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Spatial and temporal distribution of flounder fished in the southern Baltic. Analysis of the catch records from Polish cutter logbooks

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Abstract. The results of multidimensional statistical analyses of catch records from cutters which operated in Polish sea areas between 1993 and 2000 indicated that fishing ground was the factor which most influenced variability in the cutter catch rate. These results confirmed differences between the fishing grounds in the Gulf of Gdańsk and the Bornholm Basin. The results of composition analyses of Polish flatfish catches confirmed that flounder dominated and that plaice and brill contributed less than 6%. The catch rate index for flounder was simply assumed to be the same as that for flatfish. The catch rate used to calculate the cutter catch rate index was selected based on four thresholds (>10, >25, >50 and >85%) of the percentage of flatfish in individual hauls. The flatfish catch rate in Polish sea areas grew as the threshold of flatfish occurrence in the hauls increased. Cutter size did not influence the catch rate in statistical sub-division 26 (Gulf of Gdańsk), and the flounder stock in this area is best described by the rate index of 17 m cutters. In sub-divisions 24 and 25 the most representative rate indexes were for 25 m cutters.

Key words: trawl fishery, flounder, flatfish, catch per unit effort (CPUE), target species, by-catch, Baltic Sea.

INTRODUCTION

In terms of the weight of fish caught in the Baltic Sea, flounder (*Platichthys flesus* L.) is the fourth most commonly fished Baltic species following herring, sprat and cod. The annual Baltic flounder catches varied from 9,800 to 17,000 tons in the 1990s. Prior to the Second World War, flounder was a valuable fish species not only for Polish fisheries. The very early introduction of catch regulations on an international level is testament to the importance of flounder and plaice to Baltic fisheries. In 1929 all the countries with interests in flounder fisheries wrote and implemented an international treaty which outlined measures for the rational exploitation of this fish species (Anon. 1929)

The role of flounder in Polish fisheries decreased between the mid 1960s and late 1990s (and in Baltic fisheries from 1975) due to increased catches from fishing grounds outside the Baltic and increased Baltic cod abundance. The decline in Baltic cod stocks since the mid 1980s and the recent, catastrophic state of the cod stock has prompted an increased interest in flounder, and not only in coastal fisheries.

Polish flatfish catches (mainly flounder) are currently at the level of 5,000 tons. Compliance with regulatory catch measures like legal size limits and closed seasons has meant that the fish being caught are larger, which affords consumers such delicacies as flounder fillets.

The increase seen in Baltic flounder catches in the late 1990s was caused by shifting the excess fishing effort created by cod catch limitations to this species. Flounder are caught in nearly all areas of the Baltic Sea, with the exception of the northern part of the Gulf of Bothnia. Variations in annual catches stem from the amount of fishing effort expended, the abundance of generations recruiting to the exploited populations and the availability of the fish due to environmental conditions.

Although there have been results from long series of studies on the age structure of the flounder population in the southern Baltic Sea (statistical sub-division 26), the magnitude of the resources of this species has been evaluated sporadically (Draganik 1978). The fishing mortality coefficient and stock size were estimated with a method in which only the age structure of the caught fish and the natural mortality index (assumed to be constant for all fish age groups) were used. The lack of information regarding the magnitude of the expended fishing effort makes it impossible for fisheries managers to relate the evaluated catch mortality index with current exploitation intensity. No papers have been published to date regarding the estimation of the flounder catch per unit effort index based on available fisheries statistics and changes in this index depending on fishing grounds and year in the southern Baltic Sea. One significant obstacle for publishing such articles if the lack of information which would permit determining which portion of the reported catch effort should be assigned to the biomass of flounder caught annually. Although a small number of Baltic fish species are of interest to fishermen, catches with bottom trawls are primarily opportunist, i.e. the fish caught and landed are those which happen to be within the range of the gear and are of the legal size. If the estimated catch magnitude per unit effort (standard) is known, the annual expended fishing effort can be determined. This index, in combination with the catch mortality index of the exploited stock, allows the current exploitation level to be adjusted to the stock productivity.

The aim of this paper is two-fold. Firstly, cutter types were selected whose catch per unit effort (CPUE), referred to further as catch rate, best illustrates the flatfish concentration in the fishing ground. Secondly, flounder distribution in the southern Baltic Sea is characterized, especially in Polish sea areas, using the registered catch rates (CPUE index) of selected cutter types.

MATERIALS AND METHODS

The material used in the studies (the volume of fish species caught in individual catches of given cutter types divided by haul duration) were extracts from records in the logbooks of Polish cutters which fished with bottom trawls in Polish EEZ in 1993-2000. This data was

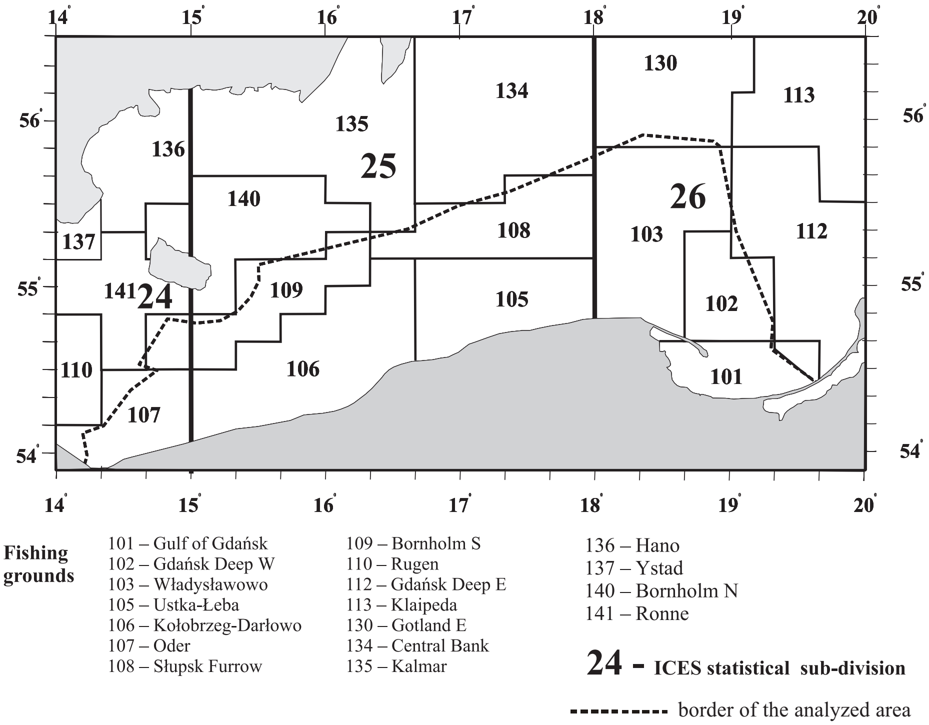


Fig. 1. Analyzed southern Baltic fishing grounds.

verified and saved in dbs format by the Department of Fisheries Economics of the Sea Fisheries Institute. The hauls were analyzed with regard to the location of fishing grounds as denoted in the Atlas of Baltic Fisheries (Długosz and Miłosz 2000; Fig.1). In fisheries science, the concept of fishing ground does not describe an area with well-defined borders. The borders of those listed in the atlas, which are used for fisheries statistics purposes, were precisely delineated and reflect the areas which Polish fishermen have traditionally used to determine where to concentrate their fishing effort.

The Polish cutter fleet operating in Polish sea areas in 1993-2000 consisted of 403-426 cutters Grzenia *et al*. 1998a, 1998b Szostak *et al.* 2000, 2002 (Table 1). The vessels varied significantly in engine power and total length and, consequently, in the size of the

Table 1. Polish cutter fleet, 1993-2000

Length [m]	1993	1994	1995	1996	1997	1998	1999	2000
	Number of cutters fishing in the Baltic Sea							
16 – 20	211	211	200	203	207	213	211	209
21 - 22	33	34	33	31	31	32	31	31
24 – 26	171	171	163	161	152	157	157	152
over 26	6	7	7	8	25	24	23	25
Total	421	423	403	403	415	426	422	417
Tonnage[BRT]	31,100	31,200	30,000	3,0000	31,400	32,100	31,900	32,100

fishing gear used; these features determined the volume of fish caught per time unit, or the so-called fishing power. A better measure of comparing the catch potential of cutters using trawl gear is the power of the main engine. However, due to the format of the available catch reports, the authors were obliged to use cutter length as the basis for classifying the catch per unit effort, which complies with the traditional report format in Polish fisheries statistics. The duration of fishing gear deployment (trawl per fish or haul duration) was reported in minutes, so the "cutter-hour" was used as the unit of fishing effort.

Multidimensional analysis, a full evaluation of the dependencies occurring between fish features and environmental variables, was used to analyze the relationships between the observed catch rate index and the location and period in which the catch was made (Aldebert 1997, Gibbons *et al*. 2002, Maret *et al*. 2002, Matern *et al*. 2002, Welsh *et al.* 2002). Three cutter length classes, 28, 30 and 33 m, were disregarded in the analysis because their frequency of occurrence in the collected materials was below 5% throughout the study period. The remaining data were used in analyses provided that they complied with the condition that one sample (fishing ground in one month and one year) was characterized by at least four variables, i.e. the catch rates of four different cutter types. The data were recalculated using the square-root in order to decrease the impact of long series of zero values in the data files.

Detrended correspondence analysis DCA was done to determine the catch rate variability model, and yielded a variability gradient length of 2.75 SD. On the basis of this, the PCA method, which ascribes the linear response of species systems to changes in environmental parameters, was confirmed to be appropriate (ter Braak and Prentice 1988).

Factors of geographical location (fishing grounds) were coded as nominal factors. A series of total and partial analyses was conducted in order to determine the variability of the rate depending on summed and single variables (Borcard *et al*., 1992). Partial analysis is used to estimate the variability determined by one factor in a part which cannot be explained as the result of the impact of two or more environmental factors. The analyses were done using CANOCO for Windows 4.0 (ter Braak and Šmilauer 1998).

In opportunistic fisheries, identifying the expended fishing effort with the aim of determining the catch rate requires that the separate relations between the weight of particular fish species caught in the trawl codend and the total weight of the fish taken aboard the vessel from each haul are established. These proportions can be used to distribute the effort according to the species which occur in the catch. Theoretically, this method allows for the total fishing effort expended on selected fish species to be estimated. It does not, however, provide a basis on which to pinpoint the species catch to which fishermen intentionally directed the fishing effort. In this paper, four filtration criteria for the registered fishing effort and the related catch of selected fish species (flounder) were used to identify the fishing effort expended on flatfish. The criteria selected to describe the percentage of flounder in the total weight of the catch in registered hauls were >10%, >25%, >50% and >85%.

After filtering the catch statistics from 1993-2000 of Polish cutters in which flatfish were observed (Table 2), the catch rate indexes for four cutter types were determined according to fishing ground, year, month and vessel type. It should be clarified here that in the available statistics Baltic flatfish are not segregated by species, but are described as flatfish or flounder only. Flounder, plaice and brill are the three commercially important

Table 2. Volume of Baltic flatfish in the analyzed Polish catches [in tons]

Year	Fishing ground									Total catches
	101	102	103	105	106	107	108	109	Total	
1993	69.7	51.3	143.6	491.1	1,571.3	563.8	85.3	203.3	3,179.5	5,101
1994	61.4	60.8	189.1	858.5	1,850.4	306.0	233.6	963.8	4,523.6	4,900
1995	196.6	133.9	330.5	597.0	2,833.1	643.9	660.4	1,640.8	7,036.3	9,199
1996	181.0	161.5	702.9	411.8	2,158.8	270.9	566.3	1,904.5	6,357.9	9,193
1997	208.5	81.4	160.9	218.8	1,084.9	617.5	97.1	482.0	2,950.9	6,278
1998	60.7	78.4	247.0	193.6	2,050.7	423.2	124.9	1,136.0	4,314.5	5,834
1999	46.3	26.3	172.2	225.7	1,578.8	467.8	265.8	903.2	3,685.9	5,629
2000	56.3	22.3	169.6	334.0	1,121.8	343.7	193.8	1,121.9	3,363.5	5,604

flatfish species which occur in the southern Baltic Sea. Analyses of samples from selected hauls throughout the study period indicated that the percentage of flounder was never less than 94%; this indicated that the impact of other fish species on variations in the flounder catch rate index were insignificant.

RESULTS

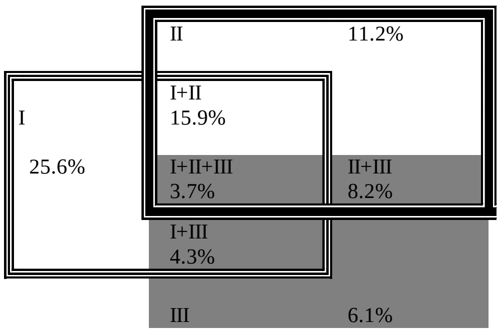
Figure 2 illustrates the location of Polish cutters operating trawls in January-February, July-August and October-November. It also shows the distribution of cutter hauls in 2000 in which the registered percentage of flounder was not less than 25%.

Over 50% of the annual flounder catches in Polish fisheries comes from two out of eight fishing grounds located in Polish sea areas 106 and 109 (Kołobrzeg-Darłowo and Bornholm S). Combined flounder catches reached 25% in fishing grounds 107 and 105 (Odra and Ustka-Łeba) (Fig. 3). The remaining four fishing grounds are of much less importance to flounder catches and were omitted in calculations of the rate index.

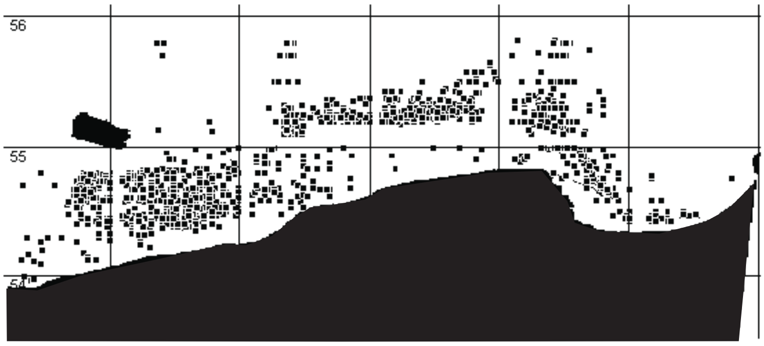
Although one would intuitively suppose that the role of season is significant in catch rate variability, the least important of all the analyzed factors was month.

The first two canonic axes in the multidimensional analysis PCA explained 44.1% of the total rate variability for all of the studied cutter types. Partial analyses indicated that the single factor which primarily explained variability was fishing ground. When considered independently of other factors, it explained up to 25.6% of the total variance in rate. The remaining two independent variables explained the variance to a much smaller degree (Table 3).

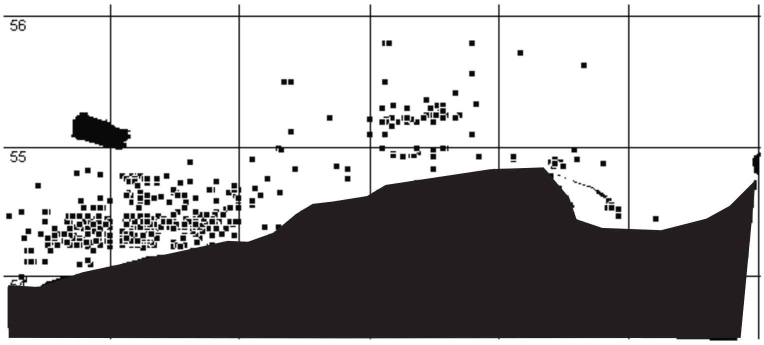
Table 3. Variance of catch rate changes for cutter types depending on independent variables considered jointly and separately in partial PCA analyses



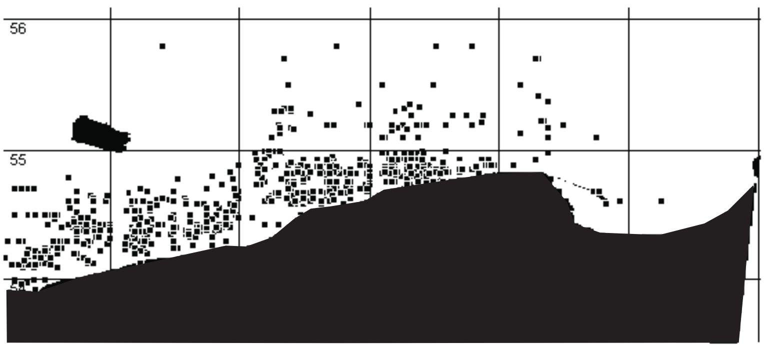
I – Fishing ground; II – Year; III – Month



January - February 2000



July - August 2000



October - November 2000

Fig. 2. Haul distribution of Polish cutters fishing for flatfish in 2000.

