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Fish biology

NUTRITIONAL STATUS OF ROACH *RUTILUS RUTILUS* (L.) IN THE RIVER ODRA ESTUARY

STAN ODŻYWIENIA PŁOCI, *RUTILUS RUTILUS* (L.) Z WÓD ESTUARIUM ODRY

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Nutritional status of roach inhabiting the River Odra estuary was studied with both a traditional (morpho-physiological) approach and a bioenergetic one. A total of 999 individuals caught from the Międzyodrze, Lake Dąbie, the Szczecin Lagoon, and the Pomeranian Bay were examined. The Pomeranian Bay individuals were found to be in the best nutritional condition. None of the traditional condition coefficients was able to clearly reflect seasonal changes over the year. Those changes could be observed instead by analysing bioenergetic indices.

INTRODUCTION

In the ichthyological and fisheries-related research, condition coefficients based upon relationships between fish body length and weight are in common use. Although of primary importance for fisheries-related studies, those characteristics, when applied to ichthyological data collected over different seasons, may prove insufficient, particularly when samples are compared which are not uniform in terms of individual features. As fishes grow and accumulate energy throughout their life span, seasonal changes in body calorific content should be a function of changes in body size. However, the nutritional status of a fish, as expressed by morpho-physiological characteristics, is not always readily translated to the body calorific content. This is due to different energetic value and variable contributions of chemical components making up the fish body. For this reason, it is often necessary to measure the body energy content.

Owing to its economic importance, the roach has been intensively studied. The ubiquity of the species and the ease with which it can be harvested make it suitable as a model organism. As opposed to that on cultured cyprinids, literature on the roach energy content is restricted to a few papers only. Comparisons are frequently rendered difficult due to variability of methods applied (Korde 1968; Penczak et al. 1977; Parent et al. 1993).

The present work was aimed at finding out how the nutritional status of roach was related to environmental conditions. A comparison of results obtained with traditional morpho-physiological methods and through measurement of the body energy content is an attempt to evaluate the applicability and limitations of the two approaches. The River Odra mouth region seems to be an area appropriate for this type of studies due to the presence of different types of water bodies and variability of their respective environments.

MATERIAL AND METHODS

The present work involved a total of 999 roach caught within April 1995–October 1997 from the Międzyodrze, Lake Dąbie, the Szczecin Lagoon, and the Pomeranian Bay. The fish examined were supplied by commercial fishermen. Tab. 1 summarises dates of capture and sample sizes.

Table 1

Date of capture and number of individuals examined

Water body	Międzyodrze		Lake Dąbie		Szczecin Lagoon		Pomeranian Bay	
Date and number of individuals	10 Nov '95*	97	11 May '95*	44	14 Jun '95*	43	4 Apr '95	53
	5 Jun '97	63	13 Jul '95*	116	24 Apr '96	75	11 Jun '96*	82
	26 Jun '97	16	13 Oct '95*	91	30 May '96*	101	24 Oct '96*	43
	1 Jul '97	23			10 Sep '96*	111		
	15 Jul '97	34						
	24 Oct '97	7						
Total		240		251		330		178
Grand total								999

* subsamples used for chemical analyses.

Adult and juvenile fish were measured to 0.5 cm and 1 mm, respectively, and weighed to 1 g. Values of the standard length (*SL*) of the body were used when analysing the data. The relationship between the standard length and the total length (*TL*) is described by the following equation:

$$TL = 1.1826\, SL + 0.2851\ (R^2 = 99\%)$$

The body length (*L*)–body weight (*W*) relationship was calculated as a power function determined separately for each water body, sex, whole fish, and gutted fish as well as before and after spawning. The Fulton condition coefficient (*F*) for whole fish as well as the Clark coefficient (*C*) for gutted fish were calculated separately for every individual and presented as linear functions of length and age. To supplement the routine nutrition assessment with condition coefficients, crude protein and lipid contents were determined to arrive at the fish body energy content. All the analyses and assays were made at the chemical laboratory of the Department of Aquaculture, Agricultural University in Szczecin. The assays were performed for the following 4 size groups: 10.0–15 cm; 15.5–20 cm; 20.5–25 cm; and >25 cm. For the assays, 3 individuals of similar gonad maturity were picked out from each group. The protein and fat content assays were carried out with the Kjeldahl and Soxhlet techniques, respectively. The fish body calorific value was calculated from the sum of energy contents of the lipid and protein levels found; the energy contents were calculated with the appropriate conversion coefficient (5.65 and 9.45 Kcal/g for protein and lipids, respectively (Fischer 1993). Based on the growth rate of the fish examined (Więski and Załachowski 2000), the weight-specific fish growth rate models were developed along with models of absolute weight energy equivalent growth rate.

RESULTS

The *L–W* relationship curve for the Pomeranian Bay showed the strongest deflection. On the other hand, within the range of empirical values, the Międzyodrze fish curve was the highest-ranging (Fig. 1). The similar parameters of the *L–W* relationship for the Lake Dąbie and Szczecin Lagoon fish were the reason for the fact that the corresponding curves were superimposed one on the other. With respect to the gutted fish, the exponent was in all the cases found to be lower than in the relationships for the whole fish. However, similarly to the case of the whole fish, the Pomeranian Bay sample showed the highest exponent, the Międzyodrze curve ran above the remaining ones. Generally, females, both gutted and whole, showed better condition than males.

