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# MORPHOLOGY OF THE COMMON GUDGEON, *GOBIO GOBIO* (L.) SENSU LATO, FROM THE VISTULA RIVER DRAINAGE IN THE CONTEXT OF RECENT LITERATURE DATA (TELEOSTEI: CYPRINIDAE)

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ABSTRACT. The common gudgeon *Gobio gobio* (L.) is considered to be highly variable and to show very good adaptability to local environmental conditions. The most recent studies show that the traditional notion of the *G. gobio* species covers a number of highly similar but distinct species that can be distinguished based on detailed analysis of morphometric characters.

This work presents the results of biometric studies on common gudgeons from two small rivers in the Vistula River drainage. The study has shown several biometric differences between the analyzed populations. Whether the two populations of the common gudgeon represent distinct species or are only evidence of intraspecific variation will be clear once the required comparative material has been gathered. Therefore, in accordance with the international trend, these populations should be treated as *Gobio gobio* (L.) sensu lato (= *G. gobio* (L.) complex).

Key words: COMMON GUDGEON, CYPRINIDAE, *GOBIO GOBIO*, MORPHOMETRICS, SYSTEMATICS, VISTULA RIVER DRAINAGE

## INTRODUCTION

The genus *Gobio* Cuvier, 1816 belongs to the subfamily Gobioninae of the family Cyprinidae. Initially it included all of the Euro-Asian gudgeons, which are now divided into several distinct genera (Naseka 1996, Bogutskaya and Naseka 2004, Kottelat and Freyhof 2007). It has been established (e.g. Gąsowska 1962, Białokoz 2000 and many others) that Poland is inhabited by five species of the subfamily Gobioninae, belonging to three genera: (1) *Gobio* Cuvier, 1816, common gudgeon, *Gobio gobio* (L.), (2) *Romanogobio* Bănărescu, 1961, white-finned gudgeon, *Romanogobio albipinnatus* (Lukasch), Kessler’s gudgeon (sand gudgeon), *Romanogobio kesslerii* (Dyb.),

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Danubian longbarbel gudgeon (stone gudgeon), *Romanogobio uranoscopus* (Agassiz), and (3) *Pseudorasbora* Bleeker, 1860, topmouth gudgeon (stone moroko), *Pseudorasbora parva* (Temminck and Schlegel). The incidence of stone gudgeon was questioned by Rolik (1959), and so far there has been no clear evidence that this species lives in Polish waters.

Until recently, the common gudgeon was considered a widespread, pan-Palearctic species with many subspecies and local "forms" in different environmental conditions (Berg 1949, Bănărescu et al. 1999, Kottelat and Persat 2005, Vasil'eva et al. 2004, 2005, Vasil'eva and Kuga 2005, Naseka et al. 2006). However, the most recent studies have shown immense morphological and osteological variation in different populations of *G. gobio* (Vasil'eva et al. 2004, 2005, Kottelat and Persat 2005, Naseka et al. 2005, 2006). Therefore, many of the former subspecies and local "forms" are now considered to be distinct species (for a review, see: Naseka et al. 2006, Kottelat and Freyhof 2007). Meanwhile, Kottelat and Persat (2005) redefined the species *G. gobio* (L.) sensu stricto, and designated a neotype (terra typica: Sieg River, Eitorf, Rhine drainage, Germany). Today, the common gudgeon is most often referred to as *G. gobio* sensu lato (*G. gobio* complex).

Previous publications on the systematics of the common gudgeon in Poland distinguished three subspecies: the nominative *G. gobio gobio* (L.) in the Vistula and Oder River drainage (Rolik 1965), the Danubian *G. gobio obtusirostris* (Val.) in the Danube River drainage: in the Czarna Orawa (Balon 1964, Balon and Holčik 1964; Polish name "kiełb dunajski" proposed by Rembiszewski and Rolik, 1975) and Prut rivers (Oliva 1962), and the Dniester gudgeon *G. gobio sarmaticus* (Berg) in the Strwiąż River of the Dniester drainage (Rolik 1967; Polish name "kiełb dniestrzański" proposed by Rembiszewski and Rolik, 1975). Most authors have ignored the subspecific variation of the common gudgeon, treating all the populations as *G. gobio* (e.g. Gąsowska 1962, Rembiszewski 1964, Skóra and Włodek 1966, 1971).

