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FECUNDITY OF VENDACE FROM TWO LAKES OF MAZURIAN LAKE DISTRICT

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A B S T R A C T. Gonads of vendace were collected in 1983 and 1984 in two Mazurian lakes. Significant correlations between absolute fecundity and body fecundity and body size (weight and length) were observed. Body length, weight, growth rate and fecundity varied between spawning populations and so did the spawning time and maturation rate of gonads.

Key words: *Coregonus albula*, ANNUAL CYCLE, FECUNDITY

INTRODUCTION

Deep, clean and well oxygenated Scandinavian lakes are the natural site of coregonid fishes. Coregonids such as vendace (*Coregonus albula* L.) are widespread in waters of Northern Poland and considered as valuable fish. The presence of vendace in our waters indicates plasticity of the species which, according to Vuorinen (1984), is related to its tetraploidic origin.

Eutrophication of lakes implies an increase of zooplankton standing crop, which results in an improvement of food resources for vendace. On the other hand, environmental conditions in eutrophic lakes deteriorate, which exerts a detrimental impact on coregonid breeding (Wilkońska, Żuromska 1981, Żuromska 1982a, b).

Stocking of natural waters with vendace has started quite recently, but considerable differences among populations are already observed (Bernatowicz 1953, Bernatowicz et al. 1975, Budych, Iwaszkiewicz 1964, Ciepielewski 1974, Mastyński 1978, Walczak 1953, Wilkońska, Żuromska 1981, Żuromska 1982a, b). In lakes of various trophic conditions and morphometry, there are differences of growth rate, body size, fecundity and quality of sexual products among the populations, and in consequence - of the survival of eggs and larvae.

A study was carried out to observe the annual cycle of gonads, to determine individual absolute fecundity and factors that might influence it. The studies were done in two Mazurian lakes: Isąg and Narie.

The results were tested using two statistical methods: simple and multiple regression analyses.

MATERIAL AND METHODS

The studies on the annual cycle of gonads and fecundity were done in two Mazurian lakes (Isąg and Narie) of different morphometric and limnologic parameters. Lake Isąg is situated North-West of Olsztyn (area 395.7 ha, max. depth 54.5 m, mean depth 14.2 m). Lake Narie is situated about 30 km North-East of Olsztyn (area 1240.1 ha, max. depth 43.8 m, mean depth 10.0 m).

Experimental material for the studies on gonad annual cycle was collected from June 1982 to March 1983 (Tab. 1, Fig. 1). The following measurements were taken: body length of fish (Lc), body weight (W) and gonad weight (Og). Gonado-somatic index (GSI) was calculated (Tab. 1).

The age of fish was estimated basing on the number of annual rings on scales (Tab. 1).

TABLE 1

Age (A), range of body length (Lc), body weight (W) and gonado-somatic index (GSI) vendace from Isąg and Narie Lakes

Month	Lake Isąg						Lake Narie					
	n	A	Lc (cm)	W (g)	GSI (%)		n	A	Lc (cm)	W (g)	GSI (%)	
					$\bar{x}$	STD					$\bar{x}$	STD
June	2	-	18.0–19.0	82.0–86.0	0.63	0.53	5	-	18.0–20.0	65.0–114.0	5.22	2.77
July	8	2–4	20.0–24.0	101.0–185.0	2.27	0.44	7	2–3	17.0–21.0	62.0–105.0	2.34	0.48
August	4	2–3	20.0–21.5	116.0–146.0	3.09	0.73	5	2	16.5–18.5	57.0–86.0	2.63	0.51
September	8	1–3	19.0–23.0	90.0–152.0	8.05	1.53	7	2–3	17.0–20.5	64.0–110.0	4.97	1.62
October	-	-	-	-	-	-	4	1–3	15.0–16.5	37.0–55.5	12.84	0.94
November	7	1–3	20.5–23.0	102.0–161.0	23.39	4.21	10	1–2	16.5–18.5	50.2–83.0	20.84	2.65
December	-	-	-	-	-	-	14	-	15.5–22.5	50.0–145.0	[a]21.0 [b]0.78	2.16 0.56
January	-	-	-	-	-	-	7	-	19.0–23.0	65.0–110.0	0.52	0.17
March	8	2–5	19.5–24.0	76.0–142.0	1.17	0.18	6	-	15.5–18.5	43.5–61.5	0.50	0.17