The Fulton and Clark condition coefficients were observed to increase with fish age and length, the increase being most pronounced in the Międzyodrze (the best condition) and in the Pomeranian Bay (Fig. 2). Seasonal variations in the condition illustrated considerable between-habitats variation (Figs. 3 and 4). In June, the high values of both coefficients in the Międzyodrze fish were accompanied by much lower coefficients found in the Pomeranian Bay.

The calorific content tended to increase with fish size, the strength of the trend being variable (e.g. a stronger growth in autumn) (Figs. 5 and 6). The exception was supplied by the Międzyodrze sample in which the lowest calorific content was detected in late autumn, the values being similar in different size classes. Strong correlations between the regression coefficients (b) of the functions $ENERGY = a + b \cdot L$ and $ENERGY = a + b \cdot W$ and the time elapsing from the date of spawning (assumed to have happened on 10 May) were possible only when the Międzyodrze regression coefficients were excluded from calculations (Tab. 2; Fig. 7).

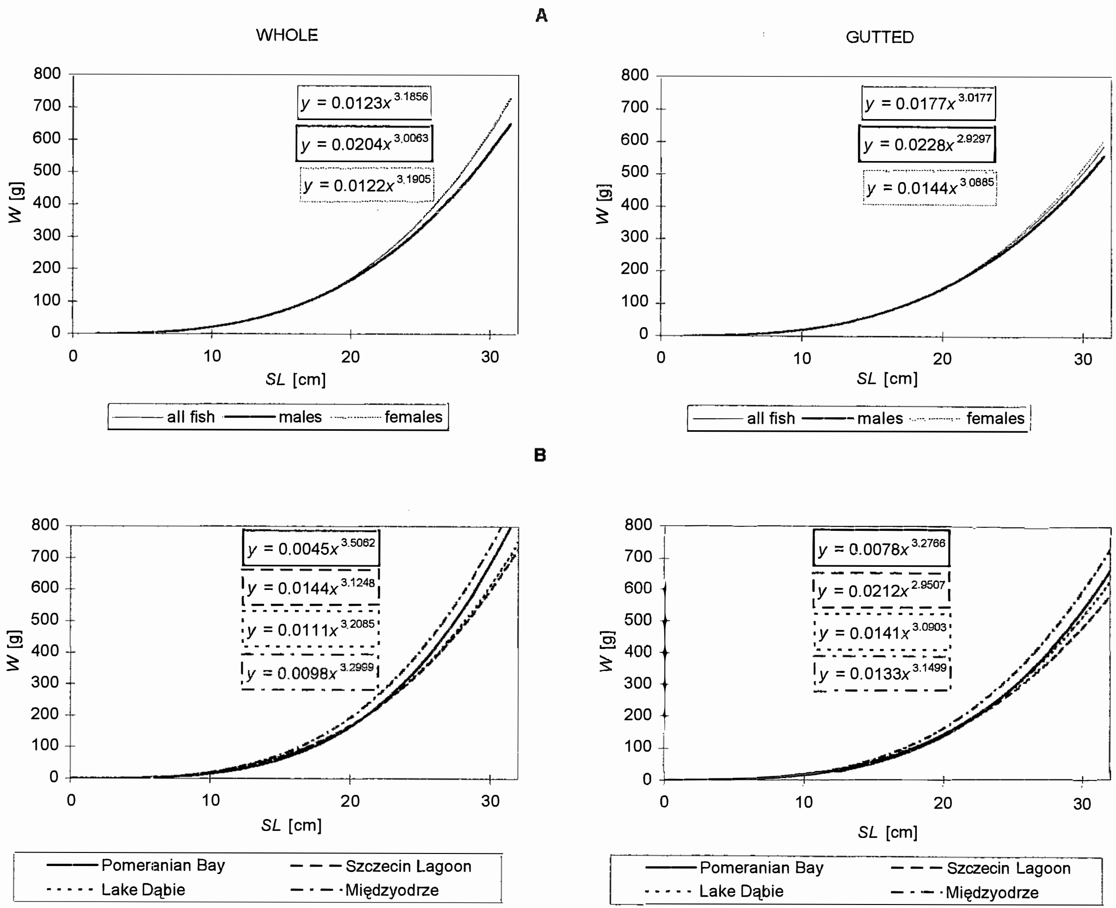

Fig. 1. The *L–W* relationship for whole and gutted roach by sex (A) and site of capture (B)