Much of the misunderstandings in the systematics of gudgeons stemmed from the different measurement methods used in Western and Eastern Europe (Kottelat and Persat 2005, Naseka et al. 2006, Kottelat and Freyhof 2007). The measurements used today (Naseka and Freyhof 2004, Freyhof and Naseka 2005, Kottelat and Persat 2005, Naseka et al. 2005, 2006, Kottelat and Freyhof 2007) are based on the system by Hubbs and Lagler (1958).

The present study contributes to the exploration of the morphological variation in the common gudgeon in the Vistula River drainage, with regard to current European trends and changes that have recently occurred in the systematics of the *Gobio* genus.

## MATERIAL AND METHODS

A total of 118 gudgeon specimens of both sexes were investigated. Sixty-five specimens were caught from the Rudawa River (a left-bank tributary of the Vistula River) at the Fishery Experimental Station of the Department of Ichthyobiology and Fisheries, Agricultural University of Kraków. Fifty-three specimens were caught from the Silnica River (a tributary of the Bobrza River in the drainage of the Czarna Nida River, a left-bank tributary of the Vistula River) in Kielce (Fig. 1). Fish were harvested using a lift net, anesthetized at the harvesting site by bathing in an aqueous extract of Propiscin (Etomidate), and fixed in 4% formalin.


Fig. 1. Area of the presented study: 1 – Rudawa River in Kraków; 2 – Silnica River in Kielce.

All the gudgeons were analyzed for 28 morphometric characters and 10 meristic characters according to the design proposed by Naseka and Freyhof (2004), based on the method by Hubbs and Lagler (1958), which is proposed to be an international one (Kottelat and Freyhof 2007). All the measurements were performed by the "point-to-point" method, using a caliper to the nearest 0.1 mm. Abbreviations used: TL – total length; SL – standard length, distance from the tip of the snout to the end of hypural complex, point determined by bending back the caudal fin in either direction, which reveals a clear edge; HL – head length, distance from the tip of the snout to the posteriormost point of the opercular membrane; aD – predorsal length; aV – prepelvic length; aA – preanal length; P-V – distance between the bases of the pectoral and pelvic fins; V-A – distance between the bases of the pelvic and anal fins; V-an – distance between the end of the pelvic-fin base and anus; an-A – distance between the anus and anteriormost point of the anal-fin base; pl – length of caudal peduncle, measured from the vertical line running through the end of the anal-fin base to the end of the hypural complex, measured along the longer body axis; H – maximum body depth, measured in advance of the dorsal fin; h – minimum depth of the caudal peduncle; iH – width of the body in advance of the dorsal fin; ih – width of the caudal peduncle, taken at the insertion of the anal fin; lP, lV – length, consecutively, of the pectoral and pelvic fins, measured from the base of the first ray to tip of the longest ray; lD, lA – length, consecutively, of the dorsal and anal-fin bases; hD, hA – depth consecutively, of the dorsal and anal fins, measured from the base to the tip of the longest fin-ray; r – snout length; po – postorbital length, measured from the posterior osseous margin of the orbit to the posteriormost point of the opercular membrane; o – horizontal eye diameter, distance between the osseous orbital margin; io – interorbital width, the least distance between fleshy margins of the orbits; ic – head width, taken at the opercles; hc – head depth at the nape; lb – length of the barbells. Following characters: SL, HL, and po were not measured according to the Pravdin's (1966) scheme, which is commonly used in Eastern Europe, but according to the scheme by Hubbs and Lagler (1958).

The number of rays in the dorsal and anal fin were determined visually without X-ray, contrary to the method by Naseka and Freyhof (2004). The last two branched rays, set on a common pterygiophore, were counted as 1½. Along the lateral line, all the perforated scales were counted as scales on the body (to the end of the hypural complex) or scales on the caudal fin. These two numbers were separated using a "+" sign.

Scales from the lateral line to the dorsum and from the lateral line to the ventral edge were counted in longitudinal rows. The extreme dorsal and ventral rows were counted as ½. In addition, circumpeduncular rows (horizontal rows of scales around the caudal peduncle) were counted at the lowest part of the caudal peduncle. The scale pattern on the belly was characterized according to a scheme presented by Naseka et al. (2006), as illustrated in Fig. 2.

