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FECUNDITY OF VENDACE, *COREGONUS ALBULA* (L.), FROM SEVERAL LAKES IN WESTERN POMERANIA

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ABSTRACT. The aim of the study was to determine individual absolute and relative fecundity in vendace, *Coregonus albula* (L.), populations from four Western Pomeranian lakes that differ morphometrically and trophically. The highest mean total length and individual weight were recorded in the fish from the mesotrophic lakes Ińsko (229.1 mm and 106.6 g, respectively) and Miedwie (228.1 mm and 105.1 g, respectively). The highest individual absolute fecundity in particular age groups as well as individual relative fecundity were noted in the fish from Lake Miedwie (6635-24620 eggs per female and 10756-11609 eggs per 100 g female body weight, respectively), while the lowest values of these parameters were confirmed in fish from Lake Glinna (4782-6087 eggs per female and 6406-6953 eggs per 100 g female body weight). A high, statistically significant correlation between absolute fecundity and total fish length and a slightly lower correlation between absolute fecundity and fish age were noted in all of the populations studied.

Key words: VENDACE, FECUNDITY, LAKE, WESTERN POMERANIA

INTRODUCTION

Vendace, *Coregonus albula* (L.), is one of the most valuable freshwater fish species caught in Polish lakes. It is desirable as a consumer product thanks to it quality meat rich in protein and fat, as well as biologically thanks to its rapid growth rate and its shoal life strategy that simplifies catching it (Marciak 1970, Ciepielewski 1974). These traits coupled with the challenges of maintaining a high level of eel, *Anquilla anquilla* L., exploitation have prompted the rapid development of a vendace management model in lakes that provide appropriate environmental conditions for this species.

Substantial fluctuation is observed in vendace catches in individual lakes; this might be linked to natural mortality (limited reproduction, predation) or fishing mortality (impact of fisheries) (Salojarvi 1987) and to low recruitment of younger generations. The magnitude of the latter factor is dependent on the reproductive capability of a pop-

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ulation (fecundity of fish in individual basins). Estimating fecundity is particularly significant for fish with short life cycles, including vendace, which can easily be overfished if rational fisheries management is not applied. To date, analyses of vendace fecundity have been performed primarily in the lakes of Mazury (Ciepielewski 1974, Demska-Zakęś and Długosz 1995) and Wielkopolska (Budych and Iwaszkiewicz 1964, Mastyński 1978). Little data exist, however, on the value of this parameter in fish that occur in the lakes of Western Pomerania (Walczak 1953, Czerniejewski and Filipiak 2002). The aim of the current study was to perform a comparative analysis and to estimate the absolute and relative fecundity of vendace populations from four Western Pomeranian lakes that differ morphometrically and trophically.

MATERIALS AND METHODS

The study material was comprised of vendace obtained during the fall of 1999 and 2000 from lakes Miedwie, Ińsko, Woświn, and Glinna (Glinno) in Western Pomeranian. The lakes differed with regard to morphometric and trophic parameters (Table 1, Fig. 1). Catches were made with gill-nets with a mesh bar length of 24 mm, and then, immediately after being transported to the laboratory of the Department of Fisheries Management in Open Waters, University of Agriculture, Szczecin, the specimens were weighed individually to the nearest 0.1 g, total length (TL) was measured to the nearest 0.1 mm with an electronic slide caliper coupled with a computer, and age was determined from scale readings.

TABLE 1

Basic morphometric and trophic data of the individual lakes (according to IFI Olsztyn)

Lake	Surface area (ha)	Volume (thousand m^3)	Depth (m)		Trophic status
			maximum	mean	
Miedwie	3527.0	681672.4	43.8	19.3	Mesotrophic
Ińsko	486.6	65182.0	41.7	11.1	Mesotrophic
Woświn	809.1	75840.8	28.1	9.4	Eutrophic
Glinna	75.6	6238.7	16.4	8.2	Eutrophic

Individual absolute and relative fecundity (calculated per 100 g of vendace mass estimated with the dry method based on the analysis of female gonads classified as stage V (gravid) to VI (spawning) in the Maier scale (Szypuła et al. 2001). Absolute and

