AGE, GROWTH RATE, AND CONDITION OF VENDACE, *COREGONUS ALBULA* (L.), FROM SOME POMERANIAN LAKES (NW POLAND)

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Background. Vendace, *Coregonus albula* (L.), is one of the most valuable components of Polish lake ichthyofauna. The vendace from different lakes differ in their principal vital characteristics (such as growth rate etc.) and it is therefore crucial to determine those characteristics from different trophic types of lakes in order to implement proper measures of fisheries management for those coregonids. The aim of the present paper was therefore to learn principal biological features of vendace populations representing three different Pomeranian lakes.

Materials and Methods. Comparative biological studies were carried out on 136 vendace from Pelcz Wielki Lake, 304 from Bytyń Wielki Lake, and 62 from Wetyl Lake (Pomerania Lakeland) collected within 2002–2003. The age and growth rate of the fish were determined from scales. Fulton’s condition factor and the total length–weight relation were used to determine fish condition.

Results. Gillnet selectivity influenced fish age structure and size. For example, among 502 vendace obtained, in total, from the three lakes, 75.7% (380 specimens) were 2+. The results of back-calculations and the parameters of von Bertalanffy’s growth equation revealed distinct disproportions in the total length in individual age groups (Pelcz Wielki Lake: $L_t = 213.22[1 – e^{-0.49576(1 + 1.055013)}]$; Bytyń Wielki Lake: $L_t = 219.17[1 – e^{-0.733553(1 + 0.040147)}]$; Wetyl Lake: $L_t = 255.08[1 – e^{-0.571108(1 + 0.023036)}]$). Slower length- and weight growth rates were observed in the fish from Pelcz Wielki Lake.

Conclusions. The growth rates, determined using back-calculations, were different for the vendace populations representing lakes Pelcz Wielki, Bytyń Wielki, and Wetyl in the sequential years of fish lives. The fish from Wetyl Lake were characterized by average growth, whilst the fish from the remaining reservoirs were characterized by slow or very slow growth. The lower condition values and growth rates from Pelcz Wielki Lake were probably the result of poor environmental conditions in this body of water.

Keywords: fish, vendace, *Coregonus albula*, growth rate, condition, age

INTRODUCTION

The vendace, *Coregonus albula* (L.), is one of the most valuable fish species caught in Polish lakes. The factors contributing to its high value are: high quality meat, fast growth rate, shoaling behaviour, and high market value. These qualities explain why, despite the high environmental requirements of this species, its catch had been increasing systematically in Poland, in the 1980s, reaching almost 600 t per year. However, due to the transformation of the fishing industry, the vendace fishery decreased twofold in the 1990s (Leopold and Wołos 1999). The disappearance of *Coregonus sp.* in lakes has also been related to adverse changes resulting from . Vendace are found in 44 out of 1575 lakes of Polish western Pomerania (Filipiak and Raczyński 2000), although only 23 of them are explored by professional fishermen (Czerniejewski and Filipiak 2001). Unfortunately, due to a lack of knowledge on the biological features of vendace populations inhabiting these waters it is impossible, in many cases, to implement a reasonable fisheries management. We decided to focus our attention on three, hitherto not studied, vendace populations inhabiting lakes Pelcz Wielki, Bytyń Wielki and Wetyl (Table 1) and to determine the biological features of those fish, in particular their age structure, growth rate, and condition.

MATERIALS AND METHODS

Vendace, *Coregonus albula* (L.), collected for the presently reported study were caught at night with a 24-mm-mesh-size gillnets in lakes: Pelcz Wielki (136 specimens;
10 June 2003), Bytny Wielki (304 specimens; 19 June–25 October 2002), and Wetyñ (62 specimens; 5 June–21 September 2003). The fish were individually weighed (Axis electronic scales with 0.1-g accuracy) and measured (total length) (electronic Vernier calliper with 0.1-mm accuracy). The condition of the fish studied was determined using the Fulton’s condition factor (Ricker 1975, Bolgier and Connolly 1989, Nash et al. 2006) and through analysis of “n” and “K” parameters of the (total) length and weight (L–W) relation. Fish age and growth rates were estimated from their scales, collected following the method of Bernatowicz (1952). The scales were cleaned of the mucus residues with ammonia solution and mounted on slides. Fish age determination and the measurement of scale radius were performed on the oral parts of the scales using image analysis software (“MultiScan” with 0.001-mm accuracy). Due to the commonly known linear R–L relation of vendace, the back calculations were made using the Rosa-Lee procedure, assuming the length of the scale establishment as 30 mm (Grudniewski 1970). The weight growth of fish was estimated by calculating the length of the fish in the following years on their weight according to the equation

\[ W = K \cdot L^n \]

where \( W \) is total individual weight [g], \( L \) is total length (TL) [mm], \( K \) and \( n \) are parameters of L–W relation.