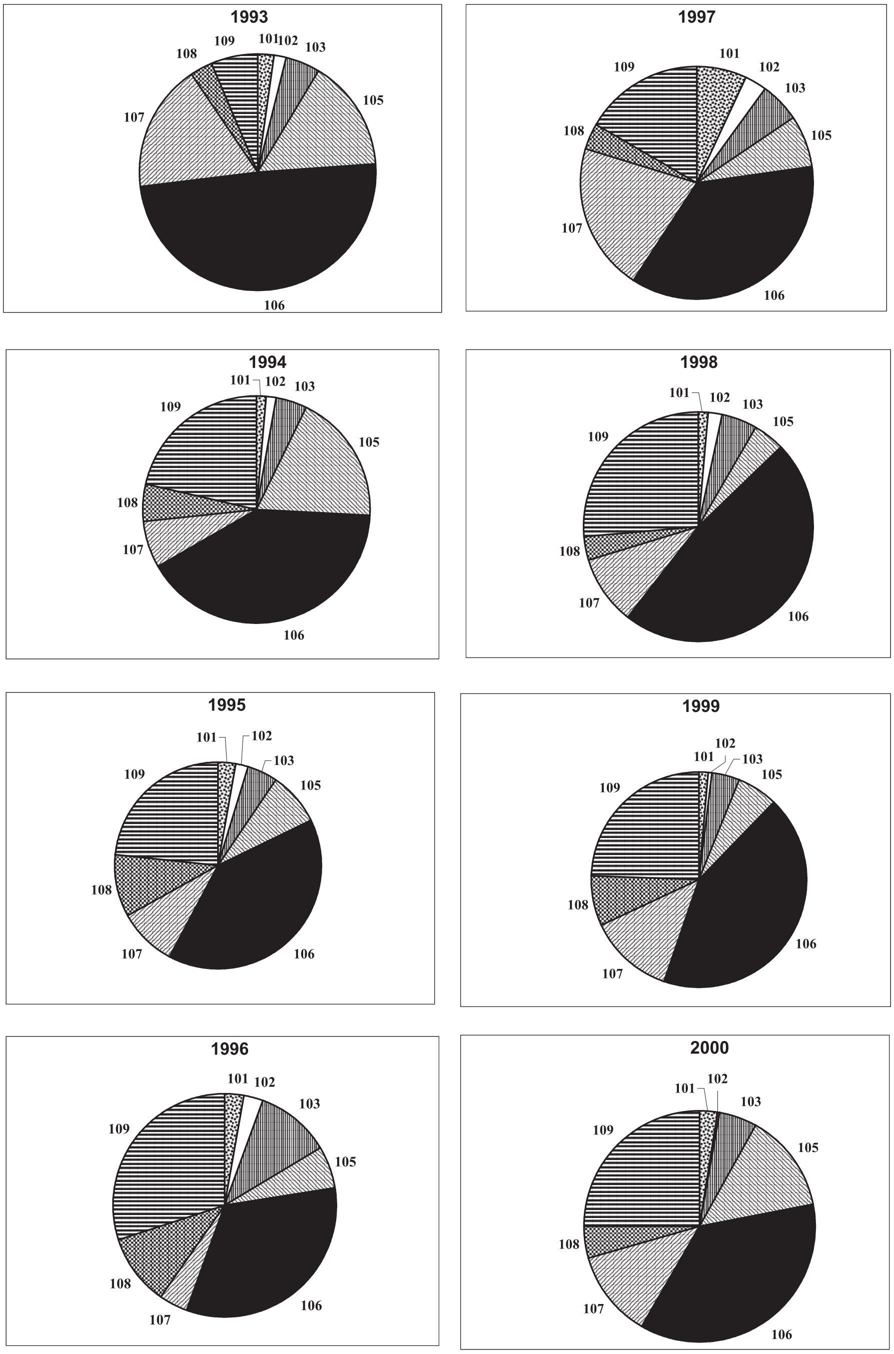


Fig. 3. Flatfish catches taken by Polish cutters in 1993-2000 by fishing ground.

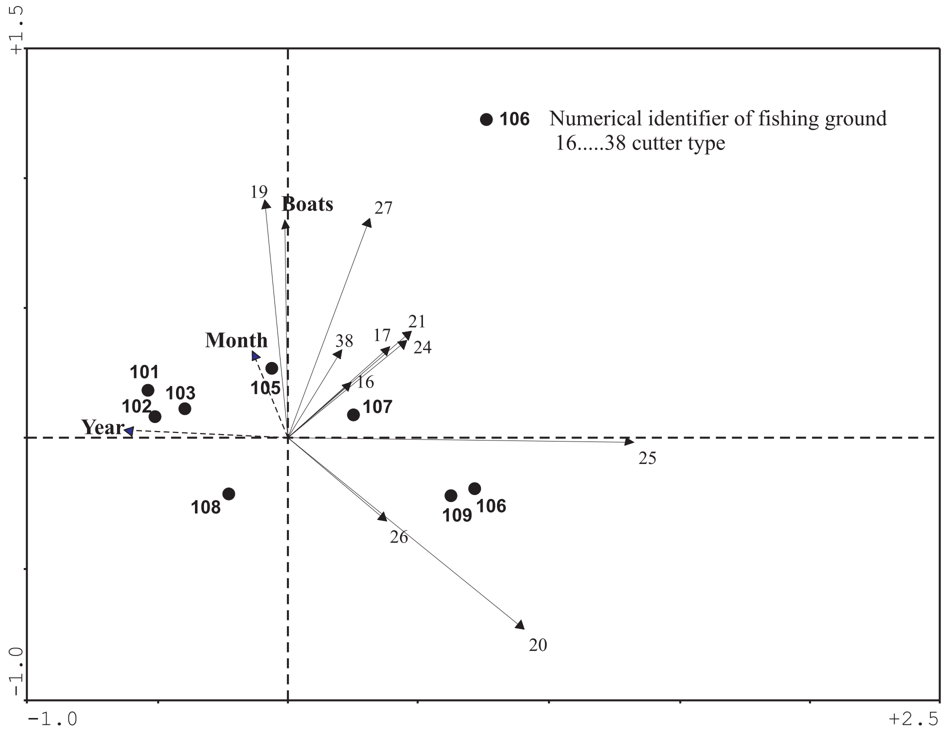


Fig. 4. Ordination diagram depicting the results of principal component analysis (PCA) on flounder catches and environment variables; arrows indicate the direction and increase of CPUE index variability in relation to time (year, month), fishing ground and cutter type.

It should be noted that the majority of variation was explained by these two variables in combination with other factors, especially fishing ground location.

Figure 4 illustrates the results of the PCA analysis of the first two canonic axes. The aggregation of some fishing grounds, coded as nominal factors, was very characteristic. The Gulf of Gdańsk (101-103) fishing grounds are similar with regard to the rates obtained by different cutter types. The same situation occurred in the Kołobrzeg-Darłowo (109) and Bornholm (106) fishing grounds. The rate of the majority of cutter types is inversely proportional to the time vector, and the highest rate variance was observed in the following cutter length classes: 20 m (frequency of occurrence in the analyses: 18%); 19 m (54%); 27 m (21%); deck boats (41%); 25 m cutters (49%).

Only four of the 14 cutter types had a significant impact on flatfish catches. The authors arbitrarily designated a total catch of 2000 tons in 1993-2000 as the measure of the significance of the participation of cutter types in catches. This criterion was applied in this paper to analyze catch statistics and the fishing efforts of cutters (further referred to as 17 m, 21 m, 24 m, 25 m; figures refer to the total cutter length in meters). The percentage of the total flatfish (flounder) catches taken by cutters from these four classes varied depending on the filter applied. When the 11% criterion was applied, it was from 75% to

90%. Increasing the flatfish percentage index to 86% reduced the contribution made by cutters from the four classes above to flatfish catches to 37% - 63%, depending on the year. The greatest contribution was made by 25 m cutters, while the lowest was made by 21 m cutters. During the study period the role of 25 m cutters in flounder catches increased as that of the other vessel types decreased.

In 1993-1994, 17 and 24 m cutters recorded much higher rates in sub-divisions 25 and 24 than in sub-division 26, and since 1995 the rate differences between 17, 21 and 24 m cutters have been large. The rates of 24 m cutters in these sub-divisions were similar during the study period (Fig. 5). Once again it should be emphasized that of the four vessel sizes subjected to detailed analysis, the 24 m cutters contributed the lowest percentage of flatfish (flounder) to the catches. Significant differentiation in the catch rate index, which is a reflection of the local population concentration, was observed for 25 m cutters in 1993-2000.

The catch rates of the four selected cutter types in Polish sea areas varied temporally and according to which criteria of flounder percentage in the total weight of the catch was applied (Table 4). When the cutters are larger, especially the 25 m type, the criterion of flatfish percentage in catches does not influence the size tendency of the catch rate index. The catch rates of the smaller cutters (17 m and 21 m) exhibit different trends. These are most apparent in the last of the analyzed series of years, and, with the 11% and 26% filters,

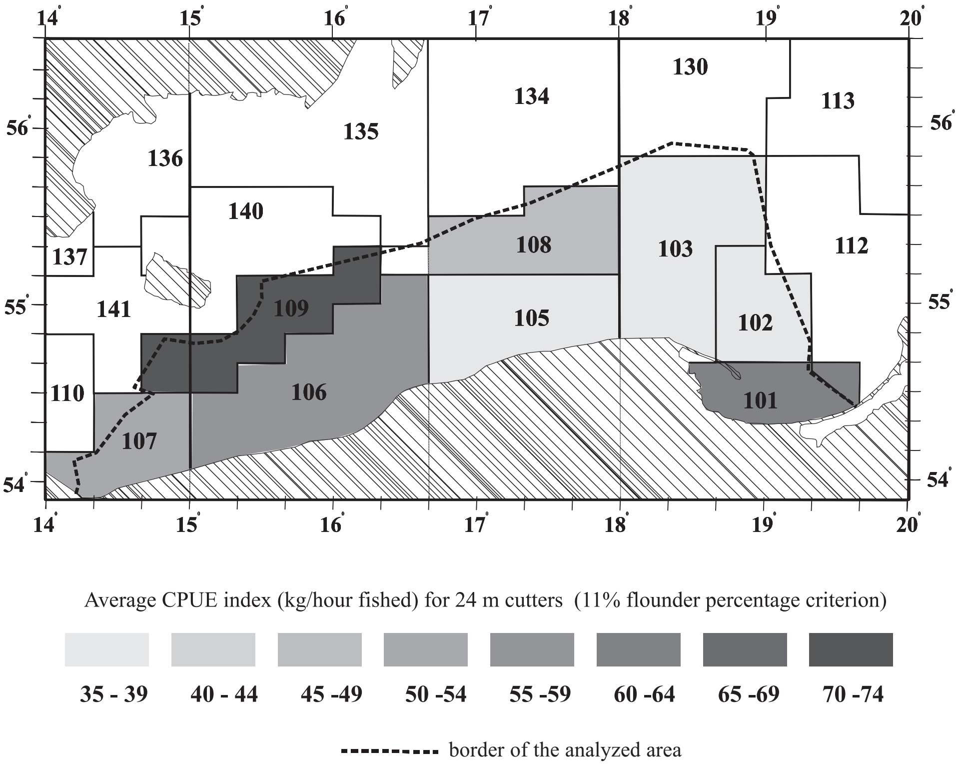


Fig. 5. Distribution of the catch rate for 24 m cutters (average for 1993-2000, 11% flounder percentage criterion).

Table 4. Catch rates for flounder fished by Polish cutters in 1993-2000 (kg/hour fished)

17 m cutters

Year	Flounder percentage criterion in hauls			
	11%	26%	51%	86%
1993	62	66	70	75
1994	55	61	68	79
1995	56	63	73	84
1996	44	51	62	75
1997	31	35	39	44
1998	25	30	38	44
1999	24	37	38	47
2000	23	28	38	52

24 m cutters

Year	Flounder percentage criterion in hauls			
	11%	26%	51%	86%
1993	77	85	92	101
1994	77	84	95	113
1995	70	78	90	109
1996	63	77	96	113
1997	34	42	46	48
1998	34	43	60	76
1999	26	41	43	66
2000	29	38	51	87

21 m cutters

Year	Flounder percentage criterion in hauls			
	11%	26%	51%	86%
1993	67	73	77	85
1994	52	58	65	71
1995	59	71	86	101
1996	57	69	84	110
1997	35	44	49	55
1998	31	39	50	62
1999	26	43	52	62
2000	29	39	57	81

25 m cutters

Year	Flounder percentage criterion in hauls			
	11%	26%	51%	86%
1993	149	160	180	213
1994	150	166	196	242
1995	137	158	184	215
1996	141	169	191	234
1997	79	94	109	118
1998	101	114	130	151
1999	86	96	114	133
2000	116	135	155	182

they were smaller than in the previous year. Increasing the size of the flatfish criterion resulted in the reverse situation. The distribution of catch rates within the analyzed area was polarized. The highest rates were recorded in fishing grounds 109, 106 and 101 (Fig. 6). Fishing ground 101 is separated from the other two by an area with much lower rates. The high catch rate index in fishing grounds 109 and 106 is correlated with catch magnitude (over 50% of Polish cutter flounder catches come from these fishing grounds), while the contribution of cutter catches from fishing ground 101 to the total cutter flounder catch is low (Fig. 3). The spatial separation of high rates that was observed may be the result of two separate flounder populations in the analyzed area.

The tendencies in the magnitude of the effective fishing effort directed at flatfish catches (depending on the criterion used) are presented in Figure 7. The results of the analyses indicate that the fishing effort of 17 and 21 m cutters conducting directed flatfish catches decreased over the last three years. This tendency is not as obvious when a different filter is applied.

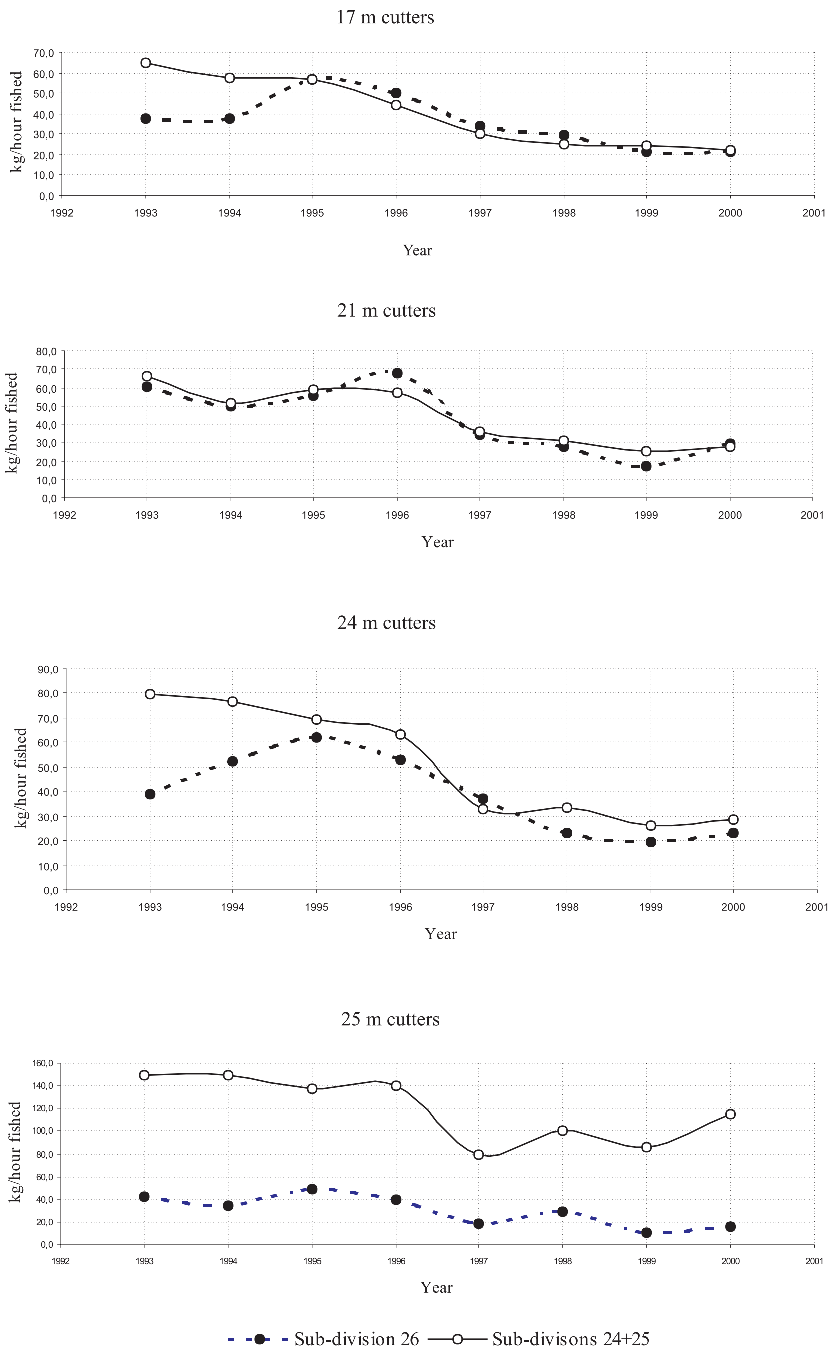


Fig. 6. CPUE indices for Baltic flatfish by cutter type and ICES statistical sub-division.

