. Inst. for Fish. Invest.

Bajkov A.D., 1935: How to estimate the daily food consumption of fish under natural conditions. Trans. Am. Fish. Soc., 65: 288–289.

Chrzan F., 1962: Pokarm i odżywianie się dorsza w Zatoce Gdańskiej (Food and feeding of cod in Gdańsk Bay) Prace MIR, 11/A: 161–199.

Daan N., 1973: Aquantitative analysis of the food intake of North Sea cod Gadus morhua. Neth. J. of Sea res., 6/4/:479–517.

Elwertowski J., 1982: Zasoby ryb użytkowych Bałtyku (Baltic commercial fish resources) MIR Gdynia, Studia i materiały, B, 50.

Ipatov W.W., Uzars D.W., 1981: Značenije obespiečennosti piščej v formirovanii sezonnych izmienienij metabolizma u baltijskoj treski. – Fish.-Forsh. Wiss. Schr., 19/2/: 65–68.

Reimann Z., 1955: Odżywianie się i pokarm młodocianego dorsza (Gadus callarias) południowego Bałtyku (Food and feeding of young cod in the Southern Baltic). Prace MIR, 8: 171–186.

Stanek E., 1973: Obserwacje nad pokarmem i odżywianiem się dorsza (Gadus morhua L.) wód Labradoru, Nowej Fundlandii i Nowej Szkocji. (Observations on food and feeding of cod in Labrador, New Foundland and Nova Scotia waters) – Prace MIR, 17/A:7–26.

Strzyżewska K., 1959: Odżywianie się i pokarm dorsza bałtyckiego (Food and feeding of Baltic cod) – „Dorsz bałtycki", Gd. Tow. Nauk.: 45–59.

Strzyżewska K., 1962: Odżywianie się i pokarm dorsza Bałtyku Południowego (Food and feeding of cod in the Southern Baltic) – Prace MIR, 11/A: 387–419.

Uzars D., 1975: Peculiarities of feeding quantitative food consumption of Eastern Baltic cod. – ICES, Baltic fish c-tee C.M./P:4.

Załachowski W., 1977: Ilościowa i ekologiczna analiza pokarmu użytkowanego przez populację dorsza w południowym Bałtyku w latach 1972–1974 (Aquantitative and ecological analysis of food utilized by cod population in the Baltic in the years 1972–1974). – A.R. Szczecin, Rozprawy, No 53.

Załachowski W., 1985: An attempt to apply Bajkov's formula to estimation of food uptake of cod in the Southern Baltic. – Acta Ichthyologica et Pisc., XV, 1.

Włodzimierz Załachowski

ILOŚĆ I SKŁAD POKARMU DORSZY W POŁUDNIOWYM BAŁTYKU W LATACH 1977–1982

STRESZCZENIE

W latach 1977–1982 zbadano żołądki 11098 dorszy złowionych w południowym Bałtyku (rys. 1). Za pomocą wzoru Bajkova wyliczono średnie współczynniki dobowe (całkowite i cząstkowe), charakteryzujące cały okres badań i poszczególne lata kalendarzowe. Stały się one podstawą dla określenia ilości i składu pokarmu pobieranego przez dorsze z grup wieku od I do VIII (tab. 2). Wykazano, że tendencja spadku całkowitego współczynnika dobowego z wiekiem dorszy, przy jednoczesnym wzroście udziału ryb w składzie pokarmu występuje każdego roku (rys. 2), podobnie jak tendencja wzrostu udziału dużych skorupiaków (*Mesidotea entomon*) i spadku udziału wieloszczetów i małych skorupiaków w części pokarmu złożonej z bezkręgowców (rys. 3). Chociaż zmiany ilości i składu pokarmu z wiekiem dorszy układają się z reguły według wyżej opisanych tendencji, to jednak zakres tych zmian w poszczególnych latach kalendarzowych wykazuje silne odchylenia od średniej wieloletniej. Skład pokarmu zmienia się z roku na rok w znacznie szerszym zakresie niż ilość (masa), co wskazuje, że dorsze potrafią rekompensować niedobór jednych składników zwiększonym spożyciem innych. Dlatego w większości przypadków nie występuje korelacja między ilością a składem poszczególnych grup konsumowanych organizmów. Stwierdzono jedynie ścisłą zależność prostą ilości zjadanych bezkręgowców od udziału w nich *Antinoella sarsi* i odwrotną od udziału *Mesidotea entomon* (tabela 4). Zmiany składu pokarmu następują najczęściej nieregularnie z roku na rok. Tylko znaczenie szprota jako składnika *Clupeidae* (rys. 5) zmieniało się według tendencji podporządkowanej dłuższemu okresowi. Mniej wyraźnie tendencja taka zaznaczyła się też w przypadku *Mysis mixta, Pontoporeia, Gadus morhua* i *Enchelyopus cimbrius.*

Włodzimierz Załachowski

КОЛИЧЕСТВЕННЫЙ И КАЧЕСТВЕННЫЙ СОСТАВ ПИЩИ ТРЕСКИ В ЮЖНОЙ ЧАСТИ БАЛТИЙСКОГО БАССЕЙНА В 1977–1982 гг.

Р е з ю м е

В период 1977–1982 исследовано 11098 желудков трески, выловленной в южной части Балтийского бассейна (рис.1). С помощью формулы Байкова вычислены среднесуточные коэффициенты (полные и частичные), характеризующие целый период исследова-

ний и отдельные календарные годы. Они являются основой для определения количества и состава пищи, употребляемой особями трески, в возрастных группах I-VIII (табл.2). Обнаружено, что тенденция уменьшения полного суточного коэффициента с возрастом трески, при одновременном возрастании участия рыб в составе пищи, наблюдается каждый год (Рис.2), как и тенденция возрастания участия больших ракообразных (Mesidotea entomon) и снижения участия полихетов и маленьких ракообразных в составе корма, состоящим из беспозвоночных (рис.3).

Хотя изменения количества и состава пищи с возрастом трески укладываются, как правило, в вышеописанную тенденцию, то предел этих изменений в отдельных календарных годах показывает сильное отклонение от средней многолетней. Состав пищи меняется из года в год в значительных пределах, больших, чем количество (масса), что показывает возможность трески рекомпенсировать нехватку одних составляющих, большим пожиранием других. Поэтому в большинстве случаев не наблюдается корреляции между количеством и качественным составом отдельных групп, употребляемях в пищу организмов. Однако, наблюдали тесную прямую зависимость между количеством съеденных беспозвоночных и участием в них Antinoella sarsi и обратнопропорциональную зависимость участия Mesidotea entomon (табл.4). Изменения в составе пищи наступают с года на год нерегулярно. Только значение шпрота,как составной Clupeidae (рис.5) менялось по тенденции, подчиняющейся длительному периоду. Менее отчётливо такая тенденция определилась в случае *Mysis mixta*, *Pontoporeia*, *Gadus morhua*, *Enchelyopus cimbrius*.

Перевод: к.т.н. Мариуш Лучак

Address:

Doc. dr hab. Włodzimierz ZAŁACHOWSKI
Instytut Ichtiologii
ul. Kazimierza Królewicza 4
SZCZECIN, 71-550
Polska (Poland)

Received: 84.11.20