**RESULTS**

The data presented in Table 2 suggest a lack of significant differences among the three populations in relation to mean length and weight. The homogeneity of values obtained can be explained by the mesh size used (24 mm) for all gillnet catches. Out of a total of 502 vendace collected, 75.7% (380) were aged 2+. In lakes Bytny Wielki and Wetyñ, 2+ fish constituted more than 80% of all fish caught (82.2% and 80.6%, respectively). In Pećcz Wielki Lake, despite the domination of 2+ fish (58.8%), a rather large proportion of 1+ fish was noted (23.5%), compared to the remaining lakes. Significant disproportions between the number of males and females obtained were probably related to the period of catching (Table 2). Among 136 specimens of vendace from Pećcz Wielki Lake, which were collected in spring, females predominated (66.9%), whilst fish obtained from autumn catches from Lakes Bytny Wielki and Wetyñ were characterized by greater numbers of males (82.2% and 74.2%, respectively).

Fulton’s condition factor of for the three populations is shown in Table 2. The difference in condition between vendace from lakes Pećcz Wielki and Wetyñ (0.75 and 0.76, respectively) were insignificant. Slightly higher condition was determined for vendace from Bytny Wielki Lake (0.79).

![Fig. 1 shows the dependence between the fish length and weight for the three populations. The exponent values (n) exceeded 2.5 in all cases, with the highest value obtained for fish from Wetyñ Lake (n = 3.5748). Much higher variation was noted for the multiplier (K), which ranged from 0.0000004 to 0.00006. Note that the n values are in reverse proportion to K values.](image)

Growth rates, determined on the basis of back-calculations, are shown in Table 3. All three populations achie-
Table 2

The average individual weights, total lengths and condition coefficients of vendace from particular lakes

| Lake             | Fish age | ♂/♀ | Total length [mm] | Individual weight [g] | Fulton’s condition factor |
|------------------|----------|-----|-------------------|------------------------|--------------------------|
|                  |          |     | Mean   | Range            | Mean   | Range            |                           |
| Pelcz Wielki     | 1+       | 18/14 | 173.3  | 154.3–199.4      | 40.2   | 31.0–58.3        | 0.75  | 0.64–0.90       |
|                  | 2+       | 54/26 | 190.0  | 170.8–212.6      | 51.0   | 38.3–70.0        | 0.75  | 0.62–0.86       |
|                  | 3+       | 19/4  | 200.4  | 185.7–216.8      | 61.4   | 53.1–74.6        | 0.76  | 0.67–0.89       |
|                  | 4+       | 0/1   | 196.5  | —                | 59.6   | —                | 0.77  | —               |
|                  | Total    | 91/45 | 187.9  | 154.3–216.8      | 50.3   | 31.0–74.6        | 0.75  | 0.66–0.90       |
| Bytyń Wielki     | 1+       | 6/18  | 199.5  | 182.0–214.0      | 63.8   | 51.3–81.5        | 0.80  | 0.69–0.91       |
|                  | 2+       | 37/213| 201.5  | 182.0–236.0      | 64.2   | 49.5–119.5       | 0.78  | 0.65–0.96       |
|                  | 3+       | 11/19 | 215.0  | 191.0–273.0      | 79.2   | 48.8–150.1       | 0.80  | 0.68–1.01       |
|                  | Total    | 54/250| 202.7  | 182.0–273.0      | 65.7   | 48.8–150.1       | 0.79  | 0.65–1.01       |
| Weltyń           | 1+       | 1/0   | 180.4  | —                | 37.5   | —                | 0.70  | —               |
|                  | 2+       | 8/42  | 201.4  | 176.6–224.7      | 65.5   | 34.2–100.8       | 0.79  | 0.59–1.09       |
|                  | 3+       | 7/4   | 203.8  | 186.9–222.2      | 68.8   | 46.0–93.5        | 0.80  | 0.69–1.00       |
|                  | Total    | 16/46 | 199.6  | 176.6–224.7      | 61.3   | 34.2–100.8       | 0.76  | 0.59–1.09       |
The fish experienced the fastest rate of length growth in their first year of life (mean values of 111.8–127.5 mm). Growth rates in the 2nd and 3rd years were 2–3 times slower compared to the values from the previous year.