The results of the morphometric measurements were subjected to basic statistical analysis using the Statsoft Statistica 7.1. The highest and lowest values of the analyzed characters, arithmetic means, and standard deviations were determined; both samples

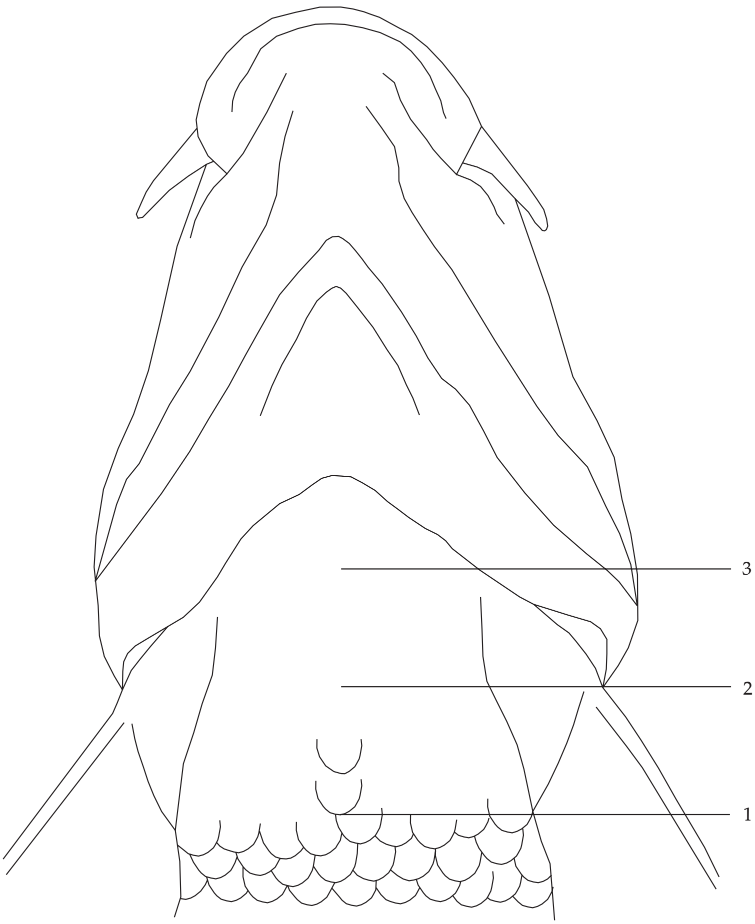


Fig. 2. Scale pattern on belly of the gudgeons. Numbers 1-3 indicate character states (according to Naseka et al. (2006), original drawing).

were subjected to Student's t-test for independent samples; and each sample was compared separately with the neotype values (Kottelat and Persat 2005) using Student's t-test for single samples. In both cases, Pearson's coefficients of correlation (r) were determined between the main morphometric characters and body length (SL).

## RESULTS

Specimens of similar size were studied from both populations (SL of 44.8-115.3 mm for gudgeons from the Rudawa River and 61.6-115.0 mm for gudgeons from the Silnica River; differences were not significant, $P \leq 0.05$). The populations did not differ significantly in terms of meristic characters (Table 1).

**TABLE 1**

Meristic characters in gudgeons from the Rudawa and Silnica Rivers. Number of branched rays in dorsal and anal fins, same as number of horizontal rows of scales, were given without "½" sign, i.e. value 7 branched dorsal-fin rays in the table refers to 7½ in the text

| | Rudawa River | | | Silnica River | | |
|---|---|---|---|---|---|---|
| Character | range | mean | S.D. | range | mean | S.D. |
| Number of unbranched rays in dorsal fin | 2-3 | 2.98 | 0.12 | 3 | 3.00 | - |
| Number of branched rays in dorsal fin | 7 | 7.00 | - | 7 | 7.00 | - |
| Number of unbranched rays in anal fin | 2-3 | 2.83 | 0.37 | 2-3 | 2.96 | 0.19 |
| Number of branched rays in anal fin | 5-6 | 5.98 | 0.12 | 5-6 | 5.98 | 0.14 |
| Number of scales in lateral row (total) | 38-44 | 40.82 | 1.25 | 38-42 | 40.49 | 1.12 |
| Rows of scales above lateral line | 5-6 | 5.82 | 0.39 | 5-6 | 5.89 | 0.32 |
| Rows of scales below lateral line | 3-4 | 3.92 | 0.27 | 4-5 | 4.11 | 0.32 |
| Circumpeduncular rows of scales | 12-15 | 13.62 | 0.66 | 12-15 | 13.27 | 0.81 |

In the dorsal fin they had 3 unbranched (1 fish from the Rudawa River had 2) and 7½ branched rays (all fish). In the anal fin they had 3 unbranched (11 fish from the Rudawa River and 2 fish from the Silnica River had 2) and 6½ branched rays (1 fish from the Rudawa River and 1 fish from the Silnica River had 5½). The lateral line of gudgeons from the Rudawa River contained 37-42 scales on the body and 1-3 scales in the caudal fin (39+2 on average). Gudgeons from the Silnica River had 37-41 scales on the body and 1-3 scales on the caudal fin (39+2 on average). In all the specimens, there were 12-15 (usually 13-14) circumpeduncular rows around the caudal peduncle. There were 5½-6½ horizontal rows of scales between the lateral line and the dorsum, and 3½-4½ horizontal rows of scales between the lateral line and the ventral edge. The most common pattern was 6½ rows of scales above the lateral line and 4½ below.