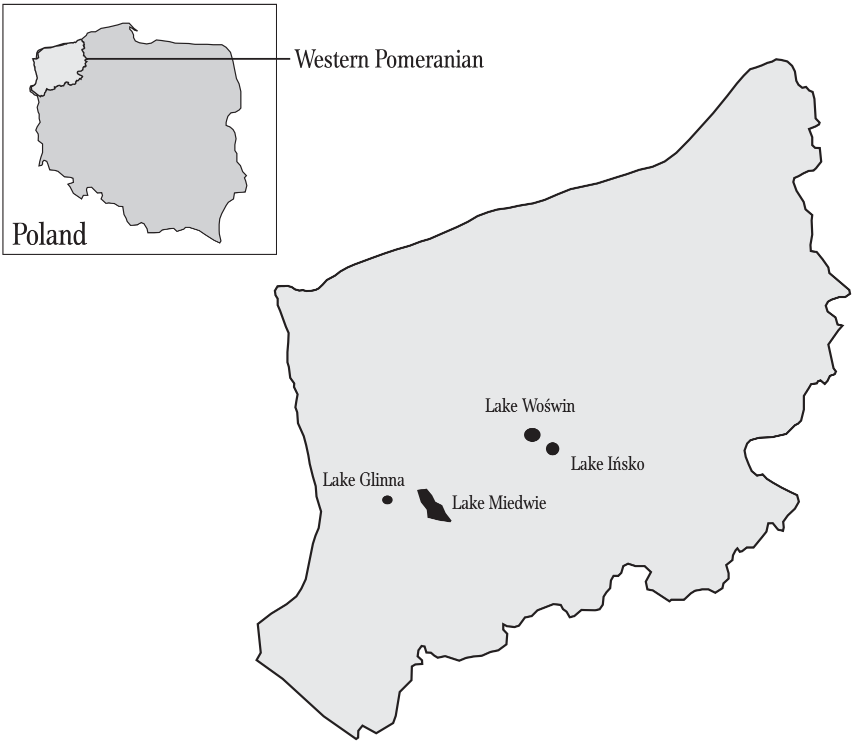

Fig. 1. Location of lakes from which vendace was caught for the study.

relative fecundity was determined based on examinations of 615 fish obtained during the spawning seasons in 1999 and 2000 (Table 2). After making an incision in the abdomen of the female, the gonads were excised with a special spoon. The weight of the whole gonad was recorded (± 0.0001 g), and then samples of 0.2-0.3 g were cut from the front, middle, and back sections. These were weighed to the nearest 0.0001 g and preserved in formalin (concentration of 4-5%). The eggs from each sample were counted automatically with the Multiscan program (Computer Scanning Systems LTD, Poland) running on a PC coupled with a SVHS camera. Then the abundance of the eggs in the samples was calculated proportionally for the mass of the whole gonad. The absolute and relative individual fecundity of the fish is presented by age group and total length. Regression analysis was used to test the dependencies between variables. The fit of the linear function to the empirical data was evaluated by calculating Pearson's linear correlation coefficient (r) and the determination coefficient (r^2). The significance of correlation coefficients for chosen relationships among the traits were subjected to the t-test (Parker 1978).

TABLE 2

Mean and range of total length, body weight, and abundance by age groups in individual lakes

		Total length (mm)		Body weight (g)		Number of fish in age groups						
Lake	N	mean	range	mean	range	1+	2+	3+	4+	5+	6+	7+
Miedwie	235	228.1	181.5-289.0	105.1	52.8-236.5	12	201	19	2	1	-	-
Ińsko	115	229.1	171.0-341.0	106.6	41.5-312.9	4	79	19	5	5	1	2
Woświn	234	196.8	169.0-245.0	70.1	43.5-125.6	28	200	5	1	-	-	-
Glinna	31	222.3	203.5-239.7	87.6	63.4-113.7	-	3	20	8	-	-	-

Before verifying the hypothesis of equality of mean individual absolute and relative fecundity in age groups among lakes, the normality of the range of the analyzed traits (Shapiro-Wilks test) and the homogeneity of variance (Levene's test) were tested. The significance of differences was tested with variance analysis (ANOVA) and the post-hoc Duncan's test (Stanisz 1998). Additionally, to depict differences in individual absolute fecundity among the vendace populations from different parts of Poland, the authors' own data were compared to that from the literature (Bernatowicz 1963, Budych and Iwaszkiewicz 1964, Ciepielewski 1974, Mastyński 1978, Demska-Zakęś and Długosz 1995, Czerniejewski and Filipiak 2002, Czerniejewski et al. 2002), and hierarchical agglomeration (cluster analysis), the measure of which is Euclidean distance, was performed.