At the end of their 1st year, fish from Pełcz Wielki Lake were more than 10 percentage points larger in length than fish from the remaining lakes. However, the growth rate of these fish declined in next years, probably due to an insufficient supply of plankton, which are the feeding base for vendace. Because of this, the highest values for length in the following years and the largest asymptotic length were achieved by fish from Weltyń Lake (Table 3).

**Table 3**

Growth rate of vendance from individual lakes as determined by back-calculation and von Bertalanffy’s mathematical model

| Method                  | Pełcz Wielki Lake | Bytyń Wielki Lake | Weltyń Lake |
|-------------------------|-------------------|-------------------|-------------|
| **Length growth [mm]**  |                   |                   |             |
| Back-calculation        |                   |                   |             |
| $l_1$                   | 127.5             | 113.5             | 111.8       |
| $l_2$                   | 169.2             | 164.4             | 169.4       |
| $l_3$                   | 189.7             | 194.8             | 209.4       |
| $l_4$                   | 193.0             | —                 | —           |
| von Bertalanffy’s       |                   |                   |             |
| $l_1$                   | 136.2             | 110.7             | 109.1       |
| $l_2$                   | 166.3             | 167.1             | 172.6       |
| $l_3$                   | 184.7             | 194.2             | 208.5       |
| $l_4$                   | 195.8             | —                 | —           |
| $l_w$                   | 213.2             | 219.2             | 255.1       |
| **Weight growth [g]**   |                   |                   |             |
| $W_1$                   | 18.93             | 12.39             | 8.41        |
| $W_2$                   | 39.61             | 37.17             | 37.15       |
| $W_3$                   | 53.40             | 61.46             | 79.27       |
| $W_4$                   | 55.86             | —                 | —           |

*denoted from the length values (back-calculations) converted to the weight ($W = K \cdot L^n$)
The lengths determined by back-calculation with the Rosa-Lee procedure were used to determine the parameters for a mathematical length growth model, according to von Bertalanffy’s equation. These models are as follows:

**Pełcz Wielki Lake:** \( L_t = 213.22[1 - e^{-0.49576(1 + 1.055013t)}] \)

**Bytyń Wielki Lake:** \( L_t = 219.17[1 - e^{-0.733553(1 + 0.040147)}] \)

**Wętyn Lake:** \( L_t = 255.08[1 - e^{-0.571108(1 + 0.023036)}] \)

Where \( L_t \) is total length [mm] of fish at age of \( t \) years.

It should be emphasized that the average absolute difference in length obtained from empirical (from back-calculations) and theoretical results (from von Bertalanffy’s model) was only 2.03 mm for fish from Bytyń Wielki Lake, 2.27 mm for Wętyn Lake fish, and 4.85 mm for vendace of Pełcz Wielki Lake. These small differences support the validity of the mathematical model based on the empirical data (Table 3).

Table 3 also shows the results of the analysis of weight growth for the three populations. In the first year of fish life, significant differences were observed in individual weights (from 8.41 g for Wętyn Lake fish to 18.92 g for Pełcz Wielki Lake fish). In the second year of life these differences largely decreased, ranging from 37.15 to 39.61 g, but in the third year fish from Pełcz Wielki Lake were definitely the smallest (53.40 g).