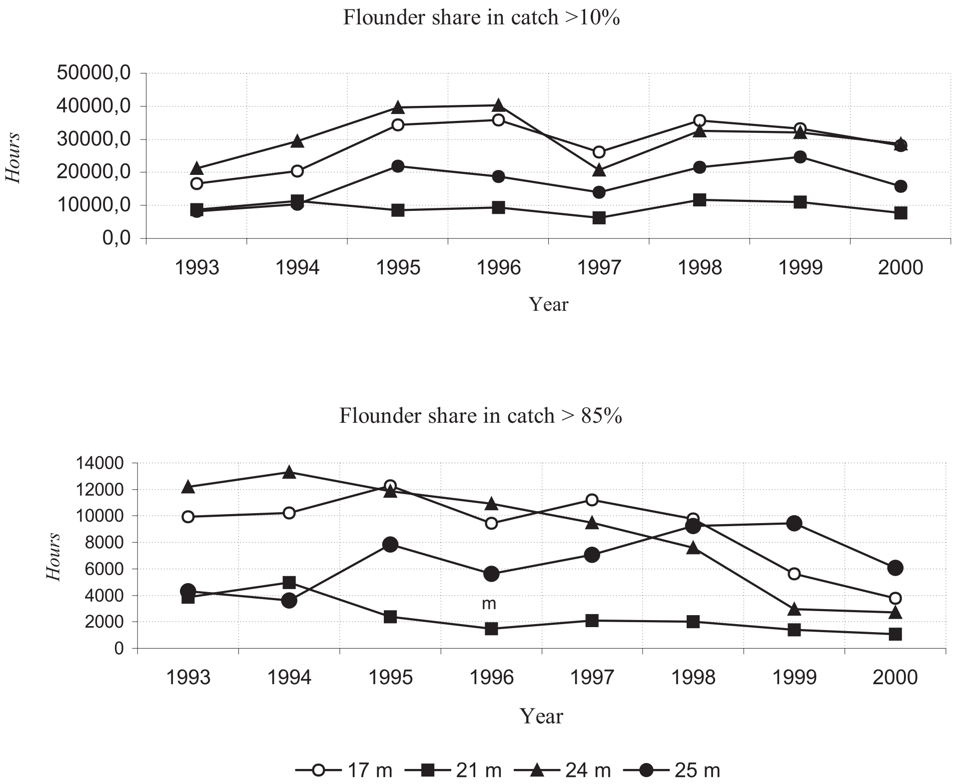


Fig. 7. Fishing effort expended on flounder according to cutter type and the flatfish percentage criterion in individual hauls.

DISCUSSION

Polish fisheries exploit two flounder stocks. The first inhabits the waters of statistical sub-division 26 which lies partially in Polish marine areas, and the second inhabits statistical sub-divisions 24 and 25. Growth rate is the feature which distinguishes these two stocks (Cięglewicz 1947). The material collected was used to estimate and compare the catch rates in both basins. Detecting significant differences in the catch rates of these two areas would fuel the argument that two distinct flounder stocks exist.

The largest flounder catches (17,000 tons) in the Baltic Sea were recorded in 1995 and 1996. The percentage of these fish caught in sub-divisions 24 and 25 was 74 and 62%, respectively. These were also the two best years for Polish flounder fisheries with catches of over 8,500 tons. A fall in catches in 1997 of 2,000 tons was accompanied by a decrease in the catch rates of all cutter types. In subsequent years, Polish flounder catches remained stable at 5,600 tons, which means that the Polish contribution to Baltic flounder catches in the last four years (1997- 2000) was over 39%. Flounder, which is common in Polish EEZ, and is fished with trawls mainly in area west of 19^0E. In January-February the bulk of the catch is taken with trawls throughout the Polish EEZ. In addition to flounder, brill and plaice also occur in these catches, but their joint contribution did not exceed 6%. The applied selection criterion for the fishing effort based on the percentage of flounder in the total weight of the catch in individual cutter hauls allowed for the calculation of the catch rates, i.e. the weight of fish caught per haul hour on cutters from total length classes 17, 21, 24 and 25 m. These indexes did not change for different size cutters in statistical sub-division 26 (Gulf of Gdańsk), but they did increase as cutter size increased in statistical sub-divisions 24 and 25 together. A characteristic feature of sub-divisions 24 and 25 is the high cutter catch rate index for 25 m vessels. The contribution of 17, 21 and 24 m cutters to total flounder catches by Polish fisheries consistently decreased throughout the analyzed period. Only the contribution of 25 meter cutters was on the rise. It is worth noting that changes in the contribution of the 25 m cutters to total flounder catches was small depending on the increase of the proportion criterion (filter) of the flounder contribution to the catches. The analyses indicate that this cutter type conducted specialized, or directed, catches of flatfish (flounder). Another interpretation of these observations may be that the flounder by-catch for 25 m cutters did not exceed 10%.

The greatest catch rate variability was observed for deck boats and 25, 19, 20 and 27 m cutters. Since cutters from the 20 and 27 m classes occurred rarely in the studied material, there was no basis for further interpretations. The significant variability of deck boat catch rates resulted from their wide size range and the patchy distribution of flounder in the areas available to these boats which were limited in their ability to change fishing grounds.

The high degree of variability in the 19 and 25 m cutter rates resulted from the opportunistic nature of the fishing they conduct, and although all cutter types perform this type of fishing, it is most apparent in these two cases. The location of the catches also had an important impact on variability. Since 25 m cutters fished in the most abundant fishing grounds (109 and 106), their catches and catch rates reflected this, while the variability of 19 m cutters depended on the location of fishing ground 105 and its seasonality. This may be interpreted as a certain type of randomness. The position of the fishing grounds on the canonic axes indicates the decisive role geographical location plays in the availability of flounder to fisheries. The results confirm that the population, or stock, which occurs west of 19^0 E and that of the Gulf of Gdańsk should be treated separately.

The thresholds of flounder percentages used in the paper (>10%, >25%, >50% and >85%, in figures and tables denoted as 11%, 26%, 51% and 86%) in individual cutter hauls allowed the fishing effort to be selected and then its relation to the number of caught flatfish to be determined. The catch rates increased as the percentage criterion increased; however, changes in threshold for 25 m cutters did not cause changes in the index trend over years Therefore, in order to estimate flounder resources, the standardized fishing effort which best reflects the state of the stock is the catch rate index for 25 m cutters, and even the filter threshold which classifies the catch rate is unimportant. Unfortunately, the contribution of this cutter type to flatfish catches in sub-division 26 is negligible, which rules out its use as the standard vessel for the fishing effort. Of the other types, 17 m cutters seem to be the most representative. When this cutter type is used as the standard vessel, it must be kept in mind that its calculated CPUE index does not reflect the same relationships in years when the selection threshold for the fishing effort is changed. When the threshold is raised (increased flatfish contribution in hauls), the proportion of this index between the two subsequent years is inverse to the same proportion for a lower limit. This attests to the opportunistic nature of the fisheries conducted by these types of cutters.

The values of the catch rate for 17 m cutters are the same in statistical sub-division 26 and the Polish sea areas located within sub-divisions 24 and 25. The rates for other cutters are different and are always lower than in sub-division 26. Provided that the catch rate index represents the changes which occur in the exploited population, then the rate of a 17 m cutter, estimated including the catch rate assigned to hauls in which the flatfish percentage was not lower than 26%, should be used for such an estimation. For the area west of 19°E the catch rate index for 25 m cutters reflects the state of flounder resources.

Can the obtained results of catch rate index analyses be interpreted as proof of the existence of two separate southern Baltic Sea flounder stocks, one in the Gulf of Gdańsk and the other in the Bornholm Basin? Variations in this index during the studied period indicate similar tendencies within both sub-divisions, and these differences may result from the lower abundance of one population caused by decreasing water salinity towards the east. They certainly indicate the diversity of flounder abundance in both of the studied areas. These results cannot rule out, however, the hypothesis that there is only one stock and differences in the catch rate indexes resulted from its distribution which decreases from west to east due to changes in water salinity. In order to confirm that the differences in catch rates point to the presence of two separate stocks as biologically diverse units, the genetic marker method should be applied to study the genetic similarity (diversity) of the fish in the two areas.

Acknowledgments
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Daily energy requirement in the mysid shrimp *Neomysis integer* in the Vistula Lagoon

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Abstract. A bioenergetics model was used to calculate the daily energy requirement (daily food ration) of the mysid shrimp *Neomysis integer* (Crustacea, Mysidacea) in the Vistula Lagoon. The growth rate defined as production (P), respiration (R) and egestion (F) was measured and the daily energy requirement (food ration) was calculated as the following sum: $C = P + R + F$. The dependence of the food ration on the body weight of *N. integer* was determined. It was confirmed that the amount of food consumed by the population of this species in late spring is half of that consumed by the smelt population during the same period.

Key words: *Neomysis integer*, daily food ration, food competition, Vistula Lagoon.

INTRODUCTION

The mysid shrimp *Neomysis integer* is an abundant species in the coastal waters of the southern Baltic Sea (Rudstam *et al.* 1986, Rudstam, Hansson 1990, Salemaa *et al*. 1990, Witek *et al*. 1993, Witek 1995, Razinkovas 1996) and the Vistula Lagoon (Fadeev and Tarasov 2001). This species is omnivorous, but it is also predatory (Maciejewska 1992). Data regarding the ecology and occurrence of *N. integer* were reported by Tattersall and Tattersall (1951) and Mauchline (1971).

The food spectrum of the Baltic *N. integer* (Kinne 1955, Sanina 1961, Maciejewska 1992) is very similar to that of herring and smelt larvae and juvenile stages that are of a similar size to these crustaceans (Arrhenius and Hansson 1994, Arrhenius 1995, Karjalainen *et al.* 1997a). Although this may result in food competition between these species, Mysidacea are an important food component for many fish such as herring and sprat (Arrhenius 1995, Stolarski 1995, Szypuła *et al.* 1997). Since *N. integer* competes for food with early fish developmental stages and is a food component of the older stages, it is clear that it plays an important role in the Baltic trophic chain.

The literature contains information regarding the quality of the food composition of *N. integer* (for a review see Maciejewska 1992), but there is a lack of information regarding the quantities of food consumed or the role this species plays in the trophic chain.

It is difficult to directly determine the food ration of small organisms since they feed on a wide variety of small food objects; this is true of *N. integer* and the larvae and juvenile stages of fish. Indirect studies which measure direct respiration, production and egestion are often the only way to determine daily food rations (Kitchell and Stewart 1977, Stewart *et al*. 1983, Rudstam 1989, Rudstam and Hansson 1990, Arrhenius and Hansson 1994, Karjalainen *et al.* 1997a, b, Cianelli *et al*. 1998, Worischka and Mehner 1998, Tolonen 1999).

The aim of the present study was to determine the daily energy requirement (i.e. the daily food ration expressed as the weight of the consumed food) of the crustacean *Neomysis integer* in the Vistula Lagoon, using the indirect method, i.e. the sum of animal production, respiration and excretion.

The comparison of the amount of the food consumed by this species with the data on its abundance will allow the role of these crustaceans in the Vistula Lagoon trophic chain to be determined.

MATERIALS AND METHODS

The *Neomysis integer* specimens used in the study were caught in the Vistula Lagoon on 30 May 2000 several hundred meters from the port in Tolkmicko in the 1.5 m surface water layer. The catches were conducted from a fishing boat during hauls lasting from two to eight minutes using a five-meter long Neuston planktonic net with 500 mm mesh and a 2 m^2 inlet.

The water temperature in the catch areas was 14°C and its salinity varied from 2.0 PSU.

The specimens that were caught were transported from Tolkmicko to the laboratory at the Sea Fisheries Institute in Gdynia. They were placed in a large, 500 l aquarium in water which had been collected at the catch site. The water temperature in the aquarium was maintained at 14°C, and the light cycle was the same as the natural diurnal cycle. After a 24 hour acclimatization period, the oxygen consumption, egestion and production of the specimens were measured by filtering the aquarium water through a net with a mesh size of 500 µm in order to eliminate larger suspensions and to retain microplankton and a portion of the mesoplankton which constituted the food of the studied specimens. Both measurements and specimen cultivation were conducted in thermostatic jars at a temperature of 14°C.

A portion of the specimens remained in the aquarium until 17 June. Between 30 May and 17 June they were fed twice daily with frozen zooplankton (mainly *Daphnia*). The unconsumed food and dead specimens were removed from the aquarium daily. The water in the aquarium was continuously aerated.

The production of the crustaceans was described as the average increase of specimen body wet weight (mg wet wt. d^{-1}) over the 18-day period from 30 May to 17 June 2001. A total of ten measurement replicates were conducted on 177 specimens.

The size structure of *N. integer* was determined on 30 May and 17 June by measuring 124 and 98 specimens, respectively. The same material from the 30 May haul was used to establish the size structure of smelt (*Osmerus eperlanus*) larvae and fry. The length of a total of 119 fish was measured. The crustaceans and fish were measured to the nearest 0.5 mm and weighed to the nearest 0.5 mg

The direct method was used to determine respiration. The oxygen consumption of individual specimens was measured using closed vessel method at the temperature of the natural environment (14°C). A total of a 100 respiration measurements were taken. Respirometric vessels of 50 cm^3 (small animals) and 100 cm^3 (large animals) were used, and the exposure time varied from two to three hours.

The concentration of oxygen in the respirometric vessels was measured with a WTW OXI 196 Oxygen Sensor. Respiration (*R*) is expressed as mm^3 ind^{-1} h^{-1}, while metabolic rate (MR) is expressed as mm^3 (mg Ww)$^{-1}$ h^{-1}.

The quantity of feces produced by the crustaceans was determined by weight. From two to five specimens were placed in glass aquaria with one liter of water at 14°C. After 24 hours of exposure the water was passed through glass filters and the deposit obtained was assumed to be the excrement of the specimens. The same aquarium setup without specimens served as the control. The filters were dried for 24 hours at a temperature of 60°C (until the constant weight), and then it was weighed to the nearest 0.01 mg. The amount of feces was expressed as mg of dry weight per specimen per day and as mg of dry weight per 1 mg of body weight per day. Sixteen measurement replicates were conducted on 58 specimens.

During these exposition time a portion of the mass of the fecal pellets is leached into the water. Measurements were taken in order to calculate these losses. Specimens were exposed for 17 and 24 hours in simultaneous experiments. Based on the fecal production for 17 hours, the anticipated production for 24 hours was calculated. This result was compared to the actual fecal production during 24 hours and the difference was assumed to have leached into the water. In total, 20 measurement replicates were conducted and the results are presented as the percentage of mass which leached out of the total amount of feces.

Thirty *N. integer* specimens were weighed and measured and them dried for 24 hours at a temperature of 60°C (until the constant weight) and then each individual was weighed. The dry weight was 22% of the specimen wet weight.

The daily energy requirement of *Neomysis integer* was described as the sum of production, respiration and egestion (see Phillipson 1966, Klekowski and Fischer 1993, Maciejewska *et al.* 2001) expressed in energy units. These were converted to weight units (as follows: 1 mg microzooplankton wet weight = 0.678 cal = 2.85 J) and the daily food ration was calculated.