[a] - *unspawning females*

[b] - *partially spawning females*

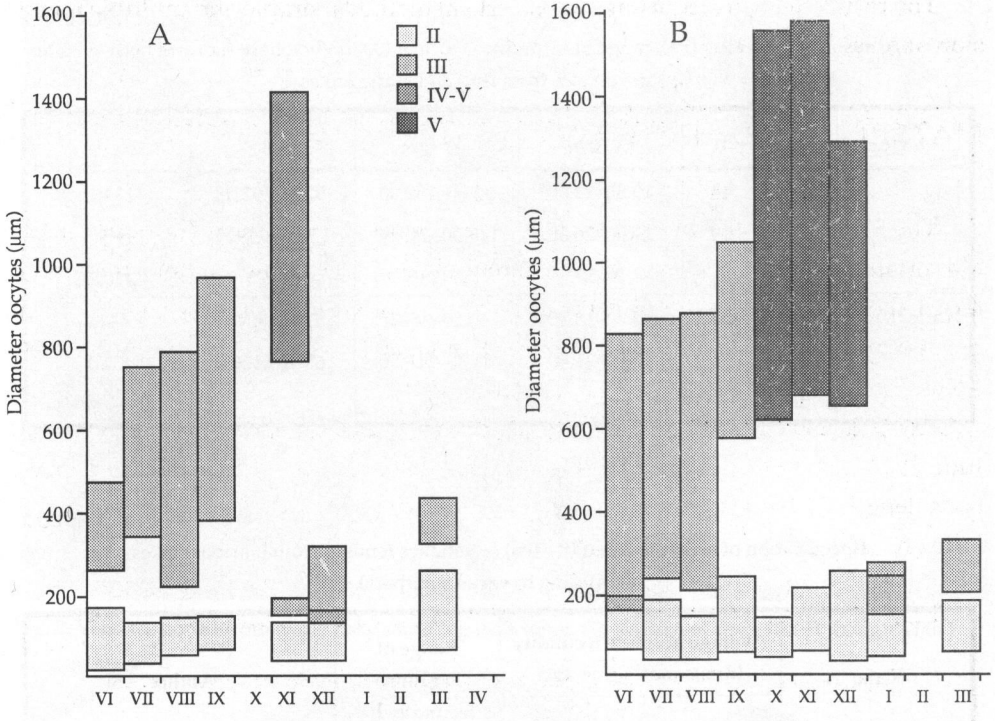

Fig. 1. Gonads development stages and diameter range of egg cells vendace from Isąg (A) i Narie (B)

Gonads for histological observations were preserved in buffered formaldehyde and embedded in paraffin wax. Histological sections 6 µm thick were stained with HE.

Oocyte diameters were measured using ocular micrometer PZO x 8 (Fig. 1). T-Student test was applied to establish the necessary number of replicates. Stages of annual cycle of sexual cells were classified according to Sakun et al. (1968). Material for the assessment of individual absolute fecundity was collected from both lakes in 1983 and 1984. Vendace females were harvested at spawning sites in late November. Immediately after the harvest, the fish were measured and weighed (Tab. 2, Figs. 5, 6). Scales were taken from each fish for the age estimation (Tab. 2). Absolute fecundity was assessed only in those females that had not spawned. Gonads were taken from 108 fish (Tab. 2).

Number of eggs in the ovaries was estimated according to the weight method, assumed to be sufficiently reliable and verified by Brylińska (1972) on bream.

To determine the relation between individual absolute fecundity (Fa) and indivi-

TABLE 2

Average absolute fecundity (Fa), range of fecundity (Fa), age (A), body lenght (Lc) and body weight (W) in vendace from Isąg and Narie Lakes

Lake	A	n	Lc (cm)	W (g)	Fa	
Isąg	1+	44	19.80–23.00	93.00–153.90	9254–19216	13462
	2+	19	21.00–26.00	148.30–240.80	15632–23959	19828
	3+	1	26.50	263.50	31073	31073
Narie	1+	35	15.30–18.90	40.30–78.40	3543–8040	4444
	2+	9	17.70–21.40	68.80–118.70	6318–11669	8770
	3+	-	-	-	-	-

TABLE 3

Specification of absolute fecundity (Fa) of vendace females from (various) lakes (according to various authors)