**DISCUSSION**

In the second half of the 20th century Polish inland fishermen were mainly dependent on the number of eels obtained. Nowadays, due to high stocking rates, vendace has become the most valuable species, especially in lakes with comparatively low trophic level and suitable hydro-chemical parameters. The preferred targets are 2- and 3-year old fish, because of their size (Bernatowicz et al. 1975). Gillnets of 24 mm mesh size are the principal gear for vendace populations are also diversified. It is evident (Table 4) that, the highest growth rate of vendace is generally observed in small reservoirs (28–120 ha) with a depth of 21–42.5 m and with high water transparency. Because of high diversity of Polish lakes, growth rates of individual vendace populations are also diversified. It is evident (Table 4) that, the highest growth rates were recorded for the populations representing the Great Poland Lakeland and Pomerania (Mastyński 1978, Marszalek 1961, Marcia 1970, presently reported data), compared to those of Masuria (Christianus 1995). Higher growth rates obviously indicate better live conditions. In order to evaluate accurately the growth rate of fish examined, taken from lakes Pełcz Wielki, Bytyń Wielki, and Wętyn, the presently acquired data were confronted with individual growth classes defined by Szczerskowska (1978) (Fig. 2). Among the three populations of vendace analyzed, the fish from Wętyn Lake were characterized by an average growth rate, whilst the populations from lakes Bytyń Wielki and Pełcz Wielki were characterized by slow growth. It is interesting that the initial rapid growth of vendace from
Table 4

The length growth rate of vendace [cm] from selected Polish Lakes

| Lake               | Total length in sequential years of life [cm] | Author         |
|--------------------|----------------------------------------------|----------------|
|                    | 1    | 2    | 3    | 4    | 5    | 6    |                |
| Maróz              | 9.50 | 13.70| 15.80| 19.20| —    | —    | Christianus    |
| Lutry              | 10.70| 14.60| 15.60| —    | —    | —    | 1995           |
| Narie              | 9.50 | 14.50| 16.60| 17.10| —    | —    |                |
| Isag               | 11.40| 16.70| 19.10| 21.40| —    | —    |                |
| Gorzyń             | 11.20| 17.90| 23.20| —    | —    | —    | Mastyński 1978 |
| Wdzydze            | 8.00 | 14.50| 19.60| 23.10| 26.10| 28.40| Marszałek 1961 |
| Płesno             | 13.20| 19.70| 23.00| —    | —    | —    |                |
| Cieszęcin          | 9.90 | 18.10| 22.90| 25.90| 27.40| —    |                |
| Łętowo             | 15.80| 20.50| 22.50| —    | —    | —    | Marciak 1970   |
| Żerdno             | 14.90| 21.30| 24.70| 26.70| —    | —    |                |
| Insko              | 13.70| 20.50| 23.50| 26.30| —    | —    |                |
| Pełcz Wielki       | 12.75| 16.92| 18.97| 19.30| —    | —    |                |
| Bytyń Wielki       | 11.35| 16.44| 19.48| —    | —    | —    | Presently      |
| Weltyń             | 11.18| 16.94| 20.94| —    | —    | —    | reported data  |

Fig. 2. The estimation of growth rate of vendace examined (according to the scale of Szczerbowski 1978)
Pelcz Wielki Lake declined in older fish. This may be due to unfavourable hydrochemical conditions during intensive growth period in the lake, along with the parasite infection (mainly Diphyllolothrium latum). As shown in the work of Waldemar Piasecki (unpublished) in Pelcz Wielki Lake, the lack of oxygen restricts vendace movement and feeding to the upper 7-m layer of water, limiting the feeding area of the fish and contributing to easier transmission of certain pathogens.

RECAPITULATION
• The growth of vendace from the three lakes was typical for the species, i.e., very fast growth in the first year of life and significant (almost 2–3-fold) decrease in the following years.
• The growth-rate analysis determined through back-calculation showed differences between the populations of vendace from lakes Pelcz Wielki, Bytyń Wielki, and Wętyn in sequential years of fish life. The fish from Wętyn Lake were characterized by an average growth rate, whilst the fish from the two other lakes grew slowly or very slowly.
• The lengths calculated by back-calculation, using the Rosa-Lee procedure, were used to determine a mathematical length growth model according to the von Bertalanffy’s equation. These models are shown as follows:
  - Pelcz Wielki Lake: \( L_t = 213.22 \times [1 - e^{-0.49576(1 + 1.055013t)}] \)
  - Bytyń Wielki Lake: \( L_t = 219.17 \times [1 - e^{-0.73353(1 + 0.040147t)}] \)
  - Wętyn Lake: \( L_t = 255.08 \times [1 - e^{-0.571108(1 + 0.023036t)}] \)
• Mean values of Fulton’s condition factor were 0.75 (range 0.66–0.90) for Pelcz Wielki Lake, 0.79 (range 0.65 to 1.01) for Bytyń Wielki Lake, and 0.75 (range 0.59 to 1.09) for Wętyn Lake. Estimated condition indexes for particular lake are close to those presented in the literature for other vendace reservoirs.

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