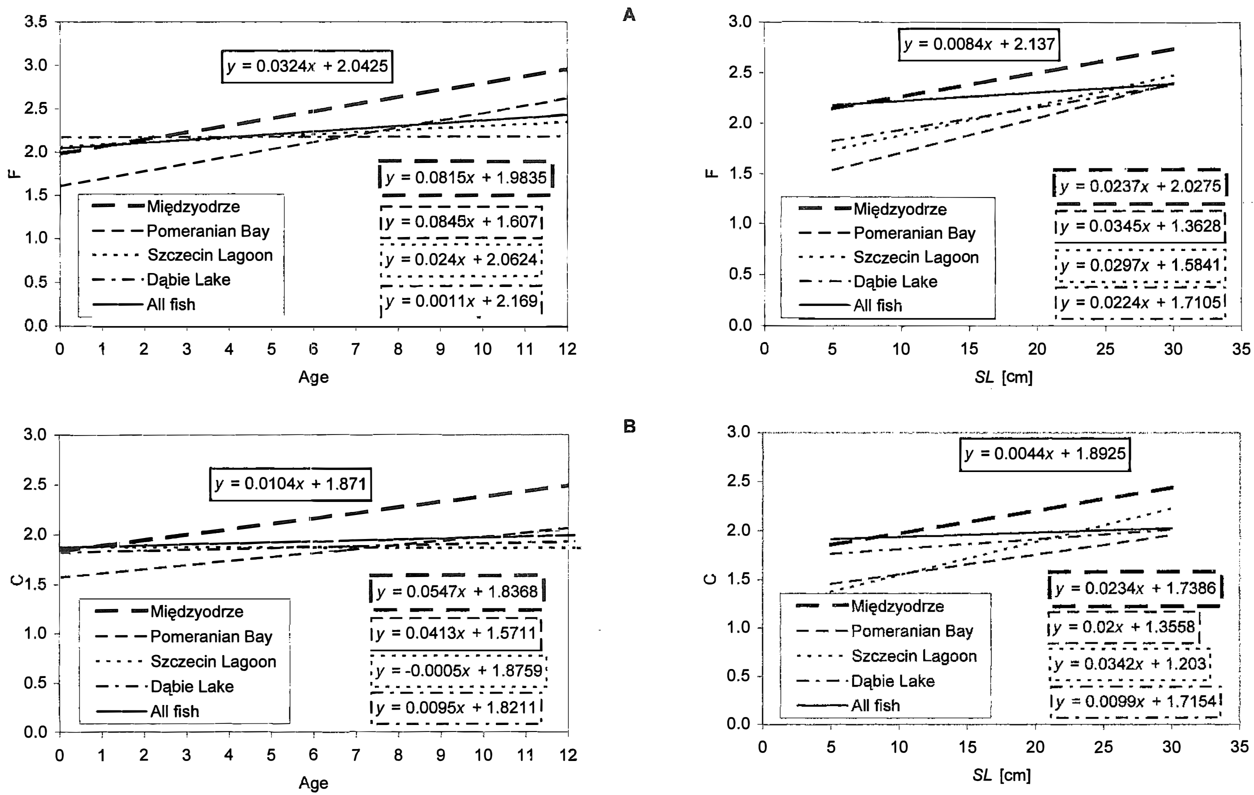

Fig. 2. Relationship between Fulton (A) and Clark (B) condition coefficients versus age and length