Lake	Average absolute fecundity (thousand egg) in age:			Range of absolute fecundity Fa	Author
	1+	2+	3+		
Lubikowskie	-	4.3	13.6	2.0–18.4	Mastyński (20)
Bechno Duże	-	7.4	11.3	4.1–12.5	Mastyński (20)
Zburza Duża	-	4.4	8.2	3.9–11.1	Mastyński (20)
Chłop	-	5.3	8.5	4.1–14.1	Mastyński (20)
Maróz 1967–70	5.7	7.8	10.6	-	Ciepielewski (10)
Mamry	4.1	4.6	8.5	-	Bernatowicz (4)
Dargin	-	6.7	8.3	-	Bernatowicz (4)
Dobskie	5.6	7.0	-	-	Bernatowicz (4)
Kisajno	-	8.3	10.7	-	Bernatowicz (4)
Śremskie	18.2	20.4	-	13.3–26.6	Budych et al. (9)
Strzyżmin	9.3	10.0	15.2	4.6–18.2	Budych et al. (9)
Chalińskie	7.1	12.3	14.8	8.9–15.5	Budych et al. (9)
Charzykowo	-	-	-	8.0–21.0	Walczak (35)
Bucerz	-	-	-	2.0–7.0	Walczak (35)
Krzemień	-	-	-	3.0–6.5	Walczak (35)
Kaleńsko	-	-	-	2.0–4.0	Walczak (35)
Isąg	13.5	19.8	31.1	9.2–31.1	badania własne
Narie	4.4	8.8	-	3.5–11.7	badania własne

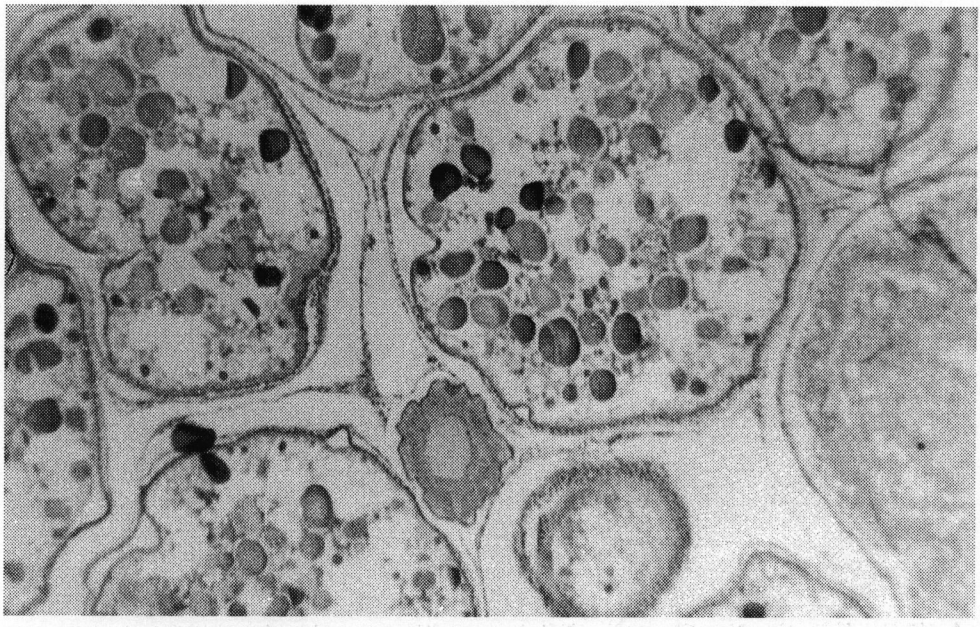

Fig. 2. Vendace gonad from Narie Lake sampling in October. Development stage IIIa-IV (magn. 200x)