The throat was essentially scaleless. In the Rudawa River gudgeons, the scale cover reached the anterior end of the pectoral fin base, corresponding to point 2 on the scale of Naseka et al. (2006), or covered part of the throat area between the gill covers, corresponding to point 3. In the Silnica River gudgeons, a narrow strip of scales usually reached the posterior end of the pectoral fin base (point 1) or slightly farther (between points 1 and 2) (Fig. 2). The scales covering the belly and throat of the Rudawa River specimens were clearly massive and large, unlike the fine scales on the belly of the Silnica River specimens.

Pectoral fins were large and accounted for an average of 85% and 78% of the P-V length in Rudawa and Silnica River gudgeons, respectively (Table 1). Pelvic fins were considerably smaller and usually covered the anus (sometimes only reaching the anus), a pattern that was more frequent in the Rudawa River specimens. In the gudgeons from the Rudawa River, their length accounted for an average of 79% of the V-A length and for 74% of the length in the gudgeons from Silnica River.

In terms of the Pearson's correlation, 13 of all 26 characters were found to be significantly ($P < 0.05$) dependent on SL in gudgeons from the Rudawa River and 9 of all 26 in gudgeons from the Silnica River. The following characters from the first sample were found to be the strongest positively length-dependent: H/SL ($r = 0.85$); ih/SL ($r = 0.71$); r/HL ($r = 0.63$). The strongest negative correlation with SL was found in hD/SL ($r = -0.60$) and o/SL ($r = -0.59$). The body proportions of gudgeons from the Silnica River showed a weaker dependence on SL. As for gudgeons from the Rudawa River, the strongest positive dependence on SL was noted in the H/SL ratio ($r = 0.38$) and the strongest negative correlation with SL was observed for the following characters: o/HL ($r = -0.69$); pl/SL ($r = -0.56$); hD/SL ($r = -0.40$).

## DISCUSSION

During the comparison with the neotype (Kottelat and Persat 2005), the following observations were made (Table 2). Gudgeons from the Rudawa River differed the most from the neotype in body depth (19.0% vs 21.7% SL, $t = -17.06$), head length (25.5% vs 27.1% SL, $t = -13.83$), and snout length (39.3% vs 43.0% HL, $t = -12.12$). In this respect, specimens from the Silnica River were much more similar to the neotype (t equal to: -2.52, -4.96 and -4.02, respectively), although the differences remained significant ($P \leq 0.05$). However, the Silnica River specimens differed the most from the neotype in caudal peduncle depth (8.2% vs 9.5% SL, t = -16.32; like specimens from the Rudawa River, t = -7.10), anal fin height (14.9% vs 16.5% SL, t = 14.83), pectoral fin length (19.1% vs 20.8% SL, t = 10.68), and head depth (62.2% vs 59.0% HL, t = 10.33). Gudgeons from the Rudawa River showed a significant resemblance in terms of prepelvic length only (48.9% vs 49.2% SL, t = -1.78), and specimens from the Silnica River in terms of caudal peduncle length (21.8% vs 21.9% SL, t = -0.63) and eye diameter (22.3% vs 22.0% HL, t = 1.69). The Rudawa River population differed significantly ($P \leq 0.05$) from the typical specimen in 15 out of the 16 body proportions analyzed (almost 94%), and gudgeons from the Silnica River in 14 out of 16 (87.5%).

The analyzed populations differed significantly ($P \leq 0.05$) in 19 out of 26 body proportions (73%) (Table 2). The differences were only non-significant for predorsal and preanal length (t = 0.14 and -0.53, respectively), caudal peduncle length (t = -1.91), caudal peduncle width (t = 0.93), anal-fin base length (t = 1.96), postorbital distance (t = 1.97), and head depth (t = -1.37).

Gudgeons of both populations were riverine, so pointed differences cannot be explained in terms of traditional "lotic" and "lentic" ecological forms (Bănărescu 1954, Bănărescu et al. 1999), as Rolik (1965) did in case of several populations from the Vistula drainage. Besides, this differentiation has been already thoroughly criticized by Kottelat and Persat (2005) as generally unclear.