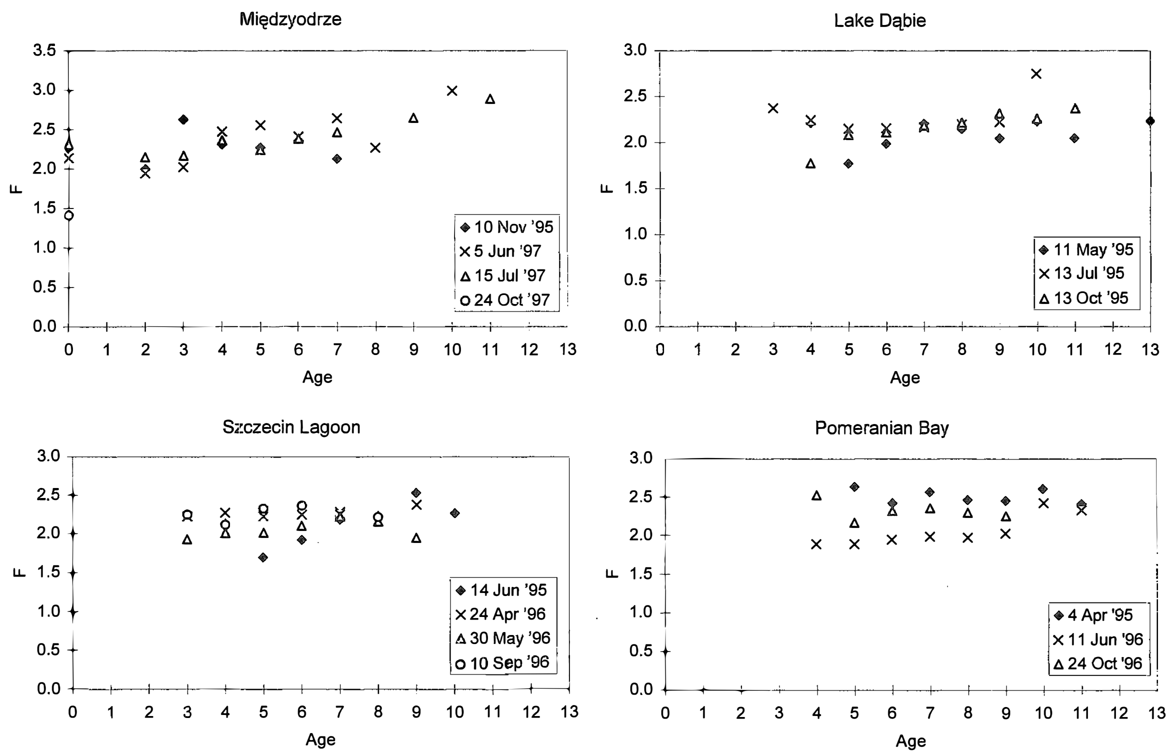

Fig. 3. Date of capture-dependent changes in the Fulton coefficient

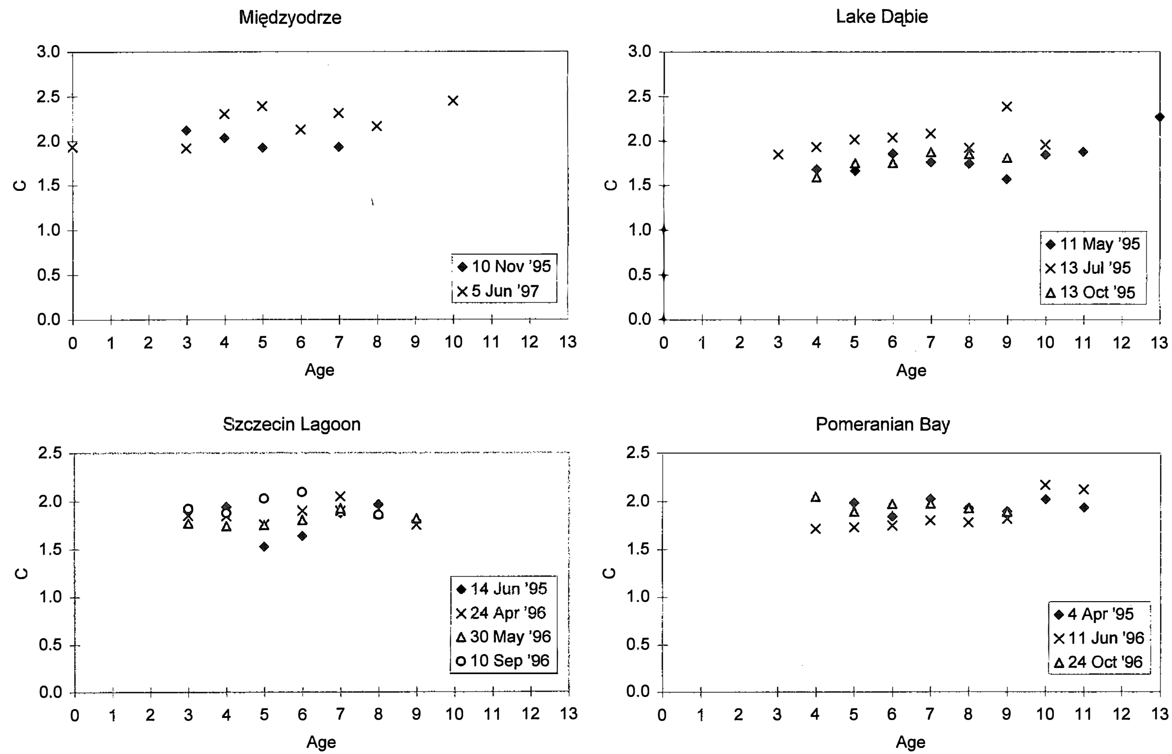

Fig. 4. Date of capture-dependent changes in the Clark coefficient

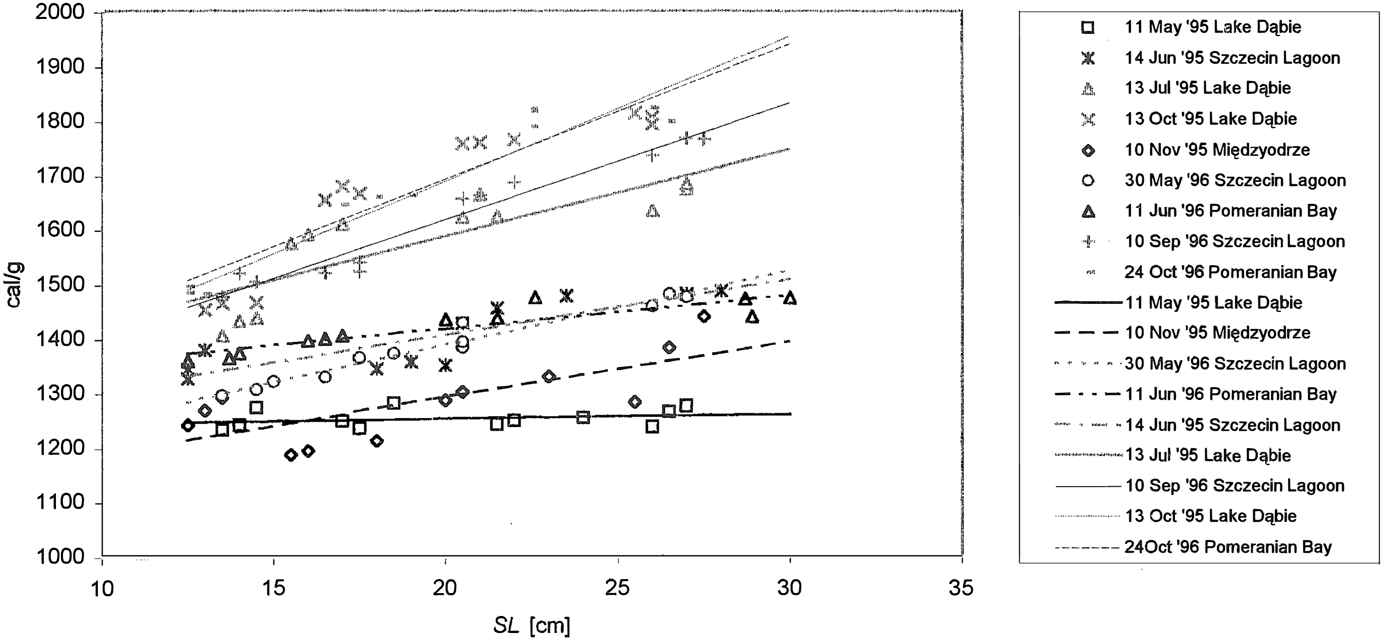

Fig. 5. Seasonal changes in fish-length dependent body calorific value