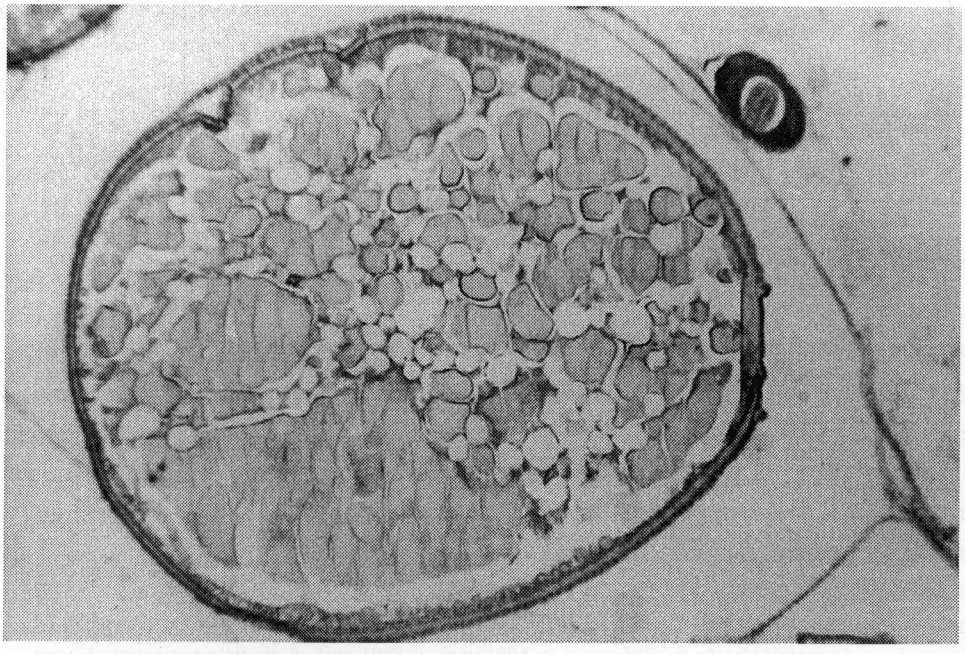

Fig. 3. Gonads histological pictures of vendace from Isąg Lake in November. Stage of oocytes development IV-V (magn. 200x)

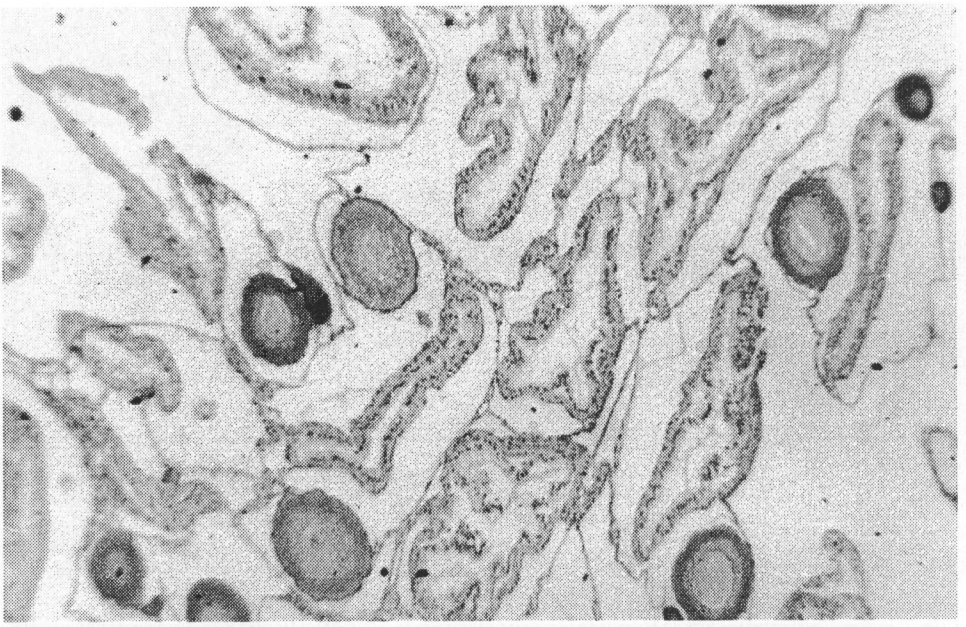

Fig. 4. January. Gonads histological pictures of vendace after spawning in Isąg Lake. Ovary development stage VI-III (magn. 200x)

dual characteristics of the fish (weight, length and age), two statistical methods were applied: simple and multiple regression analyses.

Additionally, the effect of growth rate on fecundity was analysed in both lakes.

RESULTS

Gonads of the fish from lakes Isąg and Narie for histological analyses were taken from June to December 1982 and in January and March 1983. The data concerning body length (Lc), weight (W), gonado-somatic index (GSI), age and oocyte diameter are shown in Tab. 2 and Fig. 1. Figs 5 and 6 show that fish weight, length and fecundity in each lake were rather uniform. Thus, after verification of the data using the parallelism test, mean values for each lake were analysed.