RESULTS

FISH LENGTH, WEIGHT, AND AGE

There was a substantial range in total length, individual weight, and age of the exploited segment of the vendace populations in the individual lakes (Table 2). The longest mean total length and individual weight were observed in the vendace from lakes Ińsko (229.1 mm and 106.6 g, respectively) and Miedwie (228.1 mm and 105.1 g, respectively). The analysis of fish age indicates vendace aged 2+ dominated the commercial catches in lakes Miedwie, Ińsko, and Woświn, while in Lake Glinna the dominant age group was 3+ (Table 2). The widest distribution of the analyzed traits was confirmed in Lake Ińsko, in which as many as seven age classes of vendace were caught.

INDIVIDUAL FECUNDITY

The various age groups of vendace from Lake Miedwie exhibited the highest absolute and relative fecundity, while the lowest values of these parameters were noted in the fish from Lake Glinna (Table 3). In the largest age group (2+), which comprised 78.54% of the vendace females caught for the study, the individual absolute and relative fecundity of the fish caught in Lake Miedwie was 11714 and 11434 eggs per 100 g female body weight and were significantly statistically higher that the values of the fish from the other lakes (ANOVA, $P < 0.05$). Vendace from Lake Glinna had the lowest absolute (mean 4782 eggs) and relative (mean 6406 eggs per 100 g of female body weight) fecundity.

TABLE 3

Individual absolute and relative vendace fecundity (mean±SD) in Western Pomerania lakes

Lake	Age group							Mean
	1+	2+	3+	4+	5+	6+	7+	
Individual absolute fecundity								
Miedwie	6635±682^{a}	11716±2354^{a}	16011±1882^{a}	24620±6310^{a}	24134^{a}	-	-	11967±3173
Ińsko	4946±1122^{b}	6910±1208^{b}	10036±1485^{b}	13881±2894^{b}	13740±778^{b}	16733	25301±9647	8412±3257
Woświn	4919±1041^{b}	6447±1365^{b}	10371±1986^{b}	15448^{c}	-	-	-	6386±1644
Glinna	-	4782±395^{c}	5692±433^{c}	6087±386^{d}	-	-	-	5706±537
Individual relative fecundity								
Miedwie	10756±869^{a}	11434±1495^{a}	10915±960^{a}	11609±973^{a}	11368^{a}	-	-	11358±1437
Ińsko	10290±1300^{a}	8435±1358^{b}	8632±1053^{b}	9744±887^{b}	7961±714^{b}	9843	8966±2407	8518±1330
Woświn	8761±1655^{b}	9086±1228^{b}	10094±1966^{a}	12300^{a}	-	-	-	9082±1323
Glinna	-	6406±173^{c}	6953±544^{c}	6669±348^{c}	-	-	-	6827±503

Fecundity values marked with the same letter superscript in the same column indicates a lack of statistically significant differences among the populations studied ($P < 0.05$)

DEPENDENCY BETWEEN FISH FECUNDITY AND TOTAL LENGTH AND AGE

As the vendace grew in length (Table 4) and age (Table 5), increases in both absolute and relative fecundity were noted. The measure of the strength of these dependencies are the high, statistically significant ($P < 0.05$), positive Pearson correlation coefficients (r) within a range of 0.74 (power and linear functions for the fish from Lake Glinna) to 0.93 (linear function for the fish from Lake Ińsko). No substantial differences among the values of the correlation coefficients determined with power and linear function models were noted, which, with the high values of these parameters, indicates these functions fit well with the empirical values. Slightly lower correlation coefficients were obtained from the analysis of individual absolute fecundity and age (Table 5). The regression analysis of relative fecundity with total length and age produced substantially lower correlation coefficients (in the ranges of 0.0011-0.17 and 0.06-0.24, respectively), which indicates the weak, statistically insignificant ($P > 0.05$) relationship between these traits.

TABLE 4

Relationship between individual absolute fecundity (Fa) and total length of vendace

	Power function ($Fa = a\,Lt^b$)			Linear function ($Fa = a\,Lt - b$)			
Lake	a	b	r	a	b	r	*P*
Miedwie	0.0005	3.1107	0.85	162.23	25200	0.86	0.00
Ińsko	0.0030	2.7360	0.89	129.55	20600	0.93	0.00
Woświn	0.0004	3.1152	0.81	106.69	14700	0.82	0.00
Glinna	0.1751	1.9270	0.74	48.87	5026	0.74	0.00

TABLE 5

Results of linear regression analysis between absolute individual fecundity (Fa) and fish age