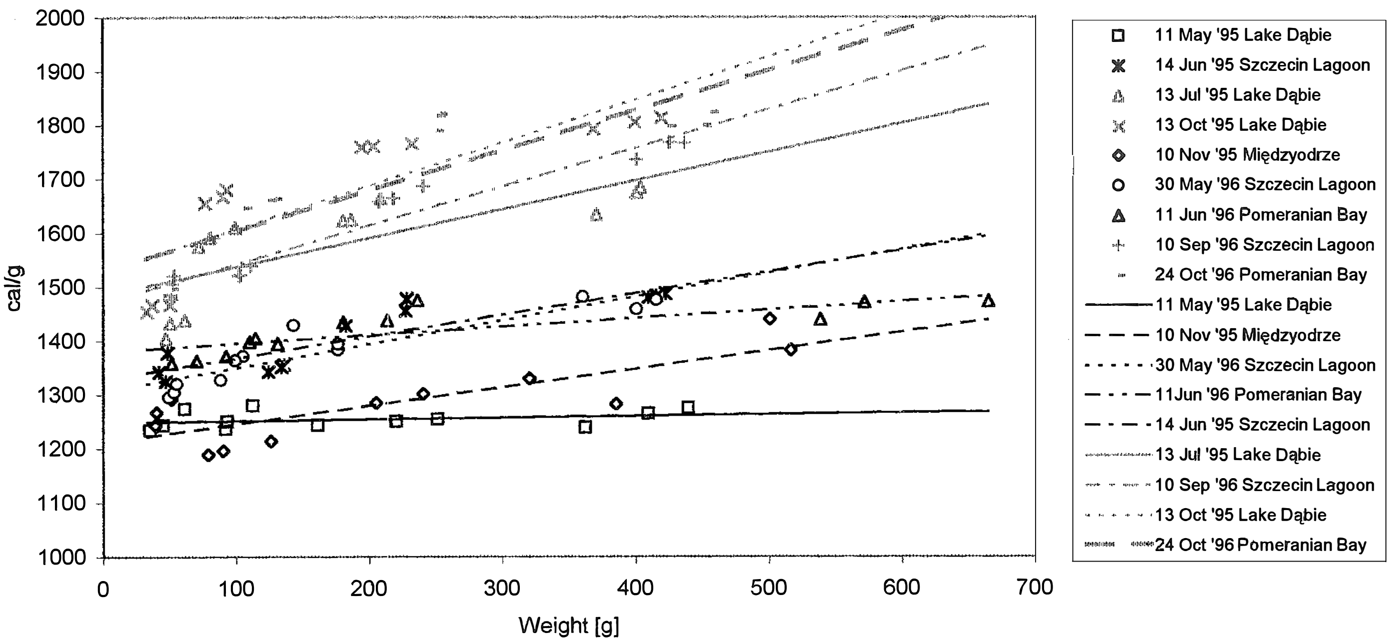

Fig. 6. Seasonal changes in fish-weight dependent body calorific value

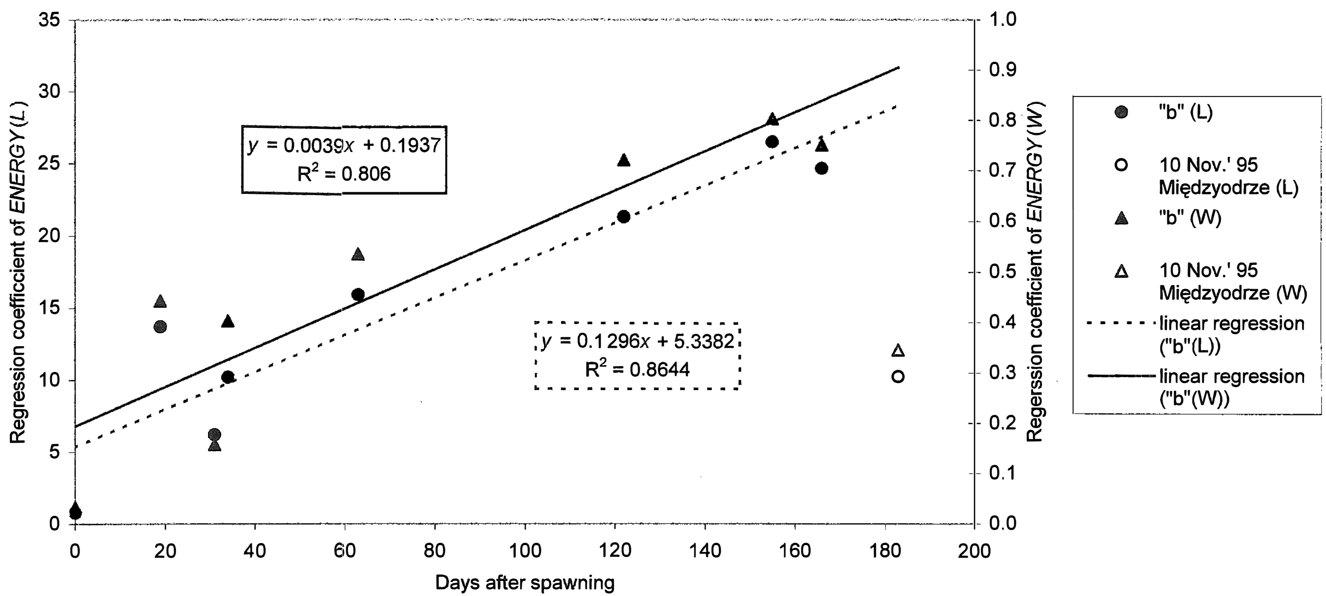

Fig. 7. Relationship between regression coefficient b of the functions $ENERGY = a + b \cdot L$ and $ENERGY = a + b \cdot W$ versus number of days elapsing since spawning