Relations between absolute fecundity (Fa) and body size (Lc, W) are shown in Figs. 5 and 6. Correlation coefficients for absolute fecundity and body length are: 0.7870 in Isąg and 0.7545 in Narie. Fig. 6 shows also that fecundity increases proportionally to body weight. Correlation coefficients are: 0.8518 and 0.8905 in Isąg and

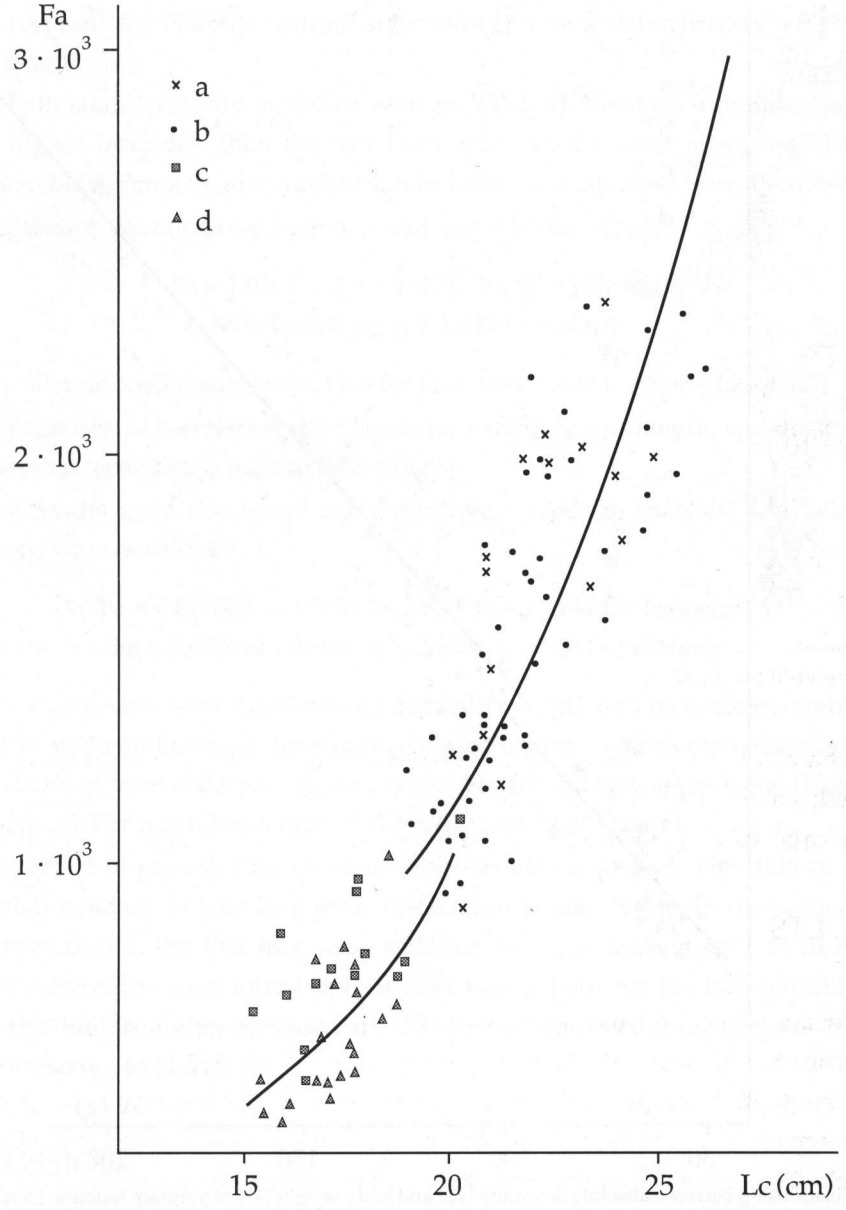

Fig. 5. Relationship between absolute fecundity (Fa) and body length (Lc) of vendace females. 1 - Fa of vendace from Isąg Lake a according to a pattern: log Fa = 3.4317 log Lc - 0.4417; 2 - Fa of vendace from Narie Lake according to a pattern: log Fa = 3.2358 Log Lc - 0.2536. Points characterizing the females, lines illustrate populations. a - Isąg 1983, b - Isąg 1984, c - Narie 1983, d - Narie 1984

