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Fish biology

FECUNDITY ASSESSMENT OF VENDACE, *COREGONUS ALBULA* L. FROM SIX LAKES IN POLISH WESTERN POMERANIA

OCENA PŁODNOŚCI SIELAWY (*COREGONUS ALBULA* L.) Z SZEŚCIU JEZIOR ZACHODNIOPOMORSKICH

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Vendace acquired for the fecundity analysis originated from six west Pomeranian lakes: Pile (97 specimens), Komorze (41), Drawsko (62), Pełcz (89), Moryńskie (91), and Leśne (70). The fish were caught during commercial catches using anchored gillnets, 24-mm mesh size. Substantial differences were stated in individual biological parameters between fish representing different lakes, even if the dominant age group everywhere were 2+ vendace. The fish of Drawsko Lake showed the highest individual weight and the total length. The highest fecundity was stated in fish from lakes Komorze and Drawsko ($7.21–16.85 \cdot 10^3$ and $6.9–22.23 \cdot 10^3$, respectively), whereas in Pełcz Lake this parameter reached the value as low as $1.61–4.12 \cdot 10^3$. All vendace exhibited a high, statistically significant correlation between the absolute fecundity and their total length.

INTRODUCTION

Fecundity of fishes is one of the basic biological features enabling survival and continuation of species and may also have a divisive effect on their population size. Because of the diversity of aquatic environment, the differences in amounts of deposited eggs are observed not only in individual species but also in populations from various bodies of water. Determination of fish fecundity is particularly significant in species of short life cycle, which are very vulnerable to overfishing related to bad fisheries practice. Vendace, attaining its market size within 2–3 years is currently one of the most economically important items of Polish ichthyofauna. It has been known for its fast growth rate, relatively high adaptive potential to different water bodies, and also shows schooling behaviour, which in turn facilitates catch and regulation of population structure. The above-mentioned advan-

tages and highly priced meat of this fish have contributed to the fact that many fisheries enterprises switched to a "vendace model" of lake management. Rational fisheries management implemented in "vendace-type" lakes should consider the values of basic biological parameters of fish from different bodies of water, including their reproductive potential.

The majority of studies assessing fecundity of vendace were (was) carried out in Masuria (Ciepielewski 1974; Demska-Zakęś and Długosz 1995) and Wielkopolska (Budych and Iwaszkiewicz 1964; Mastyński 1978). Very few data on values of this parameter are available on fish representing lakes of Polish Western Pomerania. Some randomly-taken and already outdated information on the quantities of roe deposited by vendace in lakes Kaleńsko, Bucerz, and Krzemień was provided only by a single author (Walczak 1953).

The aim of the present work was to assess the absolute- and relative fecundity of vendace collected in autumn from a number of commercially exploited by fishermen lakes of Polish Western Pomerania and comparing them with literature data.

MATERIAL AND METHODS

The material for the present study constituted vendace acquired in autumn of 1999 and 2000 from six west Pomeranian lakes: Pile, Komorze, Drawsko, Pełcz, Moryńskie, and Leśne (Fig. 1) differing largely in morphometric parameters (Table 1).