Table 2

Parameters of the equations *ENERGY* = *a* + *b*·*L* and *ENERGY* = *a* + *b*·*W*

Date, water body	*n*	*L*				*W*			
		a	*b*	*R*	*p*	*a*	*b*	*R*	*p*
11 May '95 Lake Dąbie	12	1238.19	0.76	0.24	0.46	1247.44	0.03	0.29	0.36
14 Jun '95 Szczecin Lagoon	12	1203.02	10.19	0.87	0.00	1327.97	0.40	0.89	0.00
13 Jul '95 Lake Dąbie	12	1270.12	15.90	0.82	0.00	1483.59	0.53	0.75	0.00
13 Oct '95 Lake Dąbie	12	1159.50	26.48	0.92	0.00	1526.83	0.80	0.84	0.00
10 Nov '95 Międzyodrze	12	1088.52	10.19	0.74	0.01	1210.57	0.35	0.82	0.00
30 May '96 Szczecin Lagoon	12	1114.43	13.67	0.98	0.00	1305.93	0.44	0.92	0.00
11 Jun '96 Pomeranian Bay	12	1294.34	6.18	0.90	0.00	1379.75	0.16	0.79	0.00
10 Sep '96 Szczecin Lagoon	12	1192.13	21.30	0.98	0.00	1469.63	0.72	0.97	0.00
24 Oct '96 Pomeranian Bay	12	1199.85	24.66	0.95	0.00	1527.36	0.75	0.85	0.00

In order to identify forcing exerted on the fish body calorific content, a multiple regression model was developed in which the calorific content (*ENERGY*) was related to the number of days elapsing from spawning (*DES*), body length (*L*) or weight (*W*) and capture site (*HABITAT*) [*HABITAT* = 1 (Międzyodrze); 2 (Lake Dąbie); 3 (Szczecin Lagoon); 4 (Pomeranian Bay)].

(1) The standardised model including varying length (*L*):

$ENERGY = 0.548368 \cdot DES + 0.381235 \cdot L + 0.418914 \cdot HABITAT$

(2) The standardised model including varying weight (*W*):

$ENERGY = 0.523667 \cdot DES + 0.310008 \cdot W + 0.408599 \cdot HABITAT$

Models (1) and (2) explain variability at the levels of 51 and 46%, respectively (R^2 values). A more robust approximation should include characteristics such as sex and gonad maturity stage as well as environmental factors. Those characteristics were, however, disregarded owing to incompleteness of data on hand. A better fit of the models was obtained (the respective R^2 values of 82 and 80%) when the Międzyodrze data were excluded; at the same time, the respective contributions of the individual variables to the estimated energy content changed correspondingly:

(1) $ENERGY = 0.825547 \cdot DES + 0.407829 \cdot L - 0.028440 \cdot HABITAT$

(2) $ENERGY = 0.816477 \cdot DES + 0.380866 \cdot W - 0.061789 \cdot HABITAT$

Fig. 8 illustrates comparison of the roach growth data obtained with the standard and the chemical methods; the weight growth rate as well as the weight-specific and absolute energy equivalents are compared (the energy curves were plotted from the autumn data). Compared with the weight growth rate, the curve illustrating the weight-specific energy equivalent growth rate for the Międzyodrze is less inflected, as a result of which the highest curve is that for the Pomeranian Bay. The Lake Dąbie and the Szczecin Lagoon showed a similar growth in energy content per weigh unit, similarly to the case of weight growth rate, although the difference in the amount of accumulated energy in older fish with respect to the data for the Pomeranian Bay was less than in the weight growth rate.

The efficiency of the *L–W* relationship and of the body energy values, as indicators of the nutritional status, was examined. The efficiency was measured by determining the linear correlations between regression coefficients of the *L–ENERGY* and *W–ENERGY* functions and number of days elapsing since spawning and the multiple correlations between the parameters *k* and *n* of the *L–W* relationship (Tab. 3). The correlation between *L–ENERGY* and *W–ENERGY* regression coefficients with the number of days elapsing since spawning proved strong, while that for *n* and *k* was weaker. This is an evidence of a lower efficiency of the *L–W* relationship.