	Linear function	(Fa = a Age +b)	
Lake	a	b	r
Miedwie	4837.2	2002.9	0.69
Ińsko	1051.7	2939.4	0.91
Woświn	2081.4	2253.5	0.53
Glinna	3900.6	570.95	0.62

FECUNDITY AND LAKE GEOGRAPHICAL POSITION

Even in geographically distant basins vendace fecundity can be similar (Fig. 2). The highest similarity in this parameter was confirmed in fish from Lake Siecino in Western Pomerania and the Mazurian Lake Dobskie. Among the lakes compared, the most distinct were lakes Lubikowskie and Pełcz. The fecundity of the vendace population from Lake Lubikowskie was significant, while that from Lake Pełcz was very low and similar to that of populations inhabiting northeastern Europe (Table 6).

DISCUSSION

The fecundity of vendace is relatively low, but it is compensated for this species reaching sexual maturity quickly. Depending on the environmental factors in the lake they inhabit, the male of the species is most frequently capable of reproducing in the sec-

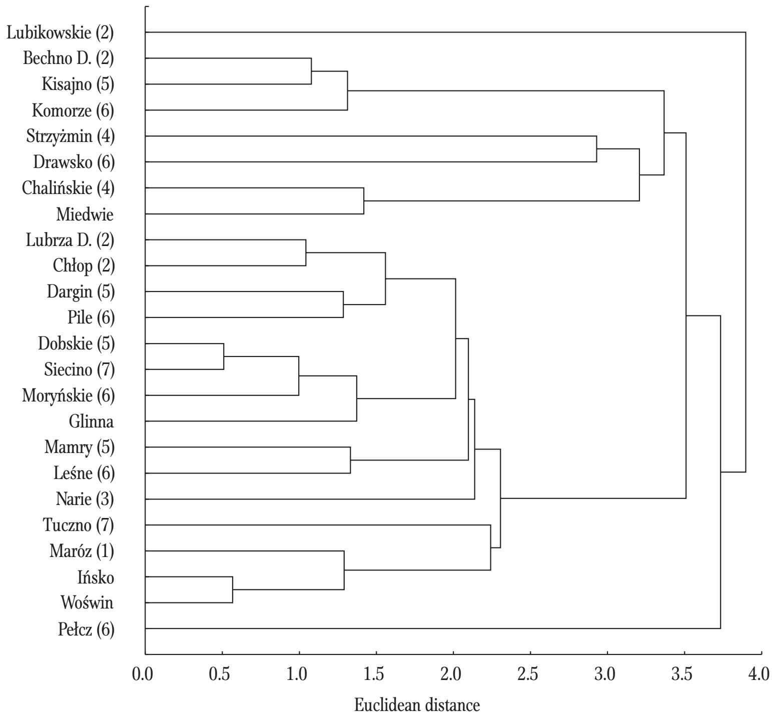

Fig. 2. Hierarchical analysis of the fecundity of vendace from different Polish lakes. Numbers by names indicate: 1 – Ciepielewski (1974), 2 – Mastyński (1978), 3 – Demska-Zakęś and Długosz (1995), 4 – Budych and Iwaszkiewicz (1964), 5 – Bernatowicz (1963), 6 – Czerniejewski and Filipiak (2002), 7 – Czerniejewski et al. (2002).

ond year of life, while the females can in the third year (Bernatowicz et al. 1975). In some cold basins in northeastern Europe, the gonads of vendace do not mature until the third year of life (Aass 1972), but thanks to the thermal regime in Polish lakes, vendace is capable of reproduction as early as at age 1+ (Budych and Iwaszkiewicz 1964, Ciepielewski 1974, Demska-Zakęś and Długosz 1995).

This has also been confirmed by the results of the authors' own research conducted in the lakes of Western Pomerania. Nevertheless, the spawning grounds are dominated by fish aged 3+, which have substantially higher individual absolute fecundity than do vendace aged 1+ (Bernatowicz et al. 1975, Długosz and Worniałło 1985). Furthermore, as Kamler et al. (1982) reported, the quality (i.e., protein, lipid, and energy contents) of the eggs produced by fish aged 2+ to 4+ is significantly better than that of eggs produced by fish aged 1+.