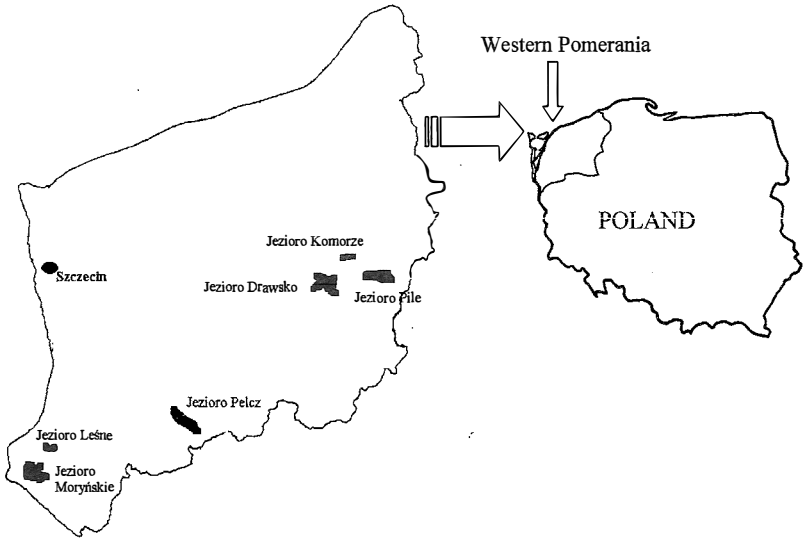

Fig. 1. Map of Polish Western Pomerania, showing lakes surveyed in the present work

The above-mentioned fish were caught with anchored gillnets of the mesh size of 24 mm. Subsequently, after transporting to the laboratory of the Department of Fisheries Management of Inland Waters, Agricultural University of Szczecin the were individually weighted to the nearest 0.1 g (on an electronic balance "Axis") and measured (total length)—with an electronic slide calliper coupled with a computer. Also their condition status was determined according to commonly accepted Fulton formula. Fish age was determined from scales collected from a defined area located above the lateral line, between dorsal- and anal fin (Bernatowicz 1952).

Table 1

Basic morphometric data of the lakes surveyed

Lake	Morphometric data						
	Surface area (ha)	Maximal length (m)	Maximal width (m)	Maximal depth (m)	Average depth (m)	Elongation factor [α]	WL
Komorze	416.7	7 550	1 050	34.7	11.8	7.20	3.43
Drawsko	1871.5	12 610	3 900	79.7	18.6	3.20	4.97
Pile	980.1	9 150	2 850	43.9	11.7	3.20	2.80
Leśne	27.1	1 240	300	11.6	5.1	4.13	2.00
Moryńskie	342.7	2 900	2 400	60.0	14.5	1.21	1.83
Pełcz	279.5	7 600	660	31.0	12.2	11.50	3.34

WL, development factor of the coastal line.

The scales were analysed based on an image formed by a microfilm projector (17× magnification). The first more-regularly suboval sclerite, appearing after a series of "horseshoe sclerites" characteristic for juvenile coregonids (Hogman 1968), was assumed as the first annual sclerite. Each fish was aged based on independent readings of three scales.

Absolute- and relative (related to 100 g of fish weight) fecundity of fish from individual lakes were determined by "wet" weight method. After determining the total weight of a gonad, two samples of 0.2–03 g were cut with a scalpel from a central part of this organ. The samples were subsequently weighed to the nearest 0.0001 g and placed in glass vials and flooded with formalin (4–5%). After 2 minutes of intensive shaking the parts of membranes surrounding the gonad were separated from eggs. Eggs in each sample were counted automatically with the aid of digital camera, microcomputer, and "Multiscan" software. In addition to the counting function, this system allowed a focus control and improvement of picture quality, which translated into enhancement of counting accuracy. Absolute fecundity of fish was presented in a table, separately for different age groups. Variance analysis (ANOVA) was used for demonstrating and interpretation of differences, similarly as hierarchical agglomeration analysis where distance between analysed objects is

Euclid's distance. Value of the latter parameter translates into a geometric distance in a multi-dimensional space. At the same time a regression analysis (Sokal and Rohlf 1998) was used to determine relation between the absolute fecundity (*Fa*) and individual characters of fish (length and age). In addition a gonadosomatic index (*GSI*) was determined, describing the percentage share of gonads in the total weight of a fish.

RESULTS

Three-year-old fish dominated in the vendace samples of all (except Drawsko Lake) lakes. They constituted between 51.4% (Leśne Lake) and 97.6% (Komorze Lake) of acquired vendace females. Only in Drawsko Lake fish aged 2+ constituted a majority of 41.9%. It can be assumed that the observed age structure resulted from employment of anchored gillnets of the same mesh size (24 mm) in all lakes. Despite considerable selectivity of this fishing gear, some differences were apparent in abundance of the remaining age groups. For instance in Leśne Lake the share of 2-year-old fish was high and it amounted to 47.1%, whereas the samples from the remaining bodies of water it was much lower and it did not exceed 8%. Also the number of fish aged 3+ was relatively low and in the analysed material only the sample form Drawsko Lake contained 41.9% of vendace representing this age group (Table 2).