Converting the weight units to energy units was as follows: animal body energy equivalent: 1.03 cal mg Ww^{-1} (4.33 J) (according to Szaniawska 1993); oxycaloric coefficient: 0.0047 cal mm^{-3} oxygen (according to Kleiber 1961, for RQ = 0.75); feces energy equvalent: 3.66 cal (mg Dw)$^{-1}$ (15.37 J) (after Urban 1984 and Urban-Jezierska 2002).

RESULTS

Production *P*

Figure 1 clearly illustrates that the peak of *N. integer* abundance for the 17 June is shifted to the right in relation to that of 30 May. This is interpreted as a reflection of the increase in the size of the animals from 30 May to 17 June.

Since two cohorts with a maximum size range of 10-11 mm and 15-16 mm and varying body length growth rates were identified (Fig. 1), production was calculated for them separately. In total, five production measurement replicates were conducted for each of the two cohorts (I – smaller animals, II – larger animals).

The average wet weight of the crustaceans in cohort I on 30 May was 6.19 mg, and after 18 days it had increased to 7.21 mg. Production during this period was 0.057 mg wet weight per specimen per day or, after conversion, 0.010 mg per mg of body weight per day (Tab.1).

The production in cohort II was the equivalent of 0.0002 mg wet weight per specimen per day and 0.0003 mg per milligram per day, thus this cohort's production was almost zero (Tab. 1). Negative production was confirmed in two measurement replicates; this can be explained by the natural dispersion of the results.

Respiration *R*

The average respiration of *Neomysis integer* 11.33 mm in length and with a wet weight of 17.47 mg was 15.54 mm^3 of oxygen per specimen per hour. The metabolic rate (MR) in relation to the wet weight was 0.889 mm^3 (mg Ww)$^{-1}$ h^{-1}. The dependence of respiration on the wet weight of *N. integer* is expressed by the equation $R = 1.97$ Ww $^{0.74}$, and when converted to body weight units by the equation MR = 1.97 mg (Ww) $^{-0.26}$ (in both cases n =100, $r^2 = 0.9563$). (See Table 1).

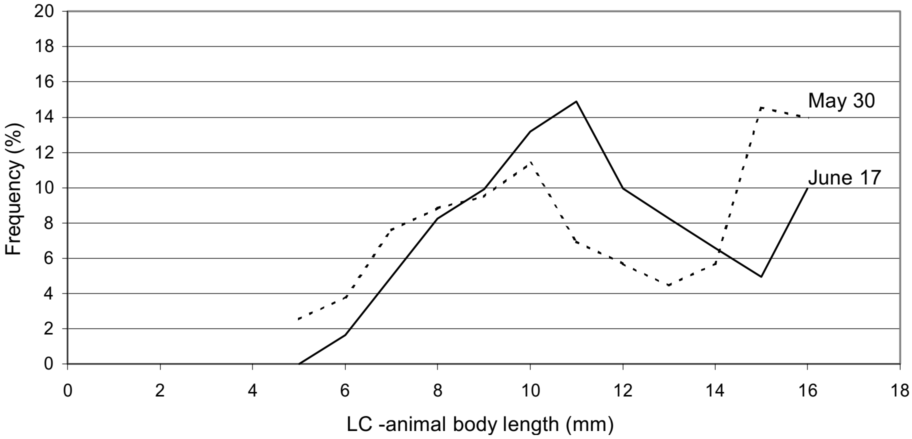

Fig. 1. *Neomysis integer* population size structure in May 2001(n = 124 individuals) and June 2001 (n = 98 individuals) in the Vistula Lagoon.

Table 1. Energy budget in *Neomysis integer* from the Vistula Lagoon. Mean values ± Standard Error

Energy budget parameters	Number of measure-ments	Number of animals used	LC [mm]	Ww [mg]	Production, Respiration, Egestion, Excretion and Consumption per individual	per 1 mg of wet wt	Dependence between rate of measured parameter and animal wet weight formula	r^2	Energy equivalent
Production *P* Cohort I Cohort II	5 5	107 70	8.33 ± 0.30 14.55 ± 0.42	6.19 ± 0,003 24.90 ± 0.003	Production *P* 0.057 ± 0.016 0.0002 ± 0.055 mg Ww ind^{-1} d^{-1}	Production Rate PR 0.010 ± 0.003 0.0003 ± 0.002 mg Ww mg Ww^{-1} d^{-1}	PR = 3.68 Ww$^{-3.3}$	0.6405	1.03 cal · mg Ww^{-1}
Respiration *R*	100	100	11.33 ± 0.39	17.47 ± 0.91	Respiration *R* 15.54 ± 0.91 mm^3 O_2 ind.$^{-1}$ h^{-1}	Metabolic rate MR 0.889±0.058 mm^3 O_2 mg^{-1} h^{-1}	MR = 1.97 Ww$^{-0.26}$	0.9563	0.0047 cal mm^{-3} O_2
Egestion *F*	16	58	13.42 ± 0.96	22.70 ± 3.77	Egestion *F* 0.169 ± 0.018 mg Dw ind^{-1} d^{-1}	Egestion rate FR 0.00788 ± 0.00098 mgDw mgWw^{-1} d^{-1}	FR = 0.052 Ww$^{-0.58}$	0.9025	3.66 cal mgDw^{-1}
Excretion *U* (literature data*)	nd	nd	7.8-15.0	5 - 30	nd	Excretion rate UR 0.009 cal mg^{-1} d^{-1}.	ammonia – N UR = 0.113 –0.0084 Dw	nd	5,44** cal mg ammonia - N^{-1}
Energy requirement *C*	calculated	calculated	14	20	Energy requirement *C* 2.860 cal ind^{-1} d^{-1}	Energy requirement rate CR 0.143 cal mg Ww^{-1} d^{-1}	C = 0.91 Ww$^{0.50}$ CR = 0.91 Ww$^{-0.50}$	0.9729 *n* = 10	3.39 cal mg Dw^{-1}

nd – no data
* after Seale, Boraas (1982)
** after Elliott (1976)

Table 2. Dry matter leached from feces of the mysid shrimp *Neomysis integer* exposed in water. Mean values ± Standard Error

Time of exposure [hours]	Number of replicates	Number of animals used	Animal length [mm]	Animal wet wt. [mg]	Animal dry wt. [mg]	Egestion rate [mg Dw mg Dw^{-1}]
17	4	17	15.3 ± 2.0	26.8 ± 5.3	5.9 ± 0.3	0.0016±0.0001
24	12	46	12.8 ± 1.7	21.4 ± 3.5	4.7 ± 0.2	0.0018±0.0007

Calculation of losses:
anticipated weight of egesta after 24 h exposure:
0.0016 mg + 7/17 x 0.0016 mg = 0.0023 mg;
measured weight of egesta after 24 h: 0.0018 mg;
the difference (leached fraction): 0.0023 mg – 0.0018 mg = 0.0005 mg d^{-1};
the "soluble" fraction built up 22 % of feces dry weight.

Egestion *F*

Since the feces excreted by the animals was collected following 24 hours of exposure in the water, it was essential to take into consideration how much dry matter was leached from the feces by the water. During 24 hours of water exposure, the feces lost 22% of their mass. In order to determine the actual amount of excreted feces, 28% must be added to the mass of the measured amount of egested feces (Tab.2).

Sixteen replicates of feces excretion measurements were conducted on various size groups. The average daily feces egestion by *Neomysis integer* specimens of an average length of 13.42 mm and wet weight of 22.70 mg was 0.169 ± 0.018 mg (Dw) per specimen per day and 0.00788 mg (Dw) for 1 mg of body weight per day. Compensation for leaching was 0.216 mg and 0.01000 mg, respectively. The dependence of the amount of egested feces (converted for 1 mg animal weight) on the animal wet weight is expressed with the equation $FR = 0.052\ Ww^{-0.58}$, n =16, r^2 = 0.9025 (Tab. 1).

Excretion *U*

As the current study did not include measurements of *N. integer* excretion of the metabolic products of nitrogen, values for ammonia-N and urea-N were taken from Seale and Boraas (1982) for *Mysis relicta* (0.179 i 0.164 µg mg^{-1} h^{-1}, respectively, after compensating for temperature differences with the coefficient Q_{10} = 2.9, see Maciejewska *et al.* 2001). The energy equivalent of ammonia-N and urea-N were taken from Elliott (1976): 0.00594 and 0.00551 cal µg N^{-1}, respectively.

The dependencies presented in Seale and Boraas (1982) – ammonia-N = 0.113-0.0084 Dw i urea-N = 0.00084 + 0.0011 Dw – were used to calculate the energy contained in the nitrogen metabolites of *N. integer*.

Consumption *C* (daily food ration, daily energy requirement)

The daily energy requirements for various size categories of *N. integer* were calculated based on the production, respiration and egestion results presented in Table 1. The values of energy requirements per individual and per 1 mg of individual body weight as well as the daily food ration per individual in various weight classes is presented in Table 3.

Table 3. Daily energy requirement (food ratio) *C* in *Neomysis integer* from the Vistula Lagoon as the sum of production *P*, respiration *R*, egestion *F* and excretion *U*

Size class [mg]	*P* Production [cal mg^{-1} d^{-1}]	*R* Respiration [cal mg^{-1} d^{-1}]	*F* Egestion [cal mg^{-1} d^{-1}]	*U** Excretion [cal mg^{-1}d^{-1}]	*C* Energy requirement		*C* Consumption [mg Ww of microzooplankton per ind. per day]
					[cal mg^{-1} d^{-1}]	[cal ind^{-1} d^{-1}]	
2	0.374	0.186	0.127	0.009	0.696	1.392	2.05
5	0.018	0.146	0.075	0.009	0.248	1.235	1.81
10	0.002	0.122	0.050	0.008	0.182	1.820	2.68
15	0.0005	0.110	0.040	0.008	0.158	2.370	3.49
20	0.0002	0.102	0.033	0.008	0.143	2.860	4.22
25	0.00009	0.096	0.029	0.007	0.125	3.125	4.61
30	0.00005	0.092	0.026	0.007	0.118	3.540	5.22
35	0.00003	0.088	0.024	0.007	0.113	3.955	5.83
40	0.00002	0.085	0.022	0.006	0.108	4.320	6.37
45	0.00001	0.083	0.021	0.006	0.105	4.725	6.97

*recalculated after Seale, Boraas (1982)

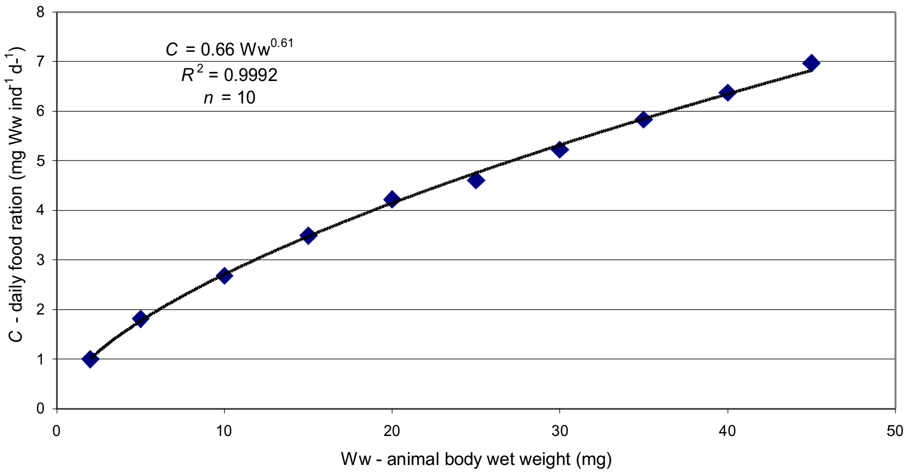

Fig. 2. Dependence of the daily food ration (*C)* on animal body wet weight (Ww) in *Neomysis integer* in the Vistula Lagoon.

Table 3 and Figure 2 clearly indicate that animals with a body weight of approximately 20 mg Ww (the average weight of specimens used in the study) consumed 2.74 cal of food daily. If the caloric value of the zooplankton is 3.39 cal mg Dw^{-1} (Vijverberg and Frank 1976, Rudstam 1989), the daily food ration for animals of this size is 4.22 mg of zooplankton wet weight. The dependence of the daily food ration (*C* – in mg Ww of microzooplankton ind^{-1} d^{-1}) of *Neomysis integer* on animal size (Ww, in mg) is expressed as: $C = 0.66\ \mathrm{Ww}^{0.61}$, $r^2 = 0.9992$, $n = 10$.

DISCUSSION

Neomysis integer is an important zooplankton community component, and its recorded biomass has been as high as 18 g m^{-2} (Beattie and Kruijf 1978). It is both a significant dietary component of fish (Mauchline 1982) and an equally valuable consumer of zooplankton (Fulton 1982). Despite all this, the energy budget of this species (as is the case with other Mysidacea) has yet to be fully described. Only this will allow its role in the energy flow and matter cycling in the pelagic ecosystem to be fully understood.

Of the various elements of the Mysidacea energy budget, the literature only contains data regarding production calculated from animals growth curve (Beattie and Kruijf 1978, Bremer and Vijverberg 1982, Schrotenboer 1979), respiration (Weisse and Rudstam 1989, Raymont *et al*. 1966, Roast *et al.* 1999) and nitrogen metabolite excretion (Seale and Boraas 1982). There is no information in the literature regarding either the daily food ration or feces egestion.

The results obtained during the present study regarding the energy budget parameters of *N. integer* are presented in Table 4 along with data from the literature. The production results obtained in the current study are significantly lower than those presented in Fig. 10 in the paper by Bremer and Vijverberg (1982). The differences could stem from the different environmental conditions between the animals studied in Holland (high chloride levels, high pH) and those of the current study. It is striking that the production of animals in natural and laboratory conditions was nearly the same (0.283 and 0.277 mg Ww mg Ww^{-1} d^{-1}, respectively; see Tab. 4).

The values of *N. integer* metabolic rates obtained in the current paper are higher than those reported by other authors for both this species and other Mysidacea (Tab. 4). However, the dependencies of respiration (R) on body wet weight (Ww) for all species are very close - an intercept "*a*" value is ranging from 0.96 to 2.41, and a regression coefficient "*b*" value is ranging from 0.62 to 0.74. This is evidence that in mysids energy is expended on metabolism similarly.

There is no data in the literature regarding the amount of feces egested by *N. integer* and other Mysidacea, nor is there any information regarding fecal pellets losing mass during exposure in water. The values obtained for the decreasing weight of feces (22% of initial weight or 28% of the weight following exposure) have a certain impact on describing the level of the food ration (*C*) and assimilation (*A*), for example, if an individual weighs 20 mg the difference in describing the food ration is 5%, and assimilation is 82%, after taking feces weight loss into consideration – 78%.

The results concerning the decrease in fecal mass during its exposure in water can only be compared to data on the decrease of feed mass used in fish culture exposed in water. According to data in the literature, this can be from 18-21% (Lipka and Kubacka 1975) to 24-78% (Urban *et al.* 1984) of the initial weight.

The daily food ration calculated for the crustacean *Neomysis integer* is essentially the same as that for smelt larvae *(Osmerus eperlanus*) of the same size and body weight and calculated using the same method (Maciejewska *et al*. 2001; see Fig. 3).

The average density in June of *Neomysis integer* specimens in the Vistula Lagoon was approximately 6.7 specimens m^{-3}; this is close to the abundance of smelt larvae at 5.0 specimens · m^{-3} (Fadeev and Tarasov 2001, Margoński and Fey, unpublished data).