Table 3

Linear regressions of regression coefficients. *b* (*L–ENERGY*; *W–ENERGY*) and number of days elapsing since spawning (*DES*) as well as multiple regression parameters of the relationship L–W (*k*, *n*) and number of days elapsing since spawning

		β*	*B***	*p*	R^2
b (*L*–calorific value)–*DES*		0.929727	6.6718	0.000822	0.864
b (*W*–calorific value)–*DES*		0.897784	207.4957	0.002469	0.806
(*k*, *n–DES*)	*k–DES*	2.349836	6350.49	0.065558	0.484
	n–*DES*	2.034877	496.40	0.099431	0.484

* β, standardised regression coefficient
** *B*, regular regression coefficient

DISCUSSION

Judging by the criteria established by Wilkońska (1975), the Pomeranian Bay and Międzyodrze roach examined showed good and very good condition, while the Dąbie and Szczecin Lagoon individuals showed condition close to intermediate and poor, respectively. Fig. 9 shows plots of the *TL*-based *L–W* relationship for both the roach examined in this study and data for selected European water bodies. The roach caught off the islands of Rügen and Usedom (Hahlbeck 1988) showed condition which was poorer than that found in the Pomeranian Bay individuals, but close to the average for the Odra estuary. This, when viewed in the light of the fact that the condition of the roach caught in the Szczecin Lagoon was similar to that of the desert Lake Yakshan (Turkmen) (Jarvalt and Tuvikene 1993), may indicate either a conservative character of the parameter in question or a complex nature of environmental effects on roach condition, whereby a similar state under widely differing regimes is produced.

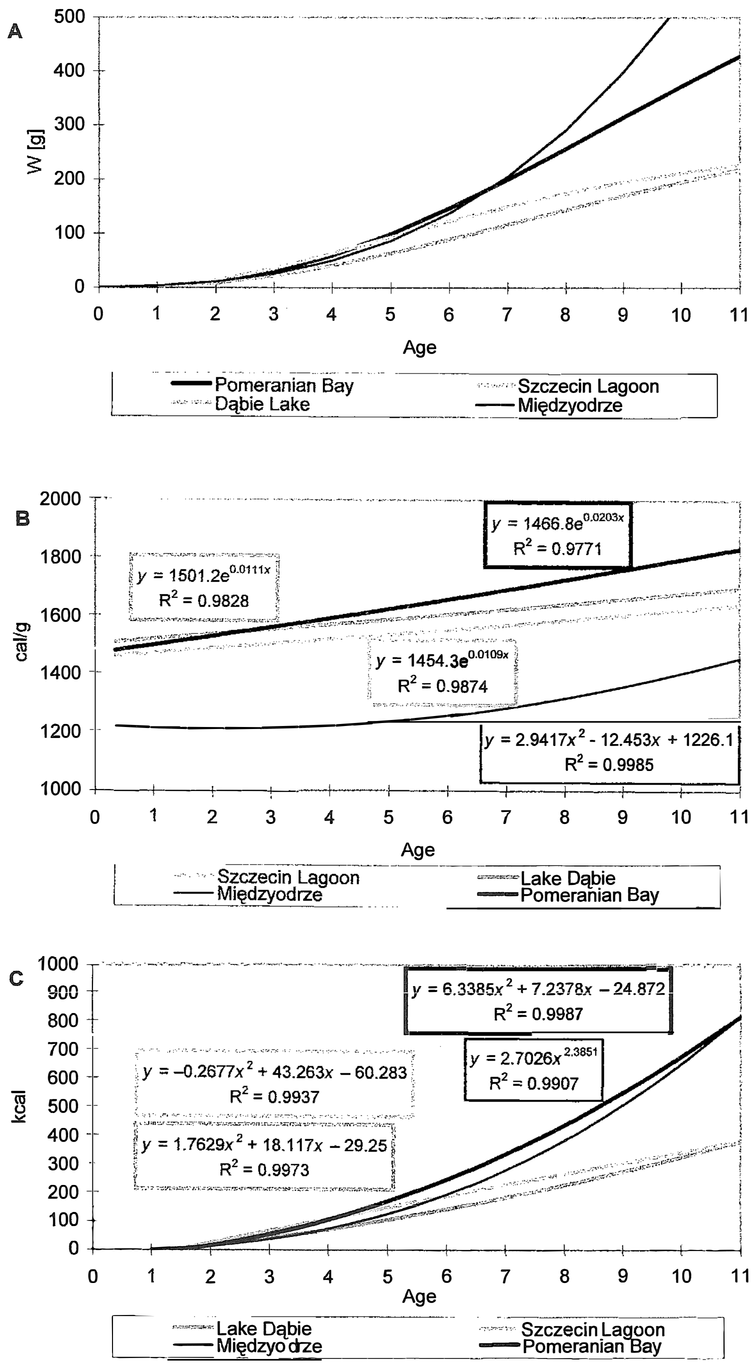

Fig. 8. Growth rates of roach weight (A) as well as weight specific (B) and absolute (C) weight energy equivalents [(A) from Więski and Załachowski (2000)]