Table 2

Total length (mm), individual weight (g), and age structure of vendace studied

Lake	Date of catch	No. of fish in different age groups				Total length		Individual weight		Condition factor	
		1+	2+	3+	4+	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Komorze	12 Oct 2000	0	40	1	0	210.4	185.0–237.8	81.5	64.0–116.0	1.14	0.91–1.30
Drawsko	5 Oct 2000	0	26	26	10	237.9	202.2–284.9	127.6	70.7–221.6	1.22	1.01–1.45
Pile	22 Nov 1999	7	78	12	0	215.8	181.4–285.4	84.7	42.8–149.7	1.30	0.90–1.49
Leśne	6 Nov 1999	33	36	1	0	184.7	163.8–232.3	55.1	41.3–113.0	1.20	0.92–1.39
Moryńskie	23 Nov 2000	7	78	6	0	201.2	185.6–225.0	74.3	55.2–143.3	1.20	0.90–1.59
Pełcz	2 Nov 2000	2	77	10	0	176.2	149.0–213.9	45.3	29.1–85.3	1.16	0.96–1.43

Table 2 contains also the remaining data on the total length, individual weight, and condition factor of vendace from respective lakes. The values of the above-mentioned parameters show substantial differences between the fish collected. The highest level of differences was observed between vendace of lakes Pełcz and Drawsko. The total length of fish of the former body of water, compared to that of fish of Drawsko Lake was by 26 percentage points shorter and the Pełcz lake vendace had almost 3 times lower individual weight. The reason behind the above-mentioned differences were different environmental conditions of these bodies of water. Highly eutrophic Pełcz Lake, known for oxygen defi-

ciencies below than 7 m (in 2000, according to Czerniejewski and Filipiak 2002) the vendace in catches is small of low condition factor (1.16). In the remaining lakes (except Komorze Lake) the vendace acquired were characterised by a relatively good Fulton coefficient (> 1.20).

Data on the absolute fecundity along with the results of variance analysis (ANOVA) are shown in Table 3. In all lakes where vandace were caught, these fish attained sexual maturity as early as at the age of 1+. Despite the lack of specimens of this age group in the analysed sample of lakes Komorze and Drawsko a similar conclusion can be drawn based on earlier published records as well as on a personal information obtained from the lessee of those bodies of water. Because as many as 76.1% of acquired vendace constituted fish aged 2+, the present work concentrated on describing results pertaining to this age group as the most reliable. The mean absolute fecundity of fish of this age from lakes of Western Pomerania varies in wide range: from 2936 eggs (Pełcz Lake) up to 8516 (Komorze Lake). It must be concluded from the results of LSD test ($p < 0.05$) that vendace from lakes (Komorze and Drawsko constitute a uniform group which shows higher fecundity and this difference is statistically significant. It is possible that the above difference has been influenced by environmental factors rather that geographical ones. The above statement may be confirmed on one hand, by the fact that Pile Lake situated also in the Drawskie Lake District has not been assigned to lakes of highest fecundity of vendace. On the other hand statistically significant differences were found in absolute fecundity between lakes Leśne and Moryńskie located nearby Pełcz Lake (Fig. 2). A similar variability of absolute fecundity of vendace can be found also in fish aged 3+ (Table 3). In all lakes the vendace fecundity increases with fish age. The correlation, however, between those parameters is week and only for the fish from Drawsko Lake, the correlation coefficient is high and it amounts to 0.88.