Table 4. Comparison of energy budget parameters in *Neomysis integer* and other Mysiadacea. Literature data are recalculated to the units used in the present paper

Species and parameter	Values and units	Temp.[°C]	Location	Source	Remarks
Production mgWw $mgWw^{-1}$ d^{-1}					
Neomysis integer	0.057	14	Vistula Lagoon, Baltic Sea, Poland	Present paper	
N. integer	0.283	?	Solermeer, The Netherlands	Bremer and Vijverberg 1982	Recalculated
N. integer	0.611	?	Bergumermmer, The Netherlands	Beattie and Kruijf 1978	Recalculated
N integer	0.277	15	Laboratory culture	Schrotenboer 1978	Recalculated
Respiration mm^3 O_2 $mgWw^{-1}$ h^{-1}					Ww – mg Ww, R – mm^3O_2 ind^{-1} h^{-1}
N. integer	0.889	14	Vistula Lagoon, Baltic Sea, Poland	Present paper	$R = 1.97\ Ww^{0.74}$
N. integer	0.41	15	East Looe River Estuary, UK	Roast *et al*. 1999	
N. integer	0.55	15	Northern Baltic Sea	Weisse and Rrudstam 1989	-
N. integer	0.25	10	River Test, Southampton, UK	Raymont *et al*. 1966	-
Mysis relicta	-	15	Kootenay Lake, B.C., Canada	Sandeman and Lasenby 1980	$R = 0.96\ Ww^{0.69}$
Mysis relicta	0.24	4	Lake Ontario, Canada	Foulds and Roff 1976	$R = 1.79\ Ww^{0.73}$
Archaeomysis grebnitzkii	0.549	15	San Juan Island, Washington, USA	Jawed 1973	$R = 1.38\ Ww^{0.70}$
Neomysis watschensis	0.672	15	San Juan Island, Washington, USA	Jawed 1973	$R = 2.41\ Ww^{0.62}$
Food assimilation %					
N. integer	80	15	Vistula Lagoon, Baltic Sea, Poland	Present paper	
Mysis relicta	85	10	Char Lake, Canada	Lasenby, Langford 1973	

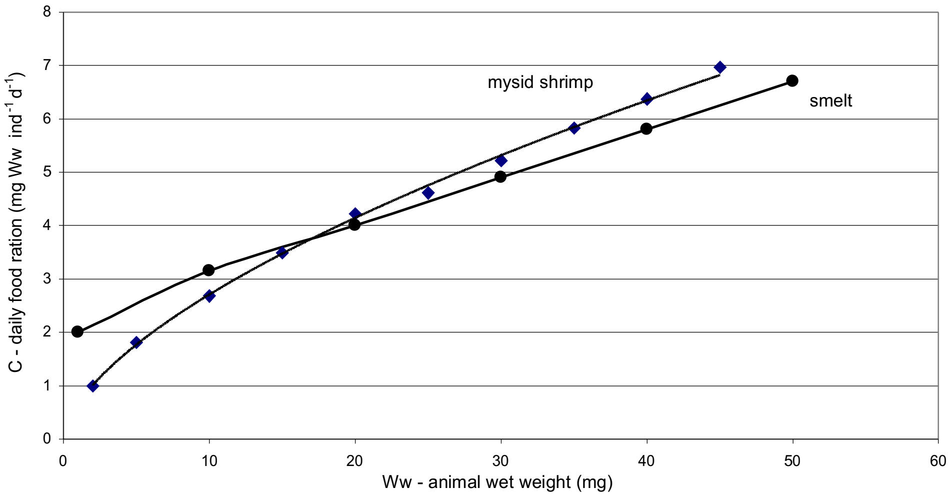

Fig. 3. Comparison of the daily food ration (*C*) of smelt (*Osmerus eperlanus*) and mysid shrimp (*Neomysis integer*) from the Vistula Lagoon. *O. eperlanus* data from Maciejewska *et al.* (2001).

Therefore, it can be assumed that the amount of food consumed by these two species is similar. However, once the differences between the size distribution of the individuals of both populations came to light, it occurred that the biomass of the smelt population is as twice as high as mysid population, and, at the same food ration, the amount of food consumed by fish larvae is twice as high as that consumed by crustaceans.

These results indicate that fish larvae are more capable of getting food. Competition for food between these two species is effectively weakened by the differences in the sizes of the individuals in both populations. In early June the abundance maxima of both of them falls in different size classes (*N. integer* – 5-7 mg, smelt – 40 mg) which certainly means that there are differences in the sizes of food consumed by both species.

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Chemical body composition of roach in the Odra River estuary

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Abstract. The chemical body composition of roach (*Rutilus rutilus* L.) from four areas of the Odra River estuary was investigated based on a sample of 132 fishes. Growth rate was analysed using a sample of 738 individuals. Larger fish were prone to more intense fat accumulation. Fat content increased as the growing season progressed, especially in the fish inhabiting coastal Baltic waters and the eutrophic Lake Dąbie. Dry matter content exhibited a similar tendency. The protein content did not change essentially, and although it did not depend on fish size in the post-spawning period, it increased slightly with fish size in autumn. Ash content was not correlated with fish size. The fastest length growth rate was observed in fish from the Pomeranian Bay, while the slowest occurred in roach inhabiting Międzyodrze.

Key words: fat, protein, growth, roach, fish bioenergetics, estuary.

INTRODUCTION

Animal growth is accomplished mainly through protein and fat production and can be regarded as a process of changes in the quantity and proportions of theses components (Diana 1995). The relationship between animal growth and energetics has often been described in the form of bioenergetic models (Elliott and Hurley 2000; Kitchell *et al.* 1977; Winberg 1956). The energy budget equation explains the source of growth plasticity, which is achieved only if energy surplus exists and, in consequence, even small shifts in the budget structure can cause large differences in growth and protein and lipid metabolism. Within various populations of the same fish species, such differences can be genetically fixed as a result of selection imposed by environmental conditions (Diana 1983; Schultz and Conover 1997).

Their ecological regimes make estuarine areas an excellent experimental field for fishery research. Populations of the same fish species that inhabit different parts of an estuary may display adaptations to local conditions, expressed as differences in growth rate or nutritional status (Jordan *et al.* 2000; Więski and Załachowski 2000a, b).

This study analyses the extent to which roach *Rutilus rutilus* L. from different parts of the Odra River estuary differs in chemical body composition.

AREA OF STUDY

The investigation was conducted in four regions of the Odra River estuary. (1) Międzyodrze, the uppermost area of the study, is located between the two branches of the Odra River to the south of the city of Szczecin and consists of wetlands with a network of channels covering 40 km^2. Its waters are the least polluted of the entire estuary. Ecologically, it is a transitional region between lotic and lentic environments. In the vicinity of Szczecin, the eastern branch of the Odra River flows through the highly eutrophicated (2) Lake Dąbie, the fourth largest lake in Poland with an area of 52 km^2. The limited influence of brackish waters is evident here, especially in autumn. Next, the Odra River flows into (3) the Szczecin Lagoon, a shallow, eutrophicated water body with an area of 910 km^2. The northern part of the lagoon has the highest salinity and the most variability. In spring, the water reaches high levels and flows into the sea, while in autumn seawater is frequently pushed into the lagoon by stormy, northern winds. The Odra River flows into the (4) Pomeranian Bay of the Baltic Sea through four narrow straits. Local gradients of physicochemical and chemical parameters are typical of this part of the estuary as the waters here are mixed by winds and wavy motion. The waters of the river mouths are permanently stratified (Majewski 1974). The inflow of Odra waters causes higher fertility in the Pomeranian Bay in comparison to that of the Baltic Sea.

MATERIAL AND METHODS

Chemical analyses were performed on 132 roach caught in nine catches from May 1995 to October 1996 (Table 2). The individual fish were assigned to and analysed in the following length (SL) classes: equal to or less than 15 cm; from 15.5 to 20 cm; from 20.5 to 25 cm; more than 25 cm. Three individuals at a similar gonad maturity stage were selected from each length class for chemical analyses. Sex could be taken into account only in two samples, which were twice as numerous as the others. All the assays were conducted on fresh material and on each specimen separately. The entire fish (excluding gonads) was homogenized prior to analyses. The protein content was determined with the Kjeldahl technique and fat content with the Soxhlet method. Dry matter and ash content were measured gravimetrically according to Kleiber (1961). The results of the chemical analyses were logarithmically transformed and subjected to simple and multiple regression analyses. The slopes of the regression lines were compared with ANCOVA using $\log_{10}$ of body weight as a covariate, and, if the lines were parallel, the significance of intercepts was tested (Zar 1984).

Table 1. Chemical components of roach bodies, according to particular areas, seasons and size groups [% wet weight].
((1) – 15 cm or less, (2) 15.5 to 20cm, (3) 20.5 to 25cm, (4) more than 25 cm; x – mean; υ – coef. of var.). Data from seasons during both study years were pooled. The sample from Lake Dąbie on 13 July 1995 was excluded as it was distant.

Area	Season	Size. group.	W (g)		Dry matter (%)		Ash (%)		Fat (%)		Protein (%)		N
			x	υ	x	υ	x	υ	x	υ	x	υ	
Między-odrze	autumn	1	46.5	0.19	21.44	0.03	2.60	0.07	3.14	0.02	15.55	0.01	6
		2	94.0	0.18	21.50	0.00	2.59	0.12	3.48	0.03	15.78	0.02	6
		3	257.5	0.15	24.35	0.00	2.93	0.04	4.05	0.12	16.58	0.02	6
		4	487.5	0.10	25.38	0.02	2.98	0.05	5.20	0.06	16.44	0.03	6
Lake Dąbie	spring	1	48.7	0.21	23.19	0.01	3.19	0.04	3.13	0.04	16.59	0.01	6
		2	97.2	0.08	23.22	0.01	3.33	0.01	3.35	0.04	16.60	0.01	6
		3	220.3	0.15	23.11	0.01	3.28	0.02	3.43	0.04	16.52	0.00	6
		4	404.8	0.07	23.42	0.01	3.26	0.03	3.48	0.03	16.53	0.01	6
	autumn	1	40.0	0.22	25.48	0.01	3.19	0.04	5.33	0.02	16.96	0.01	3
		2	86.7	0.10	27.84	0.01	3.33	0.04	7.39	0.02	17.14	0.01	3
		3	209.7	0.09	28.98	0.00	3.25	0.04	8.15	0.01	17.54	0.01	3
		4	395.3	0.07	29.41	0.01	3.21	0.02	8.63	0.02	17.50	0.01	3
Szczecin Lagoon	spring	1	49.0	0.09	23.63	0.01	3.06	0.01	4.32	0.07	16.28	0.01	6
		2	114.3	0.17	23.94	0.01	3.14	0.03	4.50	0.03	16.32	0.01	6
		3	188.7	0.18	24.69	0.02	3.11	0.02	5.37	0.06	16.30	0.01	6
		4	403.5	0.06	25.37	0.01	3.12	0.03	5.89	0.01	16.31	0.01	6
	autumn	1	52.0	0.02	25.47	0.01	3.15	0.03	6.07	0.03	16.42	0.01	3
		2	105.3	0.05	26.18	0.01	3.14	0.02	6.11	0.01	16.82	0.01	3
		3	221.7	0.08	27.39	0.00	3.10	0.03	7.48	0.03	17.02	0.01	3
		4	420.3	0.04	28.32	0.01	3.11	0.03	8.40	0.02	17.03	0.01	3
Pomeranian Bay	spring	1	71.0	0.29	23.90	0.00	2.82	0.01	4.77	0.02	16.16	0.01	3
		2	118.3	0.09	24.19	0.01	2.81	0.02	5.12	0.03	16.20	0.01	3
		3	209.7	0.13	24.74	0.01	2.82	0.03	5.63	0.04	16.24	0.01	3
		4	591.0	0.11	25.07	0.00	2.75	0.04	5.73	0.03	16.29	0.01	3
	autumn	1	49.3	0.06	25.58	0.02	3.07	0.02	5.99	0.02	16.33	0.00	3
		2	120.7	0.10	27.64	0.02	3.21	0.02	7.66	0.01	16.51	0.00	3
		3	252.3	0.01	28.81	0.00	3.13	0.02	9.01	0.01	16.95	0.01	3
		4	444.3	0.04	28.88	0.01	3.22	0.03	8.99	0.01	16.94	0.00	3

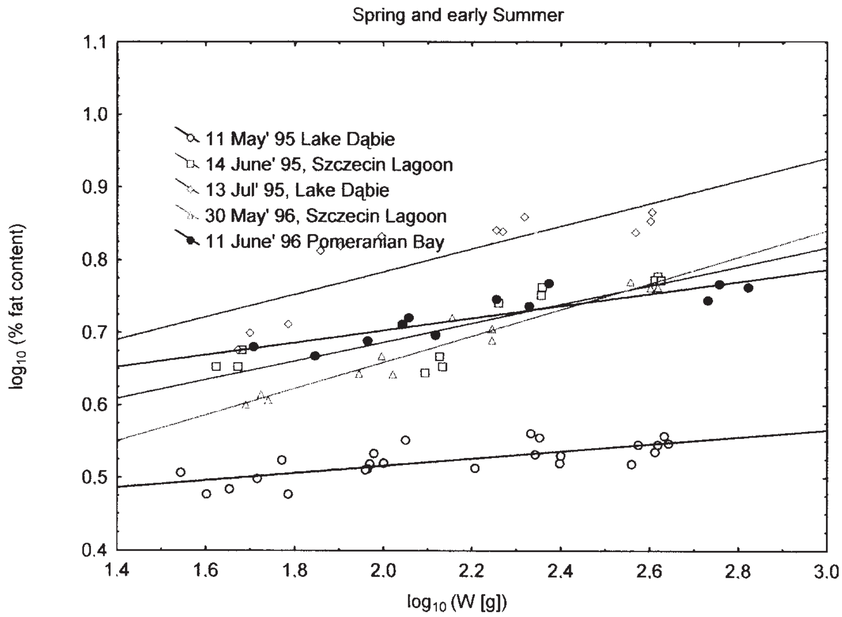
Table 2. Linear regressions of fat, protein and dry matter by weight
(log transformed; y [% wet weight]; W [g]; $y = a + b \cdot W$, $p < 0.05$)

Component	Date	Study area	r	t	N	a	b
Fat	11 May'95	Lake Dąbie	0.74	5.223	24	0.961	0.049
	30 May'96	Szczecin Lagoon	0.97	13.822	12	0.683	0.181
	11 June'96	Pomeranian Bay	0.87	5.712	12	1.231	0.084
	14 June'95	Szczecin Lagoon	0.84	4.991	12	0.983	0.130
	13 July'95	Lake Dąbie	0.82	4.468	12	1.088	0.156
	10 Sep.'96	Szczecin Lagoon	0.95	9.661	12	1.094	0.169
	13 Oct.'95	Lake Dąbie	0.93	7.924	12	1.024	0.197
	24 Oct.'96	Pomeranian Bay	0.96	10.541	12	1.070	0.194
	10 Nov.'95	Międzyodrze	0.91	10.506	24	0.365	0.198
Protein	13 July'95	Lake Dąbie	0.93	7.839	12	2.762	0.017
	10 Sep.'96	Szczecin Lagoon	0.88	5.893	12	2.734	0.018
	13 Oct.'95	Lake Dąbie	0.89	6.066	12	2.776	0.015
	24 Oct.'96	Pomeranian Bay	0.90	6.737	12	2.719	0.019
	10 Nov.'95	Międzyodrze	0.78	5.942	24	2.636	0.028
Dry matter	30 May'96	Szczecin Lagoon	0.95	9.304	12	3.020	0.034
	11 June'96	Pomeranian Bay	0.94	8.529	12	3.083	0.022
	14 June'95	Szczecin Lagoon	0.93	7.847	12	3.027	0.035
	13 July'95	Lake Dąbie	0.85	5.091	12	3.072	0.044
	10 Sep.'96	Szczecin Lagoon	0.99	18.658	12	3.030	0.052
	13 Oct.'95	Lake Dąbie	0.94	8.858	12	3.037	0.060
	24 Oct.'96	Pomeranian Bay	0.94	8.691	12	3.032	0.057
	10 Nov.'95	Międzyodrze	0.95	13.897	24	2.742	0.079

Growth rate was analysed using 738 fish specimens, from which sub-samples were selected for the chemical analysis. Fish age was determined by measuring the caudal radii of scales. The relationship between scale radius (R) and fish length (SL) was calculated. The SL-R relationship established for each individual area of study was used to estimate length growth by back-calculation. Due to the non-linearity of the relationship, the radius was corrected as described by Ricker-Lagler (Tesch 1968). The results obtained were used to express the growth rate as a von Bertalanffy equation. The length-weight (SL-W) relationship as a power function was also estimated for each sample individually.