Furthermore, the recent publication by Kottelat and Freyhof (2007), which considers many traditional subspecies or local "forms" to be valid distinct species (e.g. *Gobio carpathicus*, *G. obtusirostris,* and *G. sarmaticus* already mentioned herein), suggests that the usage of the name "*G. gobio*" is still confusing, and probably further distinct species will yet be recognized. Unfortunately, previous literature data (e.g. Rolik 1965, 1967, Skóra and Włodek 1966, 1971 and many others), as it was already stressed, were based on different and often incomparable methods of measurement, so they cannot be used in the current study. In this context, the differences identified between the analyzed populations should be taken as a starting point for further investigations.

**TABLE 2**

Comparison of morphological characters in gudgeons from the Rudawa, Silnica Rivers and neotype (Kottelat and Persat 2005). For character abbreviations, see text, SD – standard deviation

| | Rudawa River | | | Silnica River | | | |
|---|---|---|---|---|---|---|---|
| Character | mean | range | SD | mean | range | S.D. | neotype |
| TL, mm | $93.2^a$ | 53.8-136.3 | 18.09 | $91.6^a$ | 72.8-138.6 | 15.65 | 113.7 |
| SL, mm | $76.6^a$ | 44.8-115.3 | 15.54 | $76.7^a$ | 61.6-115.0 | 13.57 | 92.6 |
| | | | In per cent (%) of SL | | | | |
| HL | $25.5^a$ | 24.0-28.5 | 0.90 | $26.4^b$ | 23.7-28.3 | 0.97 | $27.1^c$ |
| aD | $47.6^a$ | 44.0-50.3 | 1.16 | $47.5^a$ | 42.0-49.6 | 1.39 | $48.4^b$ |
| aV | $48.9^a$ | 46.3-51.2 | 1.17 | $50.1^b$ | 46.6-54.1 | 1.40 | $49.2^a$ |
| aA | $70.5^a$ | 65.4-73.7 | 1.48 | $70.7^a$ | 65.0-74.2 | 1.84 | $71.5^b$ |
| P-V | $24.1^a$ | 21.1-26.0 | 1.05 | $24.5^a$ | 22.3-28.1 | 1.33 | - |
| V-A | $21.6^a$ | 18.6-24.8 | 1.06 | $21.2^b$ | 18.2-23.6 | 1.15 | - |
| V-an | $9.3^a$ | 6.6-12.0 | 1.11 | $9.8^b$ | 7.4-11.9 | 1.17 | - |
| an-A | $8.2^a$ | 5.9-10.0 | 0.85 | $7.3^b$ | 5.3-9.7 | 0.96 | - |
| pl | $21.3^a$ | 18.4-24.2 | 1.30 | $21.8^a$ | 16.8-24.6 | 1.29 | $21.9^b$ |
| H | $19.0^a$ | 16.1-22.1 | 1.26 | $21.3^b$ | 19.0-26.6 | 1.21 | $21.7^c$ |
| h | $8.7^a$ | 6.9-15.2 | 0.94 | $8.2^b$ | 6.9-9.5 | 0.56 | $9.5^c$ |
| iH | $15.6^a$ | 12.9-19.9 | 1.07 | $16.5^b$ | 14.6-19.7 | 1.03 | $14.9^c$ |
| ih | $7.9^a$ | 5.8-9.4 | 0.75 | $7.7^a$ | 6.5-10.1 | 0.77 | - |
| lD | $13.0^a$ | 11.4-15.0 | 0.64 | $12.7^b$ | 11.3-14.2 | 0.64 | - |
| hD | $21.3^a$ | 17.8-24.3 | 1.30 | $20.3^b$ | 17.9-24.2 | 1.14 | $20.7^c$ |
| lA | $8.3^a$ | 7.0-9.3 | 0.47 | $8.0^a$ | 6.4-9.9 | 0.66 | - |
| hA | $15.9^a$ | 13.8-17.7 | 0.97 | $14.9^b$ | 12.6-16.3 | 0.78 | $16.5^c$ |
| lP | $20.5^a$ | 18.0-22.7 | 1.04 | $19.1^b$ | 16.4-21.2 | 1.14 | $20.8^c$ |
| lV | $17.0^a$ | 15.2-18.5 | 0.74 | $15.6^b$ | 13.3-17.0 | 0.71 | $16.4^c$ |
| | | | In per cent (%) of HL | | | | |
| r | $39.3^a$ | 32.7-44.5 | 2.43 | $42.0^b$ | 38.9-46.1 | 1.80 | $43.0^c$ |
| po | $44.1^a$ | 38.0-50.0 | 2.01 | $43.3^a$ | 39.1-47.2 | 1.85 | - |
| o | $23.4^a$ | 18.2-27.4 | 1.81 | $22.3^b$ | 18.8-25.7 | 1.45 | $22.0^b$ |
| io | $30.7^a$ | 25.8-34.1 | 1.70 | $27.6^b$ | 24.5-31.0 | 1.42 | $29.0^c$ |
| hc | $61.5^a$ | 54.0-71.4 | 3.18 | $62.2^a$ | 55.5-66.5 | 2.18 | $59.0^c$ |
| ic | $58.4^a$ | 46.0-67.2 | 3.35 | $60.4^b$ | 51.5-65.8 | 3.31 | - |
| lb | $27.5^a$ | 18.6-32.6 | 2.52 | $25.5^b$ | 21.7-30.5 | 2.34 | - |