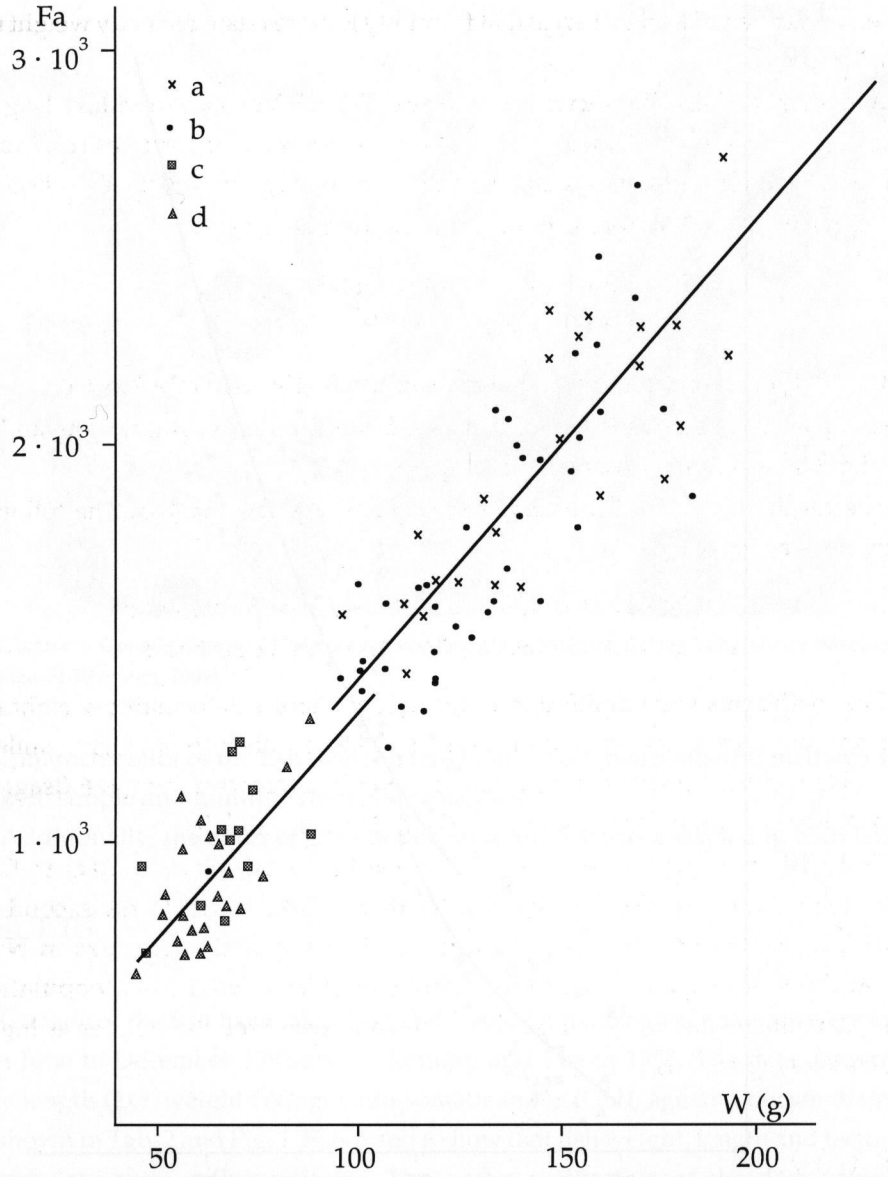

Fig. 6. Relationship between absolute fecundity (Fa) and body weight (W) of vendace females. Denotations as in Fig. 5. 1 - Fa of vendace from Isąg Lake according to a pattern: log Fa = 1.0286 log W + 1.9788; 2 - Fa of vendace from Narie Lake according to a pattern: log Fa = 1.1351 log W + 1.7381.

Narie, respectively. The data reveal that fecundity is more related to body weight than to the length.

In both lakes fecundity increased with age (Tab. 2). Vendace from lake Isąg had much higher fecundity than the fish from Narie in the same size class (Tab. 2). Considerable differences of fecundity values within one age class were also observed.

Regression equations for fecundity and age were developed:

$$Fa = 1.0167 \log A + 3.8151 \text{ for lake Isąg and}$$
$$Fa = 1.0860 \log A + 3.4159 \text{ for Narie.}$$

Correlation coefficients are: 0.4768 for Isąg and 0.4438 for Narie ($\alpha = 0.05$).

Comparison of correlation coefficients for fecundity and length, weight, and age reveales that fecundity is least related to age.

The results were also tested using multiple regression analysis. The following equations were developed:

$$Fa = 0.0775W - 0.05921c + 2.2391A + 1.1141 \text{ for Isąg and}$$
$$Fa = 0.0775W - 0.05921c + 2.2391A + 2.3117 \text{ for Narie.}$$

The coefficients were significant for fecundity-length and fecundity-weight relations and not significant for fecundity-age. Correlation coefficients were similar to those obtained from a simple regression test. For fecundity-weight: 0.866 (Isąg) and 0.743 (Narie). For fecundity-length: 0.773 (Isąg) and 0.689 (Narie).