RESULTS

The results of the chemical assays are shown in Table 1. These data were then transformed into linear functions of weight (Table 2) for further analyses. The fat content changed seasonally in a clear pattern and increased with fish size in all the samples (Figure 1). The functions differed between individual water bodies in spring (May, June) (ANCOVA, $p < 0.05$). For fish weighing 300g or less, roach from Pomeranian Bay contained the most fat, whereas among larger fish, those from the Szczecin Lagoon had the most fat. In autumn, the regression slopes did not differ (ANCOVA, $p = 0.68$); however differences between



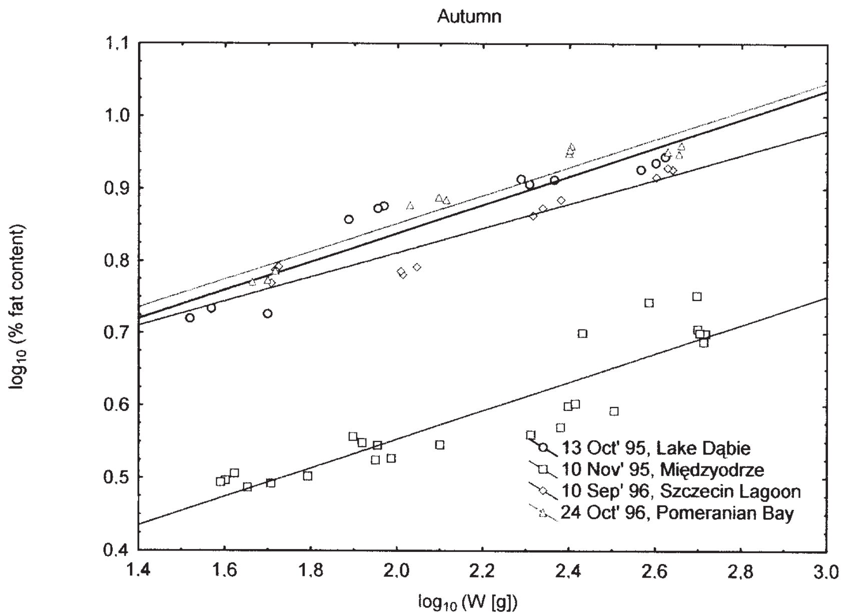


Fig. 1. Relationship between weight and fat content for roach in the Odra river estuary ($p < 0.05$).

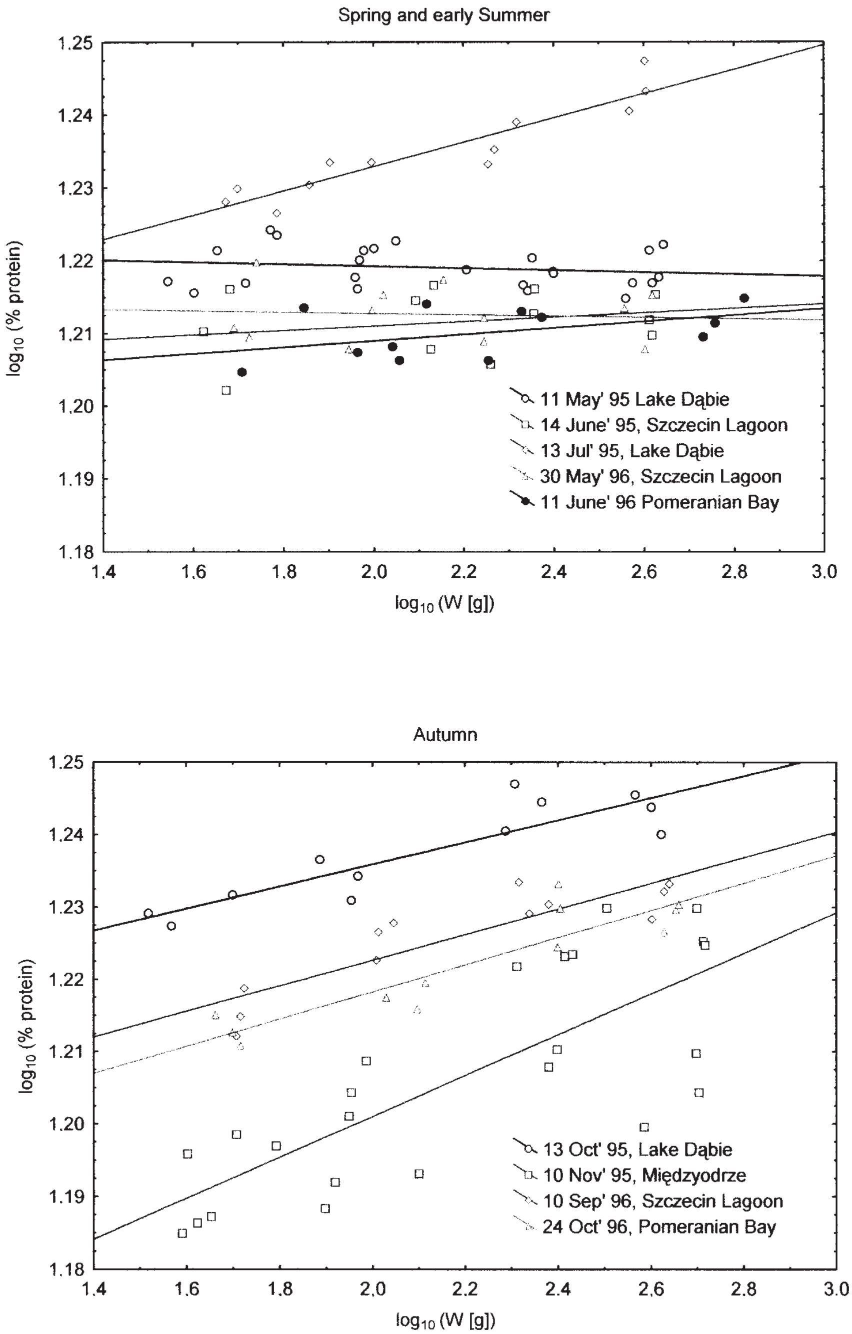


Fig. 2. Relationship between weight and protein content for roach in the Odra river estuary ($p < 0.05$).

intercepts were observed. Thus, the fattest individuals were found in the Pomeranian Bay and Lake Dąbie (with no significant differences at $p = 0.55$), whereas the leanest fish were found in Międzyodrze. The differences in fat content between roach of different sizes increased as the growing season progressed and reached a maximum in autumn, which is demonstrated by the increasing values of the regression coefficients b (Table 2).

Considerably smaller seasonal changes were observed for protein content (Figure 2). In the spring samples, no correlations were found between body weight and protein content. Differences in protein content appeared between fish of different sizes in autumn (Table 2). During this season the regression lines were parallel (ANCOVA, $p = 0.10$) as was the case with fat content. No differences in protein content were found between the two samples from Lake Dąbie ($p = 0.22$) or between those from the Pomeranian Bay and the Szczecin Lagoon ($p = 0.50$). Differences in protein content reached nearly 2% of wet weight between the fish from Lake Dąbie and Międzyodrze.

The changes in dry matter content with fish body weight were similar to those observed in fat content, but there were some slight differences (Fig. 3). In spring, the highest dry matter content was found in the fish from Lake Dąbie. For the samples from the Szczecin Lagoon or Pomeranian Bay, the trends of changes in dry matter content with body weight did not differ significantly (ANCOVA, $p > 0.05$). In autumn, the body weight – dry matter regression lines were parallel after eliminating the Międzyodrze samples (ANCOVA, $p = 0.57$).

When the Międzyodrze sample was excluded, the ash content did not change with fish size (Table 3). Following the conclusion of the vegetation period, the ash content increased although it was not statistically significant ($r = 0.54$, $p = 0.12$).

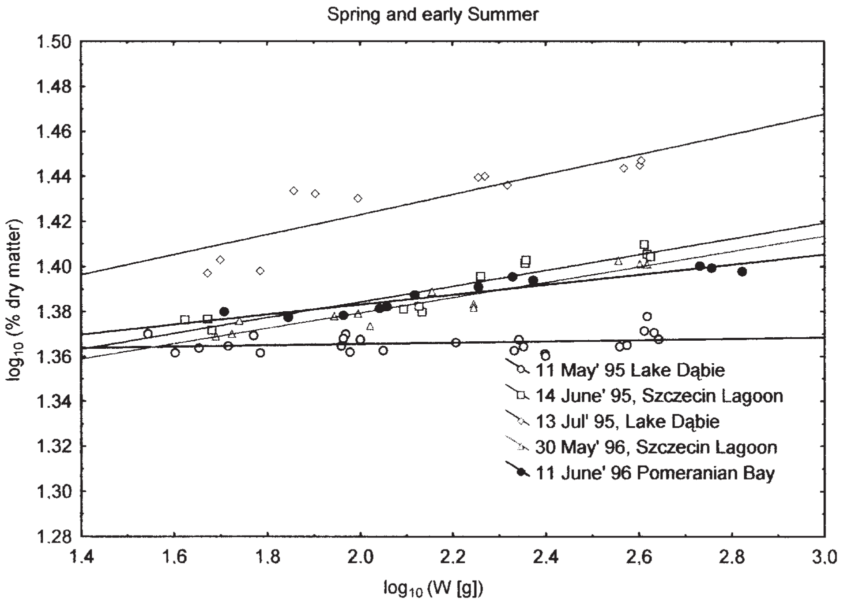
In the samples in which sex was taken into account (Lake Dąbie – 11 May and Międzyodrze – 10 November), no differences were found in the content of any of the analysed chemical components (ANCOVA, $p > 0.05$) (Figure 4).

The fastest growth rate in length was observed for roach from the Pomeranian Bay, those from the Szczecin Lagoon and Lake Dąbie exhibited intermediate growth rates and the slowest growth occurred in Międzyodrze roach (Table 4).

The length difference between the fastest and slowest growing roach increased with fish age. The difference at age 2 was about 2 cm, while at age 8 it exceeded 7 cm. The condition of the fish, expressed in the form of the length-weight relationship, fluctuated.

Table 3. Linear regressions of ash content by weight
(log transformed; y [% wet weight]; W [g]; $y = a + b \cdot W$, $p < 0.05$)

Component	Date	Study area	r	t	N	a	b	p
Ash	11 May'95	Lake Dąbie	0.16	0.78	24	1.15	0.01	0.44
	30 May'96	Szczecin Lagoon	0.09	0.28	12	1.12	0.00	0.78
	11 June'96	Pomeranian Bay	–0.39	–1.32	12	1.09	–0.01	0.21
	14 June'95	Szczecin Lagoon	0.27	0.90	12	1.09	0.01	0.39
	13 July'95	Lake Dąbie	–0.29	–0.95	12	1.22	–0.01	0.36
	10 Sep.'96	Szczecin Lagoon	–0.19	–0.61	12	1.17	–0.01	0.56
	13 Oct.'95	Lake Dąbie	0.00	0.01	12	1.18	0.00	0.99
	24 Oct.'96	Pomeranian Bay	0.52	1.94	12	1.07	0.02	0.08
	10 Nov.'95	Międzyodrze	0.63	3.78	24	0.68	0.07	0.44



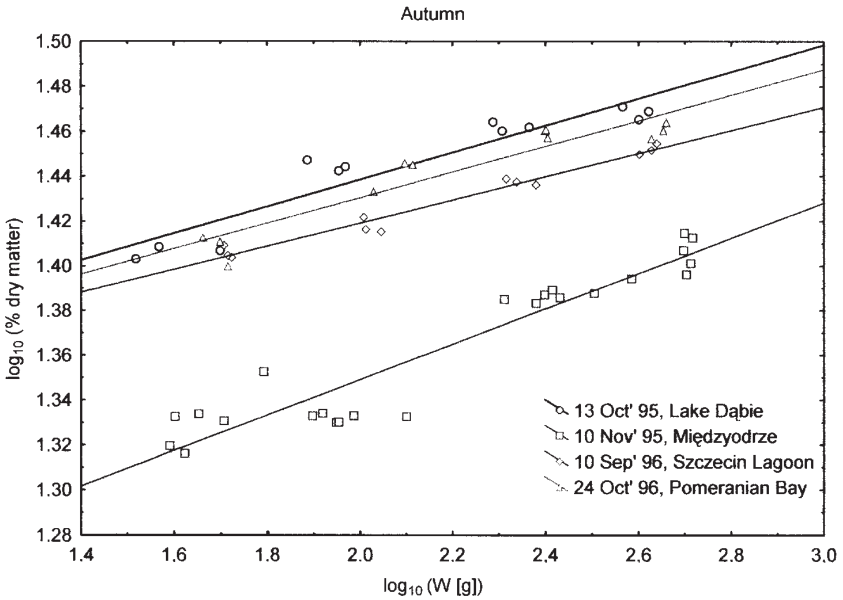


Fig. 3. Relationship between weight and dry matter content for roach in the Odra river estuary ($p < 0.05$).

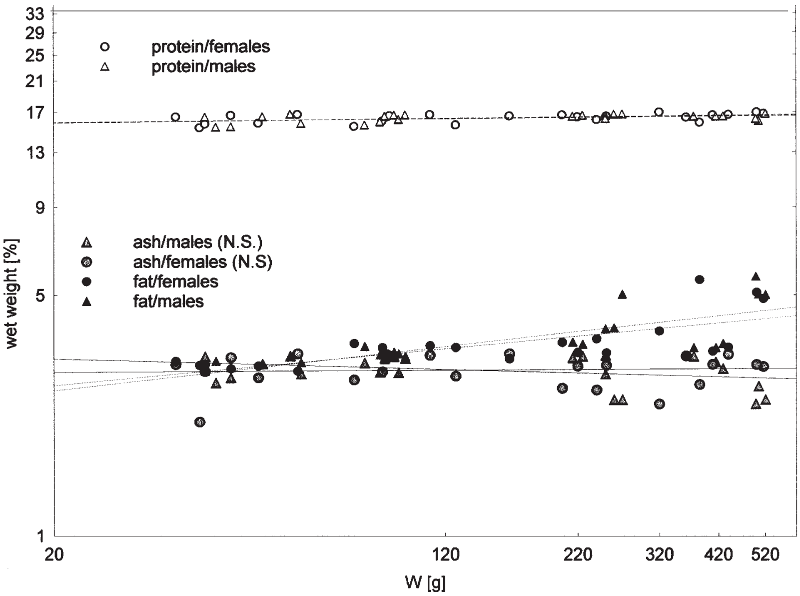


Fig. 4. Changes of body chemical components with fish weight in males and females

The influence of seasonality was more pronounced in the samples from the Pomeranian Bay than in those from Lake Dąbie (Table 4).

Multiple stepwise regression models were developed to identify the factors that affected the chemical components (Table 5). The best fit was obtained for fat and dry matter models (R^2 = 0.73 and R^2 = 0.60, respectively), and the worst was for ash (R^2 = 0.30). All the models are similar and differed only in the effect of the variables. Most of the variability was explained by exponent n (from the SL-W relationship), body weight and the number of days elapsed since spawning. In the protein content model, the effect of the catabolism coefficient *K* from the von Bertalanffy equation was observed to be slightly more important.