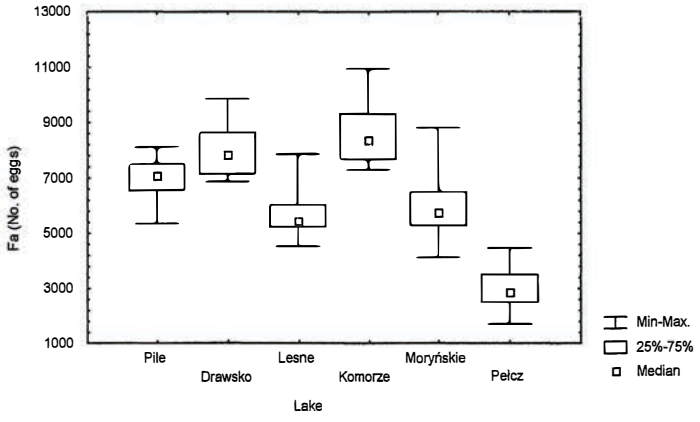

Fig. 2. Absolute fecundity of vendace at the age of 2+ from different lakes

Analyses of relation between absolute fecundity (Fa) and the total length (TL) were performed employing a linear function and a power one (Table 4). High correlation coefficients, from 0.85 (Pełcz Lake) to 0.94 (lakes Komorze and Drawsko) were obtained for the linear function, which suggests the existence of a strong linear relation. The strength of this relation was further confirmed by high determination coefficients, which also give evidence about a good fitting of the regression function to the empirical values. For example, in the case of fishes of lakes Drawsko and Komorze only 12% of information on the fecundity were not explained (determined) by a variable—total length of fish. This linear variable in vendace of all bodies of water was statistically significant ($p < 0.05$). Compared to the linear function, the power curve only in the case of vendace of lakes Drawsko and Moryńskie, better describes the existing relation. Values of determination coefficients (*D*) in the above lakes amounted to 0.93 and 0.78, respectively.

Table 3

Gonadosomatic index (*GSI*), mean absolute fecundity and results of variance analysis (ANOVA) and linear regression between absolute fecundity (*Fa*) and age (*A*) of vendace

Lake	*GSI* (%) Mean Range	Mean absolute fecundity*				Results of statistical analysis ($Fa = b \cdot A + a$)			
		1+	2+	3+	4+	*a*	*b*	*D*	*R*
Komorze	16.7 11.6–26.3	—	8516[a]	11812[ab]	—	–6659	4159	0.44	0.66
Drawsko	14.9 12.1–21.9	—	8050[a]	14884[a]	21018	–11242	6436	0.77	0.88
Pile	18.2 6.1–29.6	6375[a]	7327[b]	8280[b]	—	2163	2832	0.49	0.70
Leśne	16.3 14.1–28.2	4652[b]	5681[c]	7947[bc]	—	2941	765	0.39	0.62
Moryńskie	20.3 11.2–33.5	5820[a]	6015[c]	5731[c]	—	4092	869	0.32	0.56
Pełcz	19.2 9.3–29.3	2733[c]	2936[d]	3621[d]	—	1298	769	0.42	0.65

*Data in columns, marked with the same letter in superscript do not differ statistically ($p < 0.05$).

As mentioned earlier, the relative fecundity of vendace was defined as the number of eggs related to 100 g of body weight of a female. Results of variance analysis (ANOVA) shown in Table 5, indicate existence of statistically significant differences in individual age groups, between relative fecundity of fish from individual lakes. The distinctly lowest value of this parameter characterised vendace of Pełcz Lake. For example relative fecundity in 3-year-old fish (the most representative group) from the above-mentioned lake is by 17.5 percentage points higher from fish acquired from Moryńskie Lake and by as many as 32.9 percentage points from fish of Komorze Lake (Table 5, Fig. 3). Another conclusion from the analysis of relative fecundity was that fish from the Drawskie Lake District (lakes:

Drawsko, Komorze, and Pile), exhibited higher values of this parameter compared to the fish from south-west part of the Zachodniopomorskie Voivodeship (lakes: Leśne, Moryńskie, Pełcz).