The effect of growth rate on fecundity was also analysed. The data in tab. 2 show that vendace in lake Isąg grew faster than in lake Narie. In the second and third year of life, the fish from Isąg attained twice as high weight as in Narie. Similar differences were found in fecundity values between the two populations. Mean absolute fecundity of two-years old females was even three times as high in Isąg comparing to Narie.

DISCUSSION

Environmental conditions in lakes Isąg and Narie considerably differed and so did the fish. However, in both lakes spawning populations consisted of fish at the age 1+ and 2+. Fish 4+ and 5+ years old were observed very seldom (Tabs. 1, 2). Thus, in both lakes females attained sexual maturity at the same age.

Many authors (Backiel 1952, Backiel, Zawisza 1970, Bernatowicz et al. 1975, Budych, Iwaszkiewicz 1964, Golenisev 1951, Stejnfeld 1964) observed similar age structure of spawning vendace populations. Diatlov (1980) found out that in waters of Northern Europe vendace spawned for the first time at the age from 1+ up to 8+ years.

It is presumed that such differences in the maturation time may result from different growth rate. According to Laskar (after Brylińska 1971), under the same climatic conditions there existed a range of body size within which sexual maturity could be attained. Maximum size was achieved by the fish under optimal conditions, showing maximum growth rate. Minimum size - by those showing minimum growth rate. It seems that such differentiation is more pronounced in the fish species of longer life span. Vendace, however, has rather short life cycle. In our climatic zone, irrespective of the growth rate, fish are sexually mature in the second year of life (Backiel 1952, Bernatowicz 1953, Bernatowicz et al. 1975, Ciepielewski 1974, Długosz, Worniałło 1984, Walczak 1953). Larkin et al. ((1969) and Nümann (1970) suggest that eutrophication of water reservoirs affects the age of maturity. Eutrophication may accelerate maturation and rejuvenate age structure of the spawners. Lack of earlier data on vendace spawners age in the lakes under study does not enable verification of this supposition. However, it should be emphasized that, in the study period, vendace 1+ years old comprised 68.75 of the spawning females in Isąg, and 79,55% in Narie.

Observations and histological analyses revealed that vendace in both lakes was a monocyclic spawner.

It is well known that annual gonad development cycle is a sequence of qualitative (stages II-V) and quantitative (increase of gonad weight) phases. Gonad development may be affected by biotic and abiotic environmental factors, among which temperature plays an important role. Fish start to spawn when water temperature is appropriate for a species. Spawning of coldwater fish, such as vendace, is usually triggered by a temperature drop in autumn.

In lake Narie, the fish spawn in December, but not all the females breed at the same time. Among 14 fish harvested in December, 9 females had already spawned, and 5 were at IV-V stage of gonad maturation (Tab. 1, Fig. 1). This might have resulted from high individual variability of the oocyte maturation rate among the females. In lake Isąg all the fish harvested in November were spawning, so their gonads were at V stage. It was observed that the oocytes of the fish from both lakes varied in diameter

(Fig. 1). Especially high differences occured among the oocytes at the same maturation stage in lake Narie. In June and January in lake Narie, and in December in lake Isąg, oocytes of uniform diameter at II and III stage were observed (Fig. 1).

Fish ovaries returned to these stages after spawning. Similar observations were made by Backiel (1) in lake Wigry.

The process of regeneration and resorption of follicular envelopes lasted about 2.5 months in lake Narie and about 3 months in lake Isąg. Siniavicius et. al. (1975) who studied vendace populations in Lithuanian lakes observed that this process may have extended up to 4-4.5 months in low temperatures.

After this phase, oocytes attain stage of vacuolization and then intensive trophoplasmatic growth begins (from III to V stage). It is the longest phase of gonad maturation, lasting 6-8 months (from June to December) (Fig. 1). Fifth stage alone is short and in vendace lasts only several days. The studies of individual fecundity of vendace from lake Isąg revealed that it was similar to that of fish from highly productive lakes of Sierakowskie Lake District (Budych, Iwaszkiewicz 1964), while fecundity of fish from lake Narie resembled that of fish from lakes of Western Pomerania (Walczak 1953) (Tab. 3).