*Values with a different letter index in the same row differ significantly statistically (test t, $P \leq 0.05$)*

## CONCLUSIONS

The presented results show that different populations of the so-called *Gobio gobio* from the drainage of one river differ considerably in terms of morphometric characters. At this stage of the research, the analyzed populations of common gudgeon cannot be classified conclusively because of the lack of accurate analysis in different parts of

Poland, the often incomplete characteristics provided in publications, and the use of different (and often unspecified) measurement methods by the authors. At this point, it could be stated that they "confer" *G. gobio* sensu stricto, as it is redescribed by Kottelat and Persat (2005), but nothing more.

Because of the differences shown in morphological structure, until more comparative material is gathered it seems justified to treat the common gudgeon populations from the Vistula River drainage with a modicum of caution and to regard them as *Gobio gobio* (L.) sensu lato (*G. gobio* (L.) complex), as is the case of *Gobio* gudgeons from the rivers of Crimea classified by Vasil'eva et al. (2004, 2005), Vasil'eva and Kuga (2005) and Naseka et al. (2005).

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## STRESZCZENIE

MORFOLOGIA KIEŁBIA KRÓTKOWĄSEGO, *GOBIO GOBIO* (L.) SENSU LATO, Z DORZECZA WISŁY W KONTEKŚCIE WSPÓŁCZESNYCH DANYCH LITERATUROWYCH (TELEOSTEI: CYPRINIDAE)

Kiełb krótkowąsy, *Gobio gobio* (L.) był do niedawna powszechnie uważany za szeroko rozprzestrzeniony, bardzo zmienny gatunek, tworzący szereg podgatunków i „form" ekologicznych, w zależności od lokalnych warunków środowiska. Jednak badania prowadzone w ostatnich latach wykazały, że pod tradycyjną nazwą *G. gobio* kryje się w istocie wiele różnych gatunków, które można odróżnić morfometrycznie. W związku z tym dwie populacje kiełbia krótkowąsego z dorzecza Wisły (z rzeki Rudawy w Krakowie i rzeki Silnicy w Kielcach, rys. 1) porównano pod kątem 28 cech morfometrycznych i 10 merystycznych (rys. 2). Ponadto dokonano porównania obu populacji z neotypem *G. gobio* sensu stricto wyznaczonym w 2005 roku.

Stwierdzono, że kiełbie z obu rzek nie różnią się pod względem cech merystycznych (tab. 1). Natomiast wykazano szereg różnic morfometrycznych (tab. 2). Obie populacje różniły się istotnie ($P \leq 0,05$) pod względem 73% badanych cech. Kiełbie z Rudawy różniły się od neotypu w 94%, zaś kiełbie z Silnicy 87,5% porównywanych cech.

Na tym etapie badań i przy braku odpowiedniego materiału porównawczego nie można jednoznacznie określić, czy wykazane różnice są przejawem różnic gatunkowych, czy tylko zmienności wewnątrzgatunkowej. Dlatego sugeruje się ostrożniejsze niż w dotychczasowej polskiej literaturze podchodzenie do zagadnienia systematyki kiełbia krótkowąsego w dorzeczu Wisły i traktowanie go jako *G. gobio* sensu lato (*G. gobio* complex), co jest obecnie praktykowane w skali europejskiej.