Table 4

Comparison of correlation analyses between the absolute fecundity (*Fa*) and the total length (*TL*) of vendace

Lake	Power function (log *Fa* = *a* + *ba* log *Lt*)				Linear function (*Fa* = *a Lt* – *b*)				
	a	*b*	*D*	*R*	*a*	*b*	*D*	*R*	*p*
Komorze	–6.05	3.85	0.87	0.93	162.25	25625	0.88	0.94	0.00
Drawsko	–5.09	4.29	0.93	0.96	214.25	38007	0.88	0.94	0.00
Pile	–3.22	3.07	0.85	0.92	127.28	19226	0.86	0.93	0.00
Leśne	–2.31	2.65	0.67	0.82	90.124	11574	0.73	0.86	0.00
Moryńskie	–7.09	3.42	0.77	0.88	111.33	16376	0.76	0.87	0.00
Pełcz	–1.10	2.04	0.70	0.83	36.87	3464	0.72	0.85	0.00

Table 5

Mean relative fecundity of vendace (related to 100 g of body weight of female) in sequential years of life (with results of variance analysis ANOVA)

Lake	1+	2+	3+	4+
Komorze	—	9881^{a}	10183^{a}	—
Drawsko	—	9272^{ab}	10360^{ab}	10481
Pile	9782^{a}	8791^{b}	8456^{c}	—
Leśne	8893^{b}	8396^{bc}	8216^{c}	—
Moryńskie	9215^{b}	8031^{c}	9687^{b}	—
Pełcz	7339^{c}	6626^{d}	6938^{d}	—

*Data in columns, marked with the same letter in superscript do not differ statistically ($p < 0.05$).

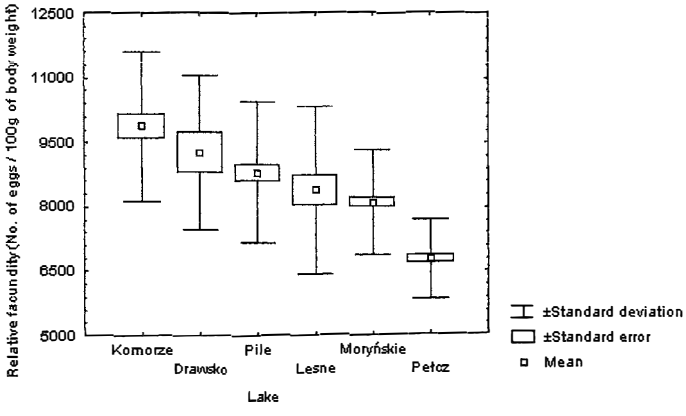

Fig. 3. Relative fecundity of vendace aged 2+ from different lakes

DISCUSSION

The vendace represents fishes of relatively low fecundity, although it compensates it with early attainment of sexual maturity. Depending on environmental conditions in lakes, females of this species are able to breed, most often, in their second year of life, whereas the males—in third (Bernatowicz et al. 1975). A number of researchers stated that in some cold bodies of water of north-eastern Europe the gonads of vendace mature as late as in the third year of their lives (Koskova 1977) and in the case of Siberian vendace—at the age of 4+ (Vyšegorodcev 1977). In Polish lakes, because of the thermal conditions of waters, the vendace is ready for reproduction as early as at the age of 1+ (Budych and Iwaszkiewicz 1964; Ciepielewski 1974; Demska-Zakęś and Długosz 1995). It has been also confirmed in the course of the present study, carried out in lakes of Western Pomerania. On the spawning ground, however, dominate 3-year-old fish of much higher fecundity than that of 1+ vendace (Bernatowicz et al. 1975).