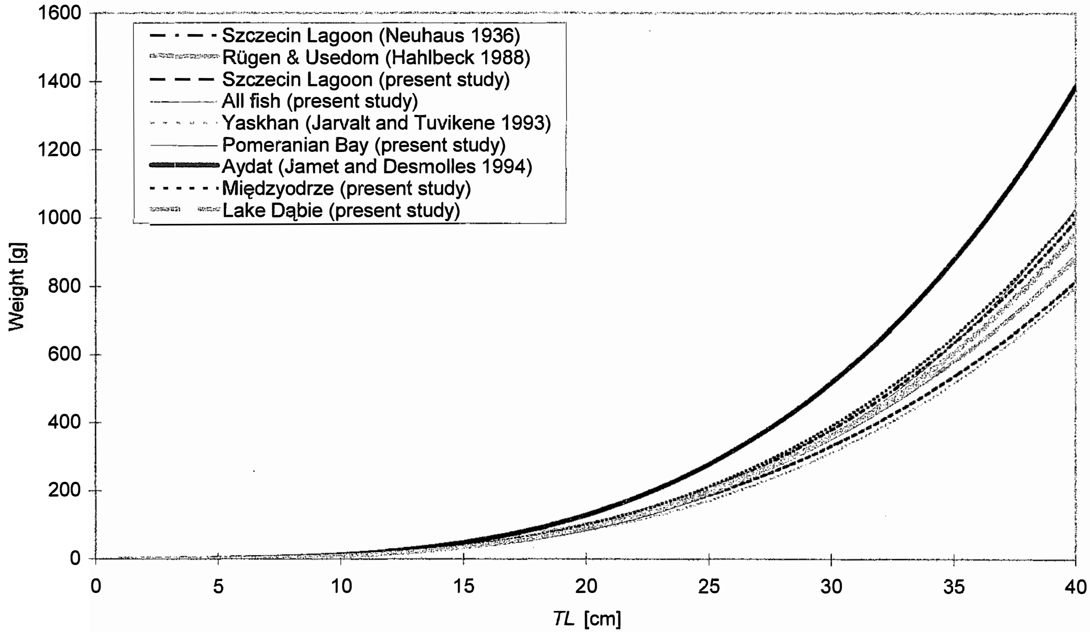

Fig. 9. Condition of roach inhabiting various water bodies

A strong influence of empirical data on the condition models calculated was particularly evident on data obtained from the fish caught before and after spawning; it was also seen as a deviation from the rule of a diminishing difference between the gutted and non-gutted fish. Similarly, effects of length distribution on the results obtained was visible in a less steep slope of the $L \rightarrow F$ and age$\rightarrow F$ functions for the entire material against the background of data for individual water bodies (Fig. 2). The reason can be sought in the presence or absence of juveniles and in the allometric growth accompanied by a change in the shape of the fish body (Załachowski et al. 1997).

The lower calorific value of the Międzyodrze fish may be a result of water temperature (Šulman 1972). It cannot be ruled out that the samples examined contained individuals which had migrated from the Dolna Odra power station cooling water canal. An elevated ambient temperature acts in favour of a high linear growth rate during the growing season and a limited storage of energy-rich materials during autumn. Of all the water bodies under study in this work, Międzyodrze is the only one in which a uniform growth was observed. Thus a possibility that a lower accumulation of energy-rich materials in fish tissues is a price paid for a faster growth of older fish cannot be excluded. This hypothesis should be tested by studying chemical composition of lacustrine populations in which uniform growth is more common. The highest relative calorific value of the Pomeranian Bay roach may have stemmed from a better availability and a better quality of food (Šulman 1972). This suggestion only superficially contradicts results obtained by Korde (1968) who studied roach and bream in Greifswalder Bodden. The much lower lipid contents found by Korde (1968), compared to the data of this study, are a result of methodological differences because she studied muscles only, while roach is known to accumulate fat primarily along the intestine (Nikolskij 1961).

CONCLUSIONS

1. The best condition, expressed by the L–W relationship, was found in those individuals caught in the Międzyodrze and the Pomeranian Bay; the condition of roach caught in Lake Dąbie and in the Szczecin Lagoon was poor. Judging by the criteria established by Wilkońska, the first two groups of roach showed good and very good condition; the Dąbie and Lagoon fish had condition close to intermediate and poor, respectively.
2. Effects of different ranges of empirical data on morpho-physiological condition models were identified. None of the morpho-physiological indices of condition managed to clearly reflect seasonal changes over the year. On the other hand, such changes were identified through analysis of bioenergetic indices.
3. The Międzyodrze roach, characteristic by their lowest weight-specific energetic value, were the only group showing a uniform growth rate.

4. The highest rate of growth of weight energy equivalent was recorded in the Pomeranian Bay and Międzyodrze roach, lower values being observed in Lake Dąbie and in the Szczecin Lagoon. In Międzyodrze, the weight energy equivalent growth rate was lower than the weight growth rate.

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STAN ODŻYWIENIA PŁOCI, *RUTILUS RUTILUS* (L.) W WODACH ESTUARIUM ODRY

STRESZCZENIE

Za pomocą metody tradycyjnej (morfofizjologicznej) i bioenergetycznej zbadany został stan odżywienia płoci z ujścia Odry. Przebadano 999 ryb pochodzących Międzydorza, jeziora Dąbie, Zalewu Szczecińskiego oraz Zatoki Pomorskiej.

Najlepszą kondycją, wyrażoną zależnością *L–W*, odznaczały się ryby z Międzyodrza i Zatoki Pomorskiej, gorszą z Dąbia i Zalewu. Żaden z tradycyjnych wskaźników stanu odżywienia wyraźnie nie odzwierciedlał sezonowości zmian w cyklu rocznym. Zmiany takie dały się uchwycić poprzez analizę wskaźników bioenergetycznych. Płocie z Międzyodrza, wyróżniające się najmniejszą wartością energetyczną na jednostkę masy, były zarazem jedynymi spośród zbadanych, które wykazywały równomierne tempo wzrostu. Największym tempem wzrostu ekwiwalentu energetycznego masy odznaczały się płocie z Zatoki Pomorskiej i Międzyodrza, mniejszym – z Dąbia i Zalewu. W Międzyodrzu tempo wzrostu ekwiwalentu energetycznego było mniejsze niż tempo wzrostu masy.

Analiza regresji wykazała lepszą efektywność wartości energetycznej ciała od wskaźników morfofizjologicznych jako metody oceny stanu odżywienia płoci.

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