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# THE SIGNIFICANCE OF STONE MOROKO, *PSEUDORASBORA PARVA* (TEMMINCK AND SCHLEGEL), IN THE SMALL-SIZED FISH ASSEMBLAGES IN THE LITTORAL ZONE OF THE HEATED LAKE LICHEŃSKIE

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ABSTRACT. The aim of the study was to determine changes in the seasonal abundance of stone moroko, *Pseudorasbora parva* (Temminck and Schlegel), and to identify the role this alien species plays in the littoral zone of a heated lake. This study also aimed at defining the habitat preferences of this species and describing the relations between the relative abundance of stone moroko and the occurrence of submerged vegetation. A significant dependence was determined of the degree to which the lake bottom is covered with macrophytes and the occurrence of stone moroko. The fish caught belonged to 14 species and 2 families. Stone moroko preferred habitats that were abundantly overgrown with submerged vegetation and avoided areas devoid of macrophytes. Thus, as the bottom cover increased, so did the relative number of this fish. In light of habitat availability and its food preferences, the abundant occurrence of this species poses a serious threat to the endemic ichthyofauna.

Key words: *PSEUDORASBORA PARVA*, INTRODUCED SPECIES, INVASION, HEATED LAKES, MACROPHYTES

## INTRODUCTION

Stone moroko, *Pseudorasbora parva* (Temminck and Schlegel), is one of the most effective invasive species to have inhabited European inland waters in recent years (Caiola and De Sostoa 2002, Gozlan et al. 2002, Cakic et al. 2004, Pinder et al. 2005, Pollux and Korosi 2006). In the waters where it has settled, it prefers shallow, abundantly overgrown areas, where plentiful food resources, a spatially varied environment, and the occurrence of submerged vegetation provide advantageous living conditions. Aspects of the life history of this species that

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predispose it to settling in new aquatic basins include a wide tolerance of environmental conditions, reaching sexual maturity in the first year of life, batch spawning, and nest guarding (Pinder et al. 2005).

Lakes that are connected with a system of canals are a convenient distribution route for alien species of ichthyofauna. The most common sources of alien species introduction include aquaculture, the ornamental fish trade, controlling selected elements of biocenoses, scientific research, the use of such species as bait, and the accidental or natural movement of organisms (Bartley and Subasinghe 1996). By the end of the 1980s, 74 species of fish originating from other continents had been introduced in Europe, while another 60 fish and lamprey species were moved from their natural range of occurrence (Holčik 1991). By the mid 1990s in Poland, 23 alien species were confirmed to occur either periodically or permanently in inland waters (Witkowski 1996).

The stone moroko, a small fish of the family Cyprinidae that naturally inhabits the waters of east Asia (Gozlan et al. 2002), was first confirmed in Europe in 1960 in Romania, and was noted in Poland in 1990 at the Stawno farm near Milicz (Oder River catchment in southwest Poland). Most probably it was introduced along with stocking material of herbivorous fish that had been imported from Hungary several years earlier (Witkowski 1991). By the end of the 1990s, this fish had spread throughout all the regions of Poland inhabiting lakes, ponds, and rivers (Kotusz and Witkowski 1998). The first sighting of stone moroko in Lake Licheńskie was in 2002 (Kapusta 2004), and in subsequent years increases were noted in its abundance and its inhabiting subsequent lakes (Kapusta et al. 2006).

The aim of the current study was to determine the habitat preferences of this alien ichthyofauna species and to follow changes in its abundance throughout one year in a heated lake.

## MATERIALS AND METHODS

### STUDY AREA

Lake Licheńskie (147.6 ha) is located in central Poland near Konin in the Wielkopolsko-Kujawskie Lakeland (52°19’N-18°21’E) (Kondracki 2001). Its trough shape extends from the north to the southwest. Along with four neighboring lakes, Lake Licheńskie is part of a complex connected by a canals network that serves as the cooling system for the Konin and Pątnów power plants. The high water temperature and its continual exchange throughout the year (at an average of every five days), substantial industrial and communal pollution, and the stocking of the lakes with herbivorous fish species alien to the endemic ichthyofauna have caused a range of disadvantageous changes in Lake Licheńskie. In the 1970s *Najas marina* L. and in the 1990s *Vallisneria spiralis* L. were noted in place of naturally occurring native submerged littoral plants (Hutorowicz 2006).