The size of gonads, at the time of reproduction (described in literature using gonadosomatic index, *GSI*) is dependant on environmental conditions, age, length, and weight of fish. For example in vendace females occurring in brackish waters of the Gulf of Bothnia it fits within 10–12% (Friman 1972), whereas in neighbouring lakes Keitele and Pyhajarvi it is 23,9% and 19.3%, respectively (Lehtonen 1981; Sarvala et al. 1992). In Polish bodies of water the values of *GSI* are also very variable. In Lakes of West Pomerania (Bucerz, Krzemień, and Kaleńsko) the size of gonads constituted between 14.63 and 23.16% of the body weight of vendace (Walczak 1953). Even wider range (9.5–33.2%) was determined for Masurian lakes Dargin, Dobskie, and Kisajno by Bernatowicz (1963). The mean values of the gonadosomatic index of vendace from lakes of West Pomerania fitted into the above range, however, few specimens from lakes Pile and Pełcz showed low values of gonadosomatic index ($GSI < 10\%$), whereas in a single vendace female from Moryńskie Lake the value of the above parameter amounted to more tan 30% of the fish body weight.

Fecundity of vendace and also other fish species underwent different fluctuations, depending on environmental conditions and population aspects (Zawisza and Backiel 1970). Bernatowicz et al. (1975) believe that vendace in lakes of Western Poland shows higher fecundity than this species occurring eastern parts of the country. Cluster analysis was employed to compare and visualise literature data on absolute fecundity of vendace from lakes of Wielkopolska, Masuria, and Pomerania with the results of the present work (Fig. 4). The above statistical method demonstrated that fecundity of this species may be similar—which is evidenced by Euclid's distances—even in lakes distant to each other geographically. For example the closest similarity of this parameter was stated in vendace of west Pomeranian Pile Lake and of Masurian Dargin Lake (Euclid's distance between

those bodies of water was only 1.6). On the other hand, in the case of two Masurian lakes (Maróz and Mamry) a high value of Euclid's distance was determined (11.7). The dendrogram (Fig. 4) did not include vendace of Śremskie Lake, showing the highest fecundity. Budych and Iwaszkiewicz (1964) believed that the mean absolute fecundity of vendace from this lake was 18.2 (2+) and as many as 62.6 thousand eggs at the age of 4+.

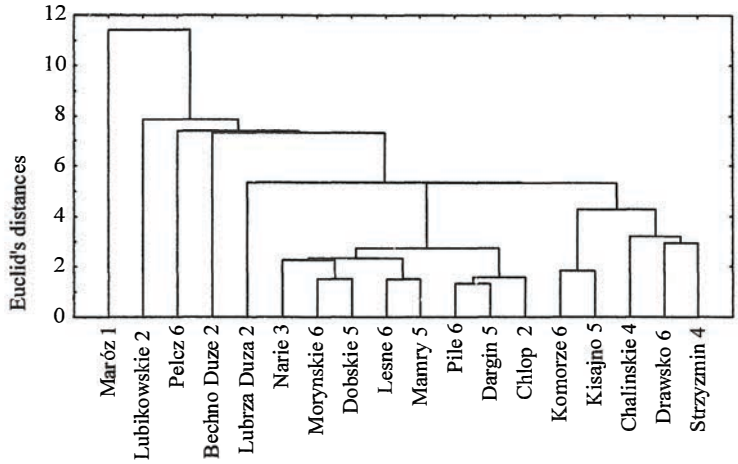

Fig. 4. Dendrogram of vendace fecundity observed in different Polish lakes. Numbers following lake names denote respective publications: 1, Ciepielewski (1974); 2, Mastyński (1978); 3, Demska-Zakęś and Długosz (1995); 4, Budych and Iwaszkiewicz (1964); 5, Bernatowicz et al. (1975); 6, present data

In the literature, fecundity of fishes is subjected to analyses of correlation and regression, to determine the nature of relations between variables (e.g. between absolute fecundity and age or length, or weight of a fish). The above relation is usually formulated as a power function (Healey and Nicol 1975; Backiel and Zawisza 1988) or a linear function (Svala et al. 1992; Anwand 1998). The results of the present work suggest that the relation between the absolute fecundity and the total length of vendace can be formulated in both ways: as a power function or as a linear one. In both cases, high determination coefficients were obtained with small, lower than 3%, differences in the above parameters (except vendace from lakes Drawsko and Leśne). It must be emphasised that in all vendace acquired from 6 lakes the absolute fecundity was much closer correlated (higher correlation and determination coefficients) with the total length of fish than with their age. It is possible that the above-mentioned difference was caused by the differences in the growth rate of vendace from those lakes. Any further, detailed regression analysis between those parameters is not possible, however, because of the lack of literature data pertaining to the growth rate

of length and of weight of fish from those bodies of water. A similar regularity in vendace was stated by Demska-Zakęś and Długosz (1995), who believed that fish showing faster growth rate, at the same time show higher fecundity and those parameters depend, in large extent, on the environmental conditions of each lake.