The results confirmed that fecundity of vendace was related mainly to body size of the fish: length and weight. It increased with the exponent three of length and was directly proportional to the weight. Similar relations were observed by Brylińska (1971), Budych, Iwaszkiewicz (1964) and Zawisza, Backiel (1970). The studies of vendace in Sierakowskie lakes made by Budych, Iwaszkiewicz (1964) revealed that fecundity increased with the age.

Simple regression analysis of the data from lakes Isąg and Narie shows significant effect of the age on fecundity, while the analysis of multiple regression reveales no relation between these parameters. Thus, it can be concluded that the increase of fecundity with age is a result of the increase of fish size. The results of the present study suggest that analysis of multiple regression is a more reliable test.

Many authors emphasize strong relation between the growth rate and fecundity. The believe that higher growth rate results in higher individual fecundity. Growth rate of the brood fish from both lakes considerably differed, despite similar age structure. In lake Narie vendace spawners were lesser and so was their fecundity. The question arises as to the causes of such differentiation. According to Wooton (1979), the cause should be searched among genetic and environmental factors. The studies

of Radziej (1973) showed that slow-growing vendace from lake Narie started to grow much faster when transferred to productive lake Wierzbiczany. This means that fish growth and fecundity are limited mainly by poor trophic conditions.

Lake Isąg, on the contrary, has optimal trophy for vendace growth and development. This was confirmed by high growth rate and high absolute fecundity (Tab. 2).

SUMMARY OF THE RESULTS

The results of the studies on vendace populations in two Mazurian lakes allow to formulate the following conclusions:

1. In both lakes the females spawn for the first time at the age 1+. Spawning in lake Isąg takes place in November, while in lake Narie in November and December (Tab. 2).
2. In the lakes under study the diameter of oocytes in the annual cycle varied considerably (Fig. 1).
3. The absolute fecundity of vendace in lake Isąg (length 20.2-26.5 cm, weight 93.0-263.5 g) fluctuated within the range 9.2-31.0 x 10^3 eggs and in fish from lake Narie - 3.5-11.6 x 10^3 eggs (length 15.3-21.4 cm, weight 40.3-118.7 g) (Tab. 2).
4. Significant relations between absolute fecundity and weight, length and age of the fish were observed. However, the analysis of multiple regression revealed that the relation between fecundity and age was not statistically significant.
5. Spawning populations of vendace in both lakes have similar age composition but differ in growth rate, body size and, in consequence, the absolute fecundity (Tab. 2, Figs. 5, 6).

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STRESZCZENIE

PŁODNOŚĆ SIELAWY Z DWÓCH JEZIOR POJEZIERZA MAZURSKIEGO

Praca przedstawia wyniki obserwacji gonad w cyklu rocznym oraz płodności sielawy (*Coregonus albula* L.) z dwóch jezior Pojezierza Mazurskiego: Isąg i Narie, różniących się pod względem morfometrycznym i limnologicznym. Czas trwania poszczególnych stadiów rozwoju owocytów w jajnikach był w tych

jeziorach nieco zróżnicowany. U samic sielawy z jeziora Narie w okresie odkładania w owocytach substancji troficznych obserwowano większe niż u sielawy z Isąga zróżnicowanie średnic. Można przypuszczać, że zostało to spowodowane zachodzącymi w ciągu roku dodatkowymi uzupełnieniami owocytów i mogło wpływać na dużą rozpiętość w czasie tarła. Tarło sielawy w Nariach odbywało się w drugiej połowie listopada i grudniu, natomiast w jeziorze Isąg w listopadzie. Po rozrodzie w jajnikach obserwowano VI - III stadium dojrzałości. Do rozrodu po raz pierwszy przystępowały osobniki w wieku 1+. Populacje tarłowe z obu jezior różniły się między sobą wymiarami ciała; większa i cięższa sielawa pochodziła z Isąga, ponadto sielawa z tego jeziora odznaczała się większą płodnością absolutną. Obserwowano wzrost płodności absolutnej w miarę zwiększania się rozmiarów ciała: masy i długości oraz wieku ryb. By znaleźć współzależność między indywidualną płodnością absolutną a cechami osobniczymi (masą, długością ciała, wiekiem) zastosowano dwie metody analizy statystycznej: korelacji oraz kowariancji w klasyfikacji podwójnej. Zależność między płodnością absolutną a rozmiarami ciała okazała się istotna statystycznie, natomiast między płodnością a wiekiem mało istotna w porównaniu z pozostałymi.

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