TABLE 6

Mean absolute individual fecundity in vendace from different lakes (in thousands of eggs)

Country	Lake	Fish age							
		1+	2+	3+	4+	5+	6+	7+	8+
Finland	Bothnian Bay[1]	1.63	3.25	4.45	4.48	5.35	6.26	-	-
	Pyhäjärvi[2]	9.88	13.51	17.36	18.90	-	-	-	-
Russia	Ładoga[3]	0.85	2.00	3.16	3.51	5.21	5.57	7.95	7.79
	Onega[4]	1.30	2.00	2.90	3.80	-	-	-	-
Germany	Stechlin[5]	3.58	5.36	7.13	-	-	-	-	-
Poland (Mazury)	Isąg[6]	13.46	19.83	31.07	-	-	-	-	-
	Narie[6]	4.44	8.77	-	-	-	-	-	-
	Maróz[7]	5.67	7.81	10.62	13.19	15.73	18.69	18.98	-
	Mamry[8]	4.10	4.60	8.50	-	-	-	-	-
	Dargin[8]	-	6.70	8.30	8.80	-	-	-	-
	Kisajno[8]	-	8.30	10.70	14.10	-	-	-	-
	Dobskie[8]	5.60	7.00	-	-	-	-	-	-
Poland (Wielkopolska)	Lubikowskie[9]	-	4.30	13.65	19.98	-	-	-	-
	Bechno D.[9]	-	7.40	11.27	14.53	16.71	-	-	-
	Lubrza D.[9]	-	4.45	8.21	12.15	-	-	-	-
	Chłop[9]	-	5.28	8.50	-	-	-	-	-
	Śremskie[10]	18.20	20.40	-	62.60	-	-	-	-
	Strzyżmin[10]	9.30	10.00	15.20	-	-	-	-	-
	Chalińskie[10]	7.10	12.30	14.80	-	-	-	-	-
	Tuczno[11]	5.07	9.80	11.46	-	-	-	-	-
Poland (Pomerania)	Siecino[11]	6.03	6.74	-	-	-	-	-	-
	Komorze[12]	-	8.52	11.81	-	-	-	-	-
	Drawsko[12]	-	8.05	14.88	21.02	-	-	-	-
	Pile[12]	6.38	7.33	8.28	-	-	-	-	-
	Leśne[12]	4.65	5.68	7.95	-	-	-	-	-
	Moryńskie[12]	5.82	6.02	5.73	-	-	-	-	-
	Pełcz[12]	2.73	2.94	3.62	-	-	-	-	-
	Miedwie[13]	6.64	11.72	16.01	24.62	24.13	-	-	-
	Ińsko[13]	4.95	6.91	10.04	13.88	13.74	16.73	25.30	-
	Woświn[13]	4.92	6.45	10.37	15.45	-	-	-	-
	Glinna[13]	-	4.78	5.69	6.09	-	-	-	-

Data according to: 1 – Lehtonen (1981), 2 – Sarvala et al. (1992), 3 – Djatlov (1978), 4 – Berg (1948), 5 – Anwand (1998), 6 – Demska-Zakęś and Długosz (1995), 7 – Ciepielewski (1974), 8 – Bernatowicz (1963), 9 – Mastyński (1978), 10 – Budych and Iwaszkiewicz (1964), 11 – Czerniejewski et al. (2002), 12 – Czerniejewski and Filipiak (2002), 13 – This study

As with other fish species, the individual fecundity of vendace undergoes a variety of fluctuations dependent on environmental and population conditions (Zawisza and Backiel 1970), which is why this parameter varies within a very wide range. At age 1+ mean individual absolute fecundity ranges from 850 in Lake Ładoga to 18200 eggs in Lake Śremskie (Budych and Iwaszkiewicz 1964, Djatlov 1978), at age 2+ from 2000 in lakes Ładoga and Onega to 20400 eggs in Lake Śremskie (Berg 1948, Budych and Iwaszkiewicz 1964, Djatlov 1978), while at age 3+ this parameter ranges from 2900 in Lake Onega to 31070 eggs in Lake Isąg (Berg 1948, Demska-Zakęś and Długosz 1995). In basins in the north (Bothnian Bay, lakes Ładoga and Onega), vendace fecundity is significantly lower than that in Polish and German lakes (Table 6). This was confirmed by Lehtonen (1981), whose results indicated there is a distinct dependence between fish fecundity and the geographical location of the lake they inhabit. One exception to this rule are the fish from the Finnish Lake Pyhäjärvi, where, according to Sarvala et al. (1992), the value of the fecundity parameter is relatively high (Table 6). Bernatowicz et al. (1975) suggested this species has higher fecundity in lakes located in western Poland than they do in Mazurian lakes. However, statistical analysis performed on data from 24 Polish lakes did not indicate there was a distinct dependency of individual absolute fecundity on geographical location. As postulated by Zawisza and Backiel (1970), the differentiations in the fecundity of various vendace populations appears to be the result of a variety of environmental (limnological type, primary production, crustaceous zooplankton abundance) and population (growth rate, population abundance) factors particular to a given lake.