Table 4. Parameters of the von Bertalanffy equation (L_∞, K, t_o) and *L-W* relationships (*k, n*) of roach from the studies samples

Date	Study area	L_∞	K	t_o	K	n	N
11 May'95	Lake Dąbie	31.84	0.1271	–0.5134	0.0100	3.2250	43
30 May'96	Szczecin Lagoon	23.62	0.2920	0.0160	0.0089	3.2666	101
11 June'96	Pomeranian Bay	38.45	0.1182	–0.2903	0.0088	3.2673	83
14 June'95	Szczecin Lagoon	26.12	0.2118	–0.0900	0.0369	2.8050	43
13 July'95	Lake Dąbie	20.70	0.2721	–0.2612	0.0152	3.1095	118
10 Sep.'96	Szczecin Lagoon	21.30	0.3244	0.0371	0.0101	3.2663	111
13 Oct.'95	Lake Dąbie	35.91	0.1209	–0.4945	0.0600	3.4134	90
24 Oct.'96	Pomeranian Bay	36.67	0.1523	–0.1852	0.0108	3.2337	43
10 Nov.'95	Międzyodrze	18.86	0.3164	–0.0956	0.0868	2.4134	98

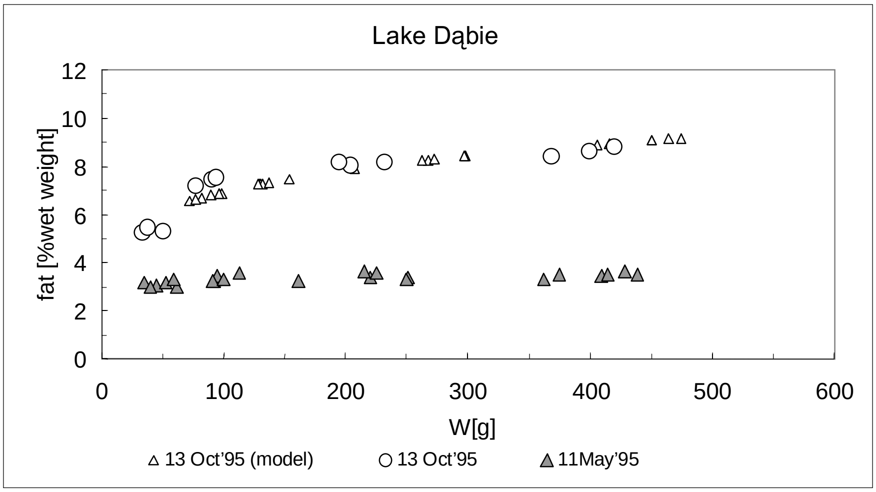
Table 5. Multiple stepwise regression between chemical body components and some chosen variables (y –% wet weight, n – exponent of the L–W relationship, DES – days elapsing since spawning, W – weight, AREA – water body, K – coefficient of catabolism)

Dependent variable (y) (transf. log.)	Indep. variable	Step	β	β SE	B	B SE	R^2	p
Fat	intercept				1.45	0.26		0.01<
	log n	1	–0.21	0.06	–0.65	0.18	0.40	0.01<
	log DES	2	0.55	0.06	0.10	0.01	0.52	0.01<
	log W	3	0.32	0.05	0.13	0.02	0.62	0.01<
	AREA	4	–0.32	0.06	–0.11	0.02	0.72	0.01<
	log K	5	–0.15	0.06	–0.12	0.05	0.73	0.01
Protein	intercept				2.81	0.03		0.01<
	log W	1	0.31	0.08	0.01	0.00	0.12	0.01<
	log n	2	–0.34	0.09	–0.09	0.03	0.19	0.01<
	log K	3	–0.23	0.09	–0.02	0.01	0.22	0.03
	AREA	4	0.18	0.10	0.01	0.00	0.24	0.08
Dry matter	intercept				3.25	0.08		0.01<
	log n	1	–0.35	0.08	–0.28	0.06	0.38	0.01<
	log W	2	0.39	0.06	0.04	0.01	0.52	0.01<
	log DES	3	0.33	0.08	0.01	0.00	0.55	0.01
	AREA	4	–0.16	0.07	–0.01	0.01	0.58	0.01<–
	log K	5	–0.16	0.08	–0.03	0.01	0.60	0.04
Ash	intercept				1.46	0.09		0.01<
	log DES	1	–0.57	0.08	–0.02	0.00	0.17	0.01<
	log n	2	–0.37	0.08	–0.28	0.06	0.29	0.01<
	log W	3	0.11	0.08	0.01	0.01	0.30	0.15

DISCUSSION

Observations confirm that there are seasonal changes in the fat content of fish that inhabit the mid latitudes (Penczak *et al.* 1977, Shulman 1972). The fish caught in Lake Dąbie in May contained the least fat, which was probably associated with spawning efforts. During this period, there was a slight (3%) difference in the fat content between the largest and the smallest fish. As was expected, the accumulation of reserve substances began with the summer growth season (samples of June and July). At this time a tendency emerged which is also characteristic of cyprinids, namely that there was more extensive accumulation by larger fish and that this persisted throughout autumn (Nikolski 1963; Vellas *et al.* 1996). A similar high fat content in larger fish during autumn was recorded for the roach population in Greifswalder Bodden and was probably due to their feeding on highly caloric malacofauna (Korde 1968). It should be stressed that a temporary autumn decrease in body fat content was not observed in the Odra estuary roach (Penczak *et al.* 1977). This effect, related to energetic expenditure for gonad development (Tanasichuk and Mackay 1989), may have been reduced by enhanced feeding (Ferroni *et al.* 1996) since the Odra mouth waters are rich in high quality food for roach (Neuhaus 1936; Wiktor 1962). The Międzyodrze fish had a much lower fat content in comparison with other populations. The fish in the samples collected from this area had probably migrated from the cooling effluent channel of the Dolna Odra Power Station. The higher water temperatures in the channel enhance metabolic processes and may have reduced the intensity of reserve accumulation in the fish (Jobling 1995).

Using data on body weight growth rate during the growing season (Więski and Załachowski 2000a), an attempt was made to estimate the rate of fat accumulation by roach of various sizes in Lake Dąbie and the Pomeranian Bay. It was assumed that the entire mass increment took place during the growing season. It seems that the fat accumulation process proceeded similarly in fish from both water bodies. The results indicate that Lake Dąbie roach contained from 2 to above 2.5 times more fat in autumn than in spring, whereas Pomeranian Bay roach had only 1.4-1.8 times more fat. However, the spring sample of Lake Dąbie roach was collected earlier (Figure 5). In comparison to the data of Ferroni



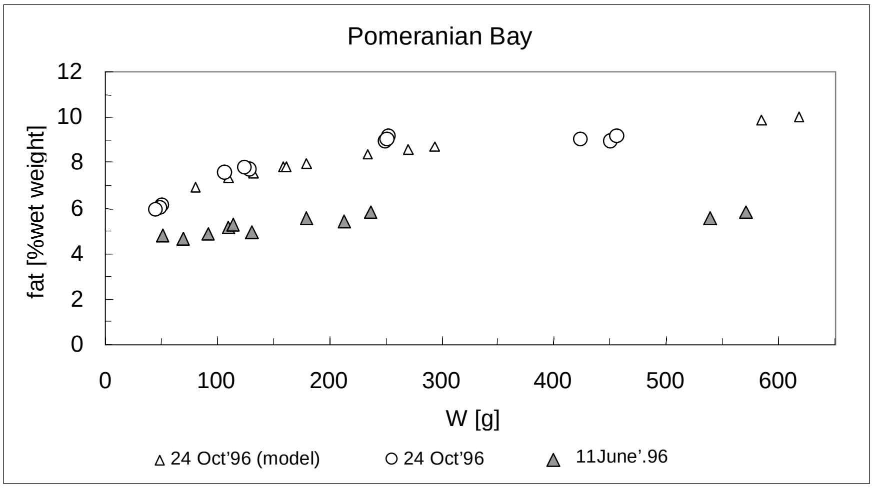


Fig. 5. Fat accumulation of roach in Lake Dąbie and Pomeranian Bay in the growing season of 1996.

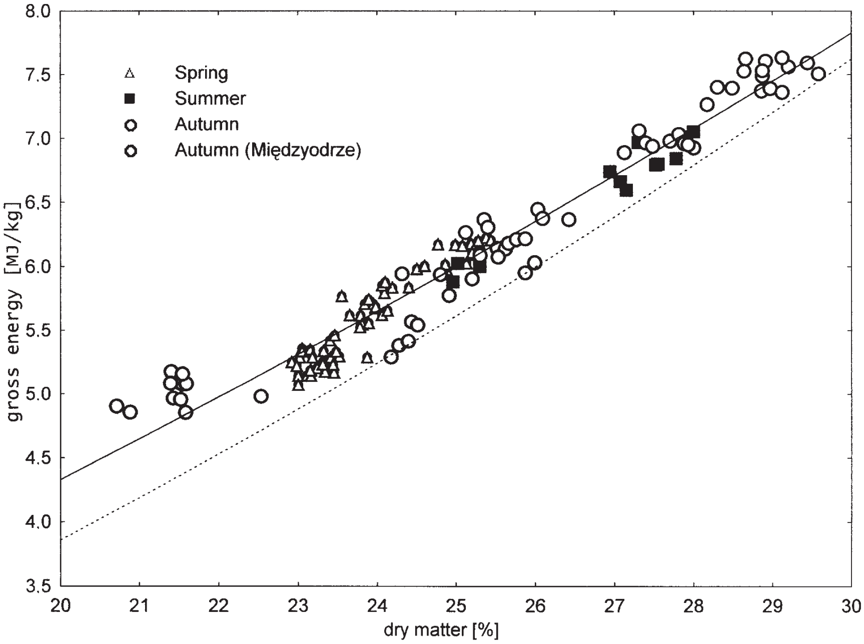


Fig. 6. Relationship between dry matter and gross energy for roach from the river Odra estuary (dotted line for 17 freshwater fish species, Schreckenbach *et al*. 2001).

et al. (1996), small Odra mouth roach seemed a little better nourished, as in the eutrophic Lake Pareloup the difference in fat content between the fish caught in October and those caught in May did not exceed 1.3 times the spring value.

The protein in an animal's body is primarily structural, therefore its content does not change as much as fat, and its cycle of change is less dependent on food availability (Shul'man 1972). The conservative character of this component was confirmed by the results from the second half of the year. No differences were observed in protein content between the autumn samples from the lagoon and the bay or even between Lake Dąbie samples from July 1995 and October 1996. The estimated protein accumulation rate during the growing season for the Lake Dąbie fish displayed a similar pattern to that shown in the Pomeranian Bay samples, where a respective increase in protein content of about 1.07 and 1.04-fold was observed. These results correspond to those obtained by Ferroni *et al.* (1996).

Ash content was uncorrelated with the size of the fish (presented in relation to body weight in Table 2); this has been partially confirmed by other authors (Penczak *et al.* 1976; Papatsouglou and Paparaskeva-Papoutsoglou 1978; Ferroni *et al.* 1996).

The similarity between the results for fat and dry mass content, as well as their multiple regression models, is due to the strong correlation between the two variables. A number of researchers propose using dry mass as the biomass index and productivity index in ecological studies (Penczak *et al.*1976; Schreckenbach *et al.* 2001). Figure 6 presents the power model by Schreckenbach *et al.* (2001) estimated from long-term data on 17 freshwater species and a similar model estimated for Odra estuary roach. It is characteristic that the Międzyodrze sample, which differed from other autumn samples, did not influence the fitting of the model because the dispersion of the observed values did not deviate from that of the spring samples. The approximated curve depicts the pattern of changes in fish body energy content in an annual cycle with low values at the beginning of the growing season and high values at the end. The factors which inhibit reserve accumulation (Międzyodrze sample), appear as a "check" in the nutritional status of the organism as it "shifts" along the curve.

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Recent observations of the sex ratio and maturity ogive of Baltic sprat in the north-eastern Baltic Sea

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Abstract. The sex ratio and maturity ogive of Baltic sprat were investigated in ICES Sub-divisions 28, 29 and 32 for the 1980-1985 and 1995-2000 periods. The mean share of females in sprat catches has been slightly above 50% in the north-eastern Baltic Sea for the last two decades. The mean share of females in sprat catches increased in the Gulf of Finland but decreased in ICES Sub-division 29 in the 1990s. It was revealed that approximately 90% of sprat mature at the age of 2 and the fraction of mature fish at the age of 3 is about 95%. The maturation of age group 1 shows high variability which ranges from 6 to 60% depending on area and year. The maturity ogive indicated that sprat matured earlier in age groups in the 1990s as compared to the 1980s. The relatively higher winter air temperatures observed in the 1990s can be at least partly responsible for this phenomenon.

Key words: Baltic sprat, sex ratio, maturity ogive, north-eastern Baltic Sea, Gulf of Finland.

INTRODUCTION

Spawning stock biomass (SSB) is one of the main parameters which indicates the status of fish stocks. The SSB of Baltic sprat is known to be extremely variable. The sprat SSB in ICES Sub-divisions 22-32 decreased from 500,000-600,000 tons in the mid 1970s to below 200,000 in the 1980-1983 period. It increased slightly afterwards. A more pronounced increase started in 1989 when then SSB rocketed up six-fold to almost 1.5 million tons in 1997. At present, the SSB is slightly more than 1 million tons (ICES 2001a).

At the same time, the mean weight at age of sprat decreased in the Baltic Sea in the 1990s by 30-50% in comparison with the 1980s (Kaljuste 1999, MEI 2000). The increasing stock numbers of sprat can at least partly explain the decrease in the mean weight at age groups in the 1990s. A rather strong negative trend was revealed between the mentioned variables.

It is obvious that the rapid increase of the SSB since 1989 is caused by a series of abundant year-classes which compensate for the negative effect of decreasing mean weights.

Other factors which have an influence on the SSB level are the proportion of mature fish in age groups (maturity ogive) and the sex ratio. To date, the ICES Baltic Fisheries Assessment Working Group (WGBFAS) has used the fixed maturity ogive for the assessment of Baltic sprat; it assumes that age groups 0 and 1 do not spawn while 70% from age group 2 and all older age groups do spawn (ICES, 2001a).

Against the background of these changes, one could also expect changes in the maturation processes of sprat which are affected by growth dynamics and population density. The possible changes in maturity ogive would clearly have an effect on the perception of stock dynamics and management advice.

The aim of this paper is to present new data on the sex ratio and maturity ogive of sprat in the north-eastern Baltic Sea in the 1980s and 1990s.

MATERIALS AND METHODS

A total of 22,813 sprats were collected from March to June in the 1980-1985 and 1995-2000 periods from commercial trawl catches in the Estonian Exclusive Economic Zone (ICES Sub-divisions 28, 29 and 32). To obtain a more precise overview, the samples were disaggregated to the zone level (Table 1).

The Estonian commercial fleet use trawls with a 10 mm mesh size in the cod-end (bar length). According to selectivity studies (e.g. Treschov and Shevtsov 1978, Shevtsov 1982) only 23.2% of sprat smaller than 10 cm escape from the trawls. The mean sprat length in the Estonian Exclusive Economic Zone varies at the age of 1 from 8 to 10 cm and at the age of 2 from 9 to 12 cm (Aps 1986, Kaljuste 1999, MEI, 2000). After fishing, the catch of particular species was not sorted by size groups or was the by-cach of juveniles discarded. Samples were taken from different fishing grounds and depths during the pre-spawning season and the beginning of the spawning season. The selection of fish by the fishing gear was low, and the meshing of fish in the trawl cod-end of was not very high. Therefore, no substantial selectivity is expected in the sprat catches from March to June. One can assume that the structure of the catches represents the structure of the sprat stock rather well, and no transformation calculations (Tomkiewicz *et al*. (1997), Kraus and Köster 2001) for sprat samples taken from commercial catches were made.

Table 1. Number of specimens collected for sex ratio and maturity ogive study of Baltic sprat from commercial trawl catches in the Estonian EEZ (disaggregated to the zone level) from March to June in the periods 1980-1985 and 1995-2000.

Zone	1980	1981	1982	1983	1984	1985	1995	1996	1997	1998	1999	2000	Total
28-2	0	0	100	0	0	0	0	0	53	100	100	100	453
28-5	0	100	0	0	0	0	202	0	0	367	0	0	669
29-2	291	480	901	349	897	37	881	305	200	1,808	1,402	551	8,102
32-1	656	300	578	451	453	704	933	920	300	900	1,102	1,125	8,422
32-2	695	750	923	400	400	550	190	250	0	370	469	170	5,167
Total	1,642	1,630	2,502	1,200	1,750	1,291	2,206	1,475	553	3,545	3,073	1,946	22,813

The collected sprats were sexed and the maturity stage was determined using the six-stage scale described by Pravdin (1966). The fish were classified as mature when the gonads were in at least the third stadium. The testes of the male are pink due to numerous blood-vessels on the surface and they occupy up to one third of the body cavity. The ovaries of female fish are filled by small eggs which are visible to the naked eye and they occupy up to one half of the body cavity. The assumption used with regard to the biological minimum, which is determined by the potential participation of fishes in spawning in a given year, was consistent with the recommendations of the ICES Baltic International Fish Survey Working Group (ICES 1999) and the ICES Study Group on Baltic Herring and Sprat Maturity (SGBHSM, ICES 2001b).

A significance level of differences in the mean share of a) mature sprat by age groups, and b) female sprat in different zones between the time periods was calculated using Student's test.

RESULTS

The mean share of sprat females in samples from commercial catches has varied in the range of 41-56% in the north-eastern Baltic Sea over the last two decades, but the mean values of both time periods have been slightly above 50% (Figure 1).

The comparison of sex ratios in the two periods investigated showed a significant increase in the fraction of females in the western part of the Gulf of Finland (zone 32-I) and a decreasing share in ICES Sub-division 29, especially in the 1995-2000 period (Figure 2). The wide confidence limits of the mean share of sprat females in zone 28-V (1995-2000) is caused by high variance and the low number of data.