CONCLUSIONS

1. Vendace in lakes of West Pomerania spawn at the age of 1+. On the other hand the dominant age group on spawning ground are 3-year-old females, which constitute 51.4–97.6%. Only in the case of Drawsko Lake this age group was less abundant (41.9%).
2. The values of absolute fecundity in vendace from different lakes of western Pomerania show substantial variability. Vendace of lakes Komorze and Drawsko show the highest absolute fecundity ($7.21–16.85 \cdot 10^3$ and $6.9–22.23 \cdot 10^3$ of eggs), whereas the lowest fecundity can be attributed to vendace of Pełcz Lake ($2.61–4.12 \cdot 10^3$)
3. Very high correlation between the absolute fecundity and the total length of fish was determined in vendace collected from 6 lakes. The correlation was similarly high in linear function and in power function. Results of regression analysis indicate that the absolute fecundity is better determined by the total length than the fish age.
4. Geographical location of lakes does not have a crucial effect on the absolute fecundity of vendace. Vendace acquired from lakes located a high distance from each other may show similar fecundity.

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OCENA PŁODNOŚCI SIELAWY (*COREGONUS ALBULA* L.) Z SZEŚCIU JEZIOR ZACHODNIOPOMORSKICH

STRESZCZENIE

Materiał do badań stanowiły samice sielaw pozyskane w okresie jesiennym (przedtarłowym) z 6 eksploatowanych rybacko zbiorników Pomorza Zachodniego: Pile (97 osobn.), Komorze (41 osobn.), Drawsko (62 osobn.), Pełcz (89 osobn.), Moryńskie (91 osobn.) i Leśne (70 osobn.). Na rybach wykonano pomiary długości całkowitej (*l.t.*) przy użyciu suwmiarki elektronicznej, masy ciała – na wadze typu Axis z dokładnością 0,1 g, obliczono współczynnik kondycji – stosując ogólnie przyjętą formułę Fultona oraz określono wiek przy pomocy łusek. Płodność absolutną i względną (w przeliczeniu na 100 g masy ciała) sielawy z poszczególnych jezior oceniono metodą wagową „na mokro", natomiast liczenie jaj wykonywano automatycznie przy użyciu programu „Multiscan" zainstalowanego na zestawie składającym się z mikrokomputera PC i sprzężonej kamery cyfrowej. Analizy wieku ryb wskazują, iż w połowach gospodarczych dominują ryby w wieku 2+. Stwierdzono wyraźne różnice w średnich wartościach podstawowych parametrów biologicznych. Najwyższą średnią masą jednostkową i długością całkowitą charakteryzowały się ryby z jeziora Drawsko (odpowiednio 127,6 g i 237,9 mm), podczas gdy najniższą wartość tych parametrów stwierdzono u sielaw z jeziora Pełcz (odpowiednio 45,3 g i 176,2 mm). Zaobserwowano istotny statystycznie wzrost płodności absolutnej w miarę zwiększania się długości ciała sielawy i wieku ryb. Wyniki analizy regresji wskazują, iż płodność absolutna jest lepiej zdeterminowana rozmiarami ciała niż wiekiem ryb. Najwyższą płodnością absolutną charakteryzują się sielawy z jezior: Komorze i Drawsko (odpowiednio $7{,}21–16{,}85 \cdot 10^3$ i $6{,}9–22{,}23 \cdot 10^3$ ziaren ikry), podczas gdy najmniej płodna jest sielawa z jeziora Pełcz ($2{,}61–4{,}12 \cdot 10^3$).

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