In the literature, correlation and regression analyses are used to test the mechanisms of the relationships among fish fecundity variables (e.g., between individual absolute fecundity and age, length or weight). These dependencies are most frequently presented as either power (Healey and Nickol 1975, Backiel and Zawisza 1988) or linear functions (Sarvala et al. 1992, Anwand 1998). The results of the current study suggest the possibility of applying both power and linear functions to describe the dependencies in vendace between individual absolute fecundity and total length. High coefficients of determination were obtained in both cases, which indicates the empirical data was well fitted to both of these functions. It is significant that, in the vendace studied, a considerably stronger relationship (higher correlation coefficient) was confirmed between individual absolute fecundity and total length than between that and age. Apparently, this disproportion is caused by the difference in the growth rates of the vendace from these basins. The highest individual absolute fecundity and simultaneously the highest growth rate were confirmed in the fish from Lake Miedwie, while the lowest values of this parameter were noted in the fish from Lake Glinna which had the slowest growth rate (Czerniejewski unpublished data). A similar dependence was confirmed in vendace from the Mazurian lakes Isąg and Narie by Demska-Zakęś and Długosz (1995), who contend fish with faster growth rates are also more fecund, and that these traits are dependent primarily on the environmental factors in each lake.

CONCLUSIONS

Vendace spawned from the second year of life in lakes Miedwie, Ińsko, and Woświn. However, the spawning grounds were dominated by 2+ females comprising from 68.70 to 85.53% of all the individuals of this sex. Only in Lake Glinna was the domination of fish aged 3+ (64.52%) confirmed.

There was substantial range in the absolute fecundity of vendace from the various lakes. The greatest absolute and relative individual fecundity was noted in fish from Lake Miedwie (6635-24620 eggs per female and 10756-11609 eggs per 100 g female body weight, respectively), while the lowest values of these parameters were confirmed in fish from Lake Glinna (4782-6087 eggs per female and 6406-6953 eggs per 100 g female body weight, respectively).

Increases in vendace absolute fecundity were confirmed as body length and age increased. Individual fecundity was more strongly correlated with body length than age.

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STRESZCZENIE

PŁODNOŚĆ SIELAWY, *COREGONUS ALBULA* (L.) Z KILKU JEZIOR POMORZA ZACHODNIEGO

Celem badań było oszacowanie płodności osobniczej bezwzględnej i względnej populacji sielaw pozyskanych z 4 zachodniopomorskich jezior (rys. 1, tab. 1). Analizy wieku ryb wskazują, iż w połowach gospodarczych prowadzonych w jeziorach Miedwie, Ińsko i Woświn dominują ryby w wieku 2+, a w jeziorze Glinna w wieku 3+ (tab. 2). Największą średnią długością całkowitą i masą jednostkową charakteryzowały się ryby z mezotroficznych jezior Ińsko (odpowiednio 229,1 mm i 106,6 g) i Miedwie (odpowiednio 228,1 mm i 105,1 g). Analiza płodności osobniczej bezwzględnej i względnej wykazała, iż ryby z jeziora Miedwie charakteryzują się najwyższymi wartościami tych parametrów (odpowiednio: 6,64-24,62 $\times 10^3$ ziaren ikry/samicę oraz 10,76-11,61 $\times 10^3$ ziaren ikry na 100 g masy ciała samicy), natomiast najniższymi z eutroficznego jeziora Glinna (odpowiednio 4,78-6,09 $\times 10^3$ ziaren ikry/samicę oraz 6,41-6,95 ziaren ikry na 100 g masy ciała samicy) (tab. 3). Zaobserwowano wzrost płodności bezwzględnej sielawy w miarę zwiększania się długości ciała (tab. 4) i wieku ryb (tab. 5). Wyniki analizy regresji wskazują, iż płodność osobnicza bezwzględna jest lepiej zdeterminowana rozmiarami ciała niż wiekiem ryb. Nie stwierdzono istotnych relacji pomiędzy płodnością osobnicza bezwzględną sielawy a geograficznym położeniem jezior na terenie Polski (rys. 2, tab. 6).