Figure 3 shows the dynamics of the percentage of mature sprat (combined males and females) at age groups in the north-eastern Baltic Sea in the investigated years. The maturation of sprat from age group 1 shows high variability ranging from 6 to 60% depending

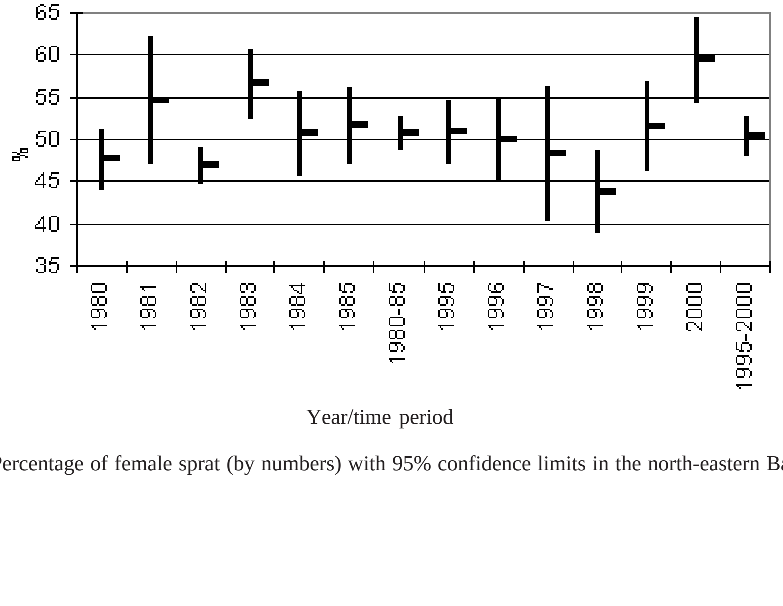

Fig. 1. Percentage of female sprat (by numbers) with 95% confidence limits in the north-eastern Baltic Sea.

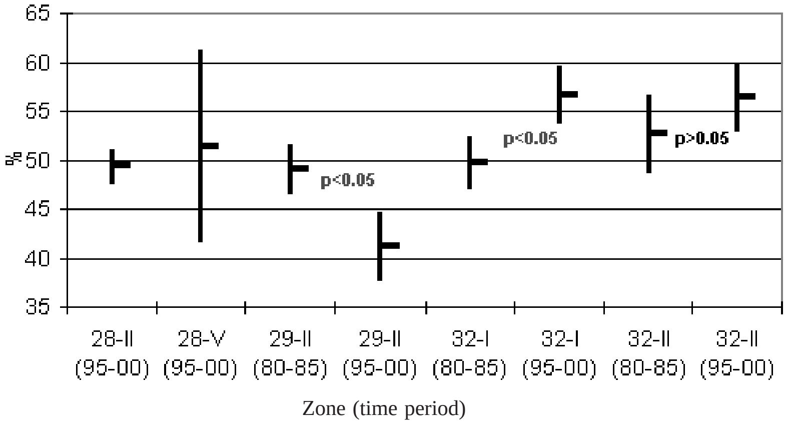

Fig. 2. Percentage of female sprat (by numbers) with 95% confidence limits in the north-eastern Baltic Sea. Significance levels of differences between the time periods in mean percent of male sprat are shown.

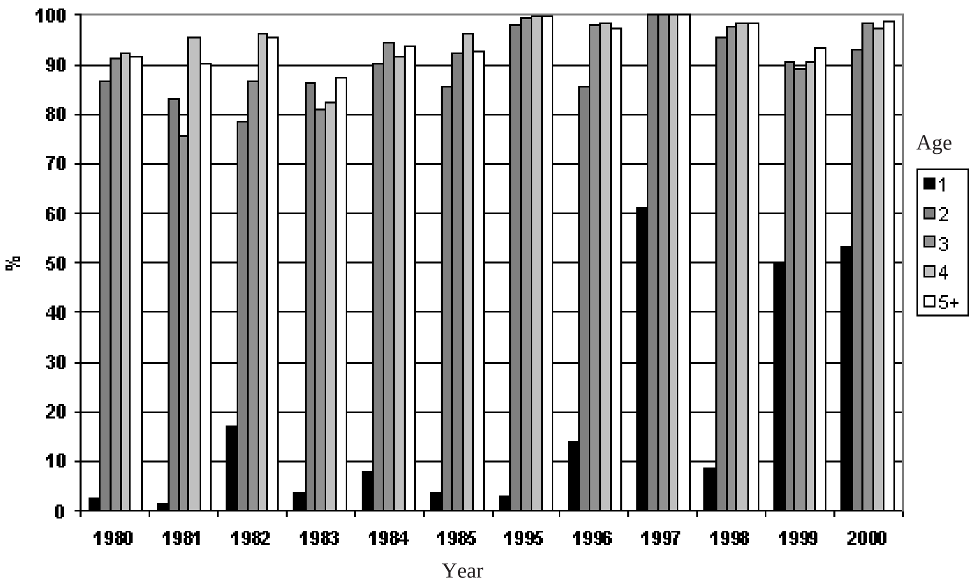

Fig. 3. Percentage of mature sprat (by numbers) at age in the north-eastern Baltic Sea.

on year and area (Figures 3, 6 and 7). Approximately 90% of sprat (males and females) mature at age 2 and the proportion of mature fish at age 3 is about 95% in the north-eastern Baltic Sea (Figure 4). Compared with the 1980s, the maturity ogive indicates that sprat matures significantly earlier in their life cycle in the 1990s (Figure 5). This trend characterizes ICES Sub-division 29 and the western part of the Gulf of Finland, but in the eastern part of the area mentioned the mean share of mature sprat at age has decreased slightly (Figures 6 and 7).

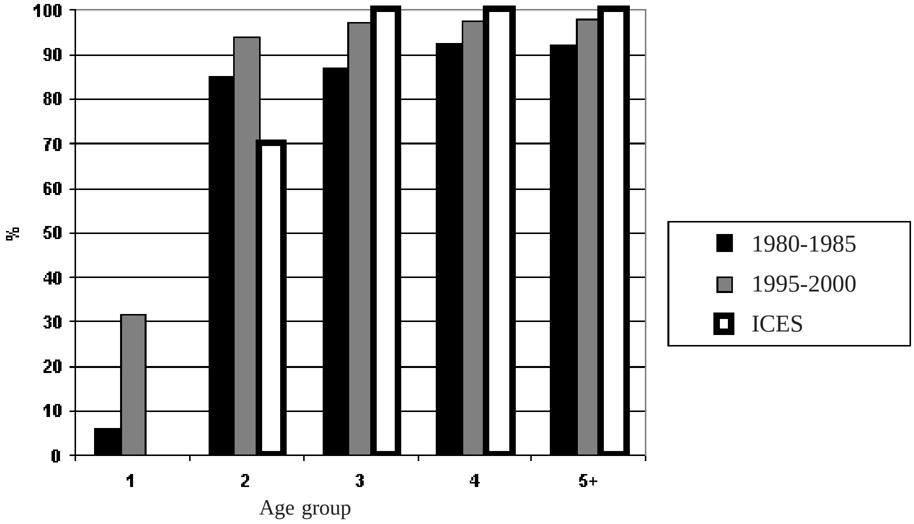

Fig. 4. Observed percentage of mature sprat (by numbers) at age in the north-eastern Baltic Sea and percentage of mature sprat at age groups assumed by ICES WG experts since 1974 for sprat spawning stock assessment in the Baltic Sea (ICES 2001a).

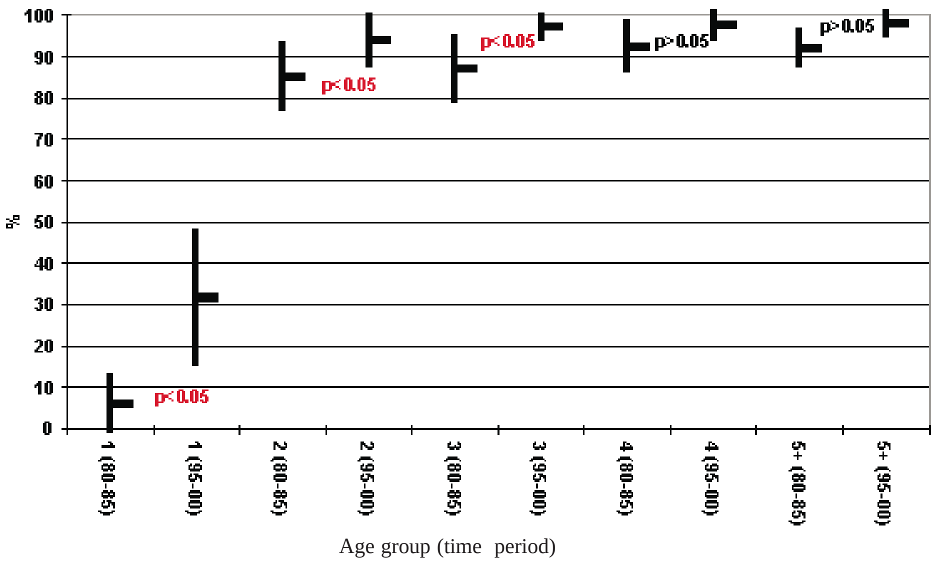

Fig. 5. Percentage of mature sprat (by numbers) at age with 95% confidence limits in the north-eastern Baltic Sea. Significance levels of differences between the different time periods in mean share of mature sprat by age groups are shown.

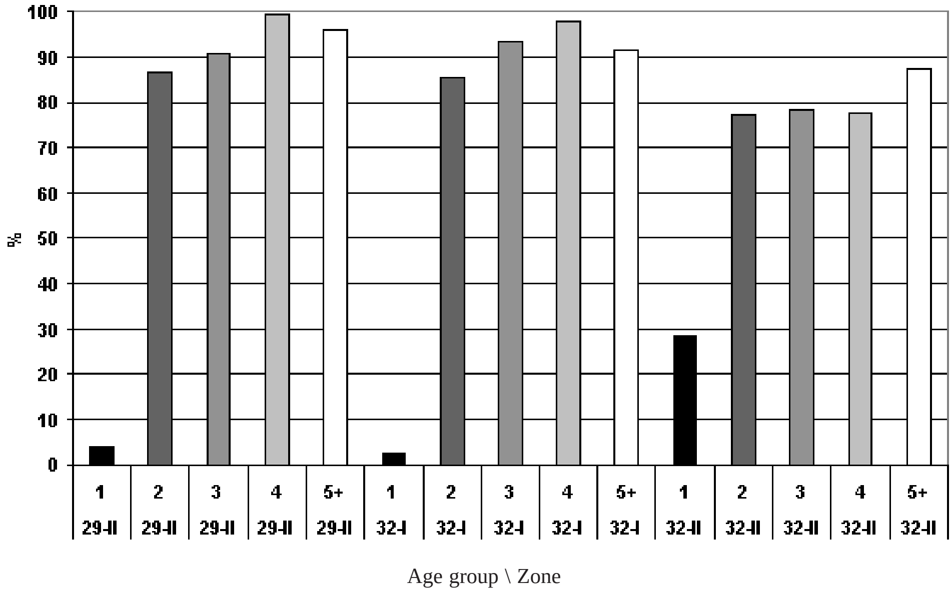

Fig. 6. Percentage of mature sprat (by numbers) at age in the north-eastern Baltic Sea in 1980-1985.

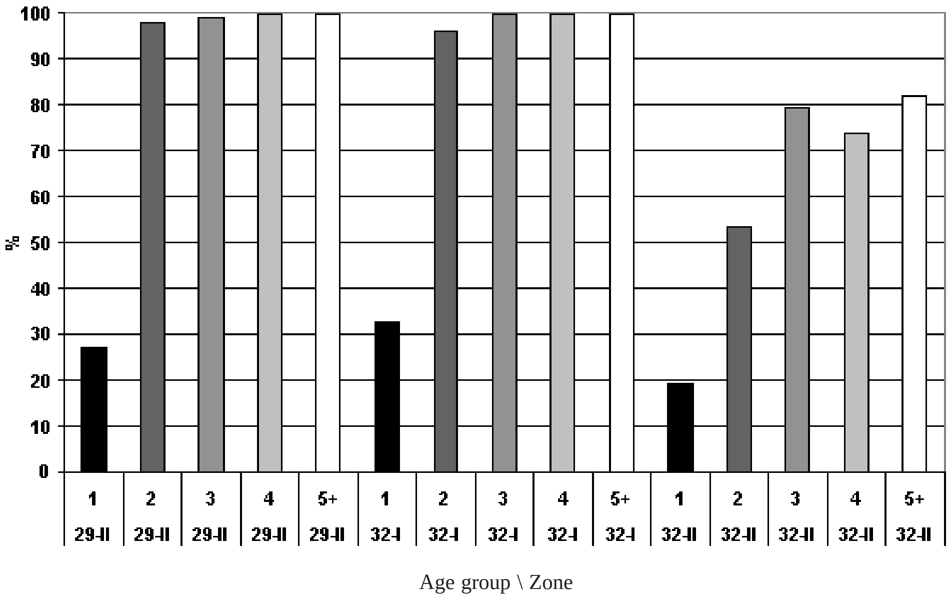

Fig. 7. Percentage of mature sprat (by numbers) at age in the north-eastern Baltic Sea in 1995-2000.

DISCUSSION

The values of the sex ratio and maturity ogive of sprat calculated in the present work are close to the values described by Grygiel (2000, 2001) for sprat caught in the Bornholm and Gdańsk basins. The sprat maturity ogive values calculated in the present work are also in good accordance with the results obtained by Feldman *et al*. (2000) for ICES Sub-division 26 in 1996-1999. Considerable differences appear only in age group 1. Remarkable differences between the observed percentage of mature sprat at age groups and that postulated by ICES WGs experts since 1974 and used by WGBFAS for spawning stock assessment in the Baltic Sea have also been reported by Grygiel (2001) and ICES SGBHSM (ICES 2001b).

Reglero and Mosegaard (2001) have found that only the fraction of the sprat cohort with a larger otolith size reaches maturity at age 1, while the fraction with a smaller otolith size did not exhibit maturity until age 2.

The results of investigations conducted by Grygiel (2001) in the 1997-2000 period in the Polish EEZ suggest that the length of the first maturation of sprat (expressed as 50% of the fraction of mature juveniles) varies in the range from 8.46 to 9.47 cm in the Bornholm Basin and from 8.34 to 10.48 cm in the Gdańsk Basin, and that the the higher proportion of females in the stock is compensated by the maturation of males at an earlier age and smaller length.

Grygiel (2001) has also reported that earlier maturation and spawning in a given year of the Bornholm Basin sprat population in comparison with the the Gdańsk Basin stock is most likely the result of differences in the ecological parameters in these areas.

Baltic sprat spawn in a several portions (8-9) during the spawning season, depending on hydrological conditions (Elwertowski 1957, Shkickij 1967, Kraus and Koster 2001). Higher temperatures in spring can induce earlier spawning so that the new-born year-class has a longer growth period in the first summer of life and greater potential to reach sexual maturity at the age of 1 (Ojaveer *et al.* 1985).

Sprat year-class strength can change considerably during the first wintering period (Ojaveer *et al*. 1985). This means that a cold winter can cause high natural mortality in young sprat. One can also assume that after a mild winter the fish has more energy left for the development of gonads, which is especially important in the first years of life.

According to HELCOM data (HELCOM 1996), records of mean annual air temperatures since the late nineteenth century for the stations at Haparanda, Helsinki, Gotska Sandon and Falsterbo show an upward temperature trend peaking with the warm period of the 1930s. From then onwards, a decrease was recorded in the northern part of the Baltic Sea until the recent warm period began in the late 1980s. The temperature anomalies are mainly concentrated in the winter and spring. The ice coverage was very modest during the 1990s. The record reveals that these conditions are unusual for such a long period. On the basis of these data it can be assumed that the hydrological conditions were beneficial for the earlier maturing of sprat in the north-eastern part of the Baltic Sea in the 1990s. The phenomenon that the mean share of mature sprat in the eastern part of the Gulf of Finland in the 1990s is lower than in the 1980s is probably caused by worsened spawning conditions as a result of decreased salinity. The long-term time series show a decrease in the salinity of the near-bottom water layer in the Gulf of Finland. This development corresponds to that found in other Baltic Sea areas. The decrease in salinity is due to the lack of a major saline water inflow through the Belt Sea into the Baltic Sea. A sixteen-year stagnation period throughout the Baltic Sea was finally terminated by a significant inflow in 1993.

The results of the present study indicate that that there is a firm basis for the revision of the presently used maturity ogive in order to improve the quality of SSB estimates and the assessment of Baltic sprat.

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Papers submitted to the Bulletin are classified according to the following three categories: 1) scientific papers, 2) short communications, 3) varia.

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