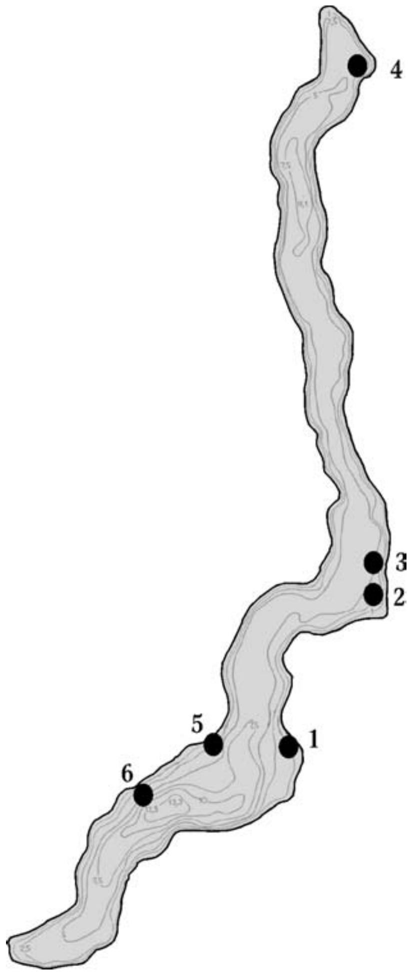


Fig. 1. Location of study stations in Lake Licheńskie.

## FISH CATCHES AND DATA ANALYSIS

Fish were caught in the littoral zone of Lake Licheńskie in April, June, July, August, and September 2004 with an experimental net (length 5 m, depth 0.8 m, mesh size 1.0 mm). Catches were made in the shore zone at six sites (Fig. 1). Fish from different sampling sites were placed in separate containers and then preserved in a 4% formaldehyde solution. The fixed fish were identified (Pinder 2001, 2005) and measured (body weight to the nearest 0.001 g and total length to the nearest 0.01 mm). A total of 329 stone moroko specimens were analyzed (Table 1).

**TABLE 1**

Number (N), length and body weight of stone moroko, *Pseudorasbora parva* from Lake Licheńskie

| Date | N | Mean total length (mm) | Total length range (mm) | Mean body weight (g) | Body weight range (g) |
|---|---|---|---|---|---|
| 30 June 2004 | 17 | 40.98 | 19.6-53.6 | 1.45 | 0.145-2.840 |
| 27 July 2004 | 90 | 15.40 | 6.9-40.9 | 0.10 | 0.002-1.350 |
| 30 August 2004 | 120 | 20.24 | 7.0-53.2 | 0.21 | 0.003-2.500 |
| 30 September 2004 | 165 | 18.78 | 8.5-66.2 | 0.19 | 0.007-5.340 |

Physicochemical conditions at the sampling sites were registered when the fish were caught. Oxygen content was measured with a DO meter (HI 9142, Hanna Instruments), while water temperature and pH were measured with a pH meter with a microprocessor (HI 991001, Hanna Instruments). The dependence between the occurrence of submerged vegetation and the relative density of stone moroko was determined by dividing the collected samples based on the quantity of macrophytes occurring at a given fishing site. At each sampling stations the total cover of macrophytes was expressed by the sum of the covers of all plant species. Macrophytes cover was estimated by visual observations of percent cover. Five-degree scale vegetation were used: I – no vegetation; II – 1-25%; III – 25-50%; IV – 50-75%; V – exceeding 75% macrophytes bottom cover.

The analysis of the material was based on determining the relative density (D) and the frequency of occurrence of given species. The evaluation of the frequency of occurrence of fish species was expressed as the frequency index (V), which is the quotient of the number of samples in which a given species occurred and the number of all samples collected. Grouping the samples confirmed in the littoral zone of Lake Licheńskie was performed with cluster analysis. Ward's method was used to perform agglomerations based on the permanence of occurrence and domination of particular species. Euclidean distance was used as the measure of distance, which permitted categorizing the confirmed species into sensible structures known as guilds. Relations between the bottom macrophytes cover and the relative number of stone moroko was determined with nonparametric analysis of variance (ANOVA Kruskal-Wallis) and Spearman rank correlation. Comparing total length of stone moroko in subsequent fishing periods was performed with the Kruskal-Wallis test. Relations between weight and total length were described with polynomial functions. All of the statistical analyses were preformed with Statistica 7.1 (StatSoft Inc.).

# RESULTS

## CHARACTERISTICS OF HABITAT CONDITIONS

Environmental conditions (water temperature, oxygen content, pH) did not differ significantly statistically among the sampling sites (Kruskal-Wallis test, $P > 0.05$). Among the designated sampling sites, only station 2 was significantly shallower than the others (Kruskal-Wallis test: $H = 12.758$, $P = 0.026$). Water temperature in the littoral zone of Lake Licheńskie during the study period fluctuated from 16.1 (on 30.09) to 29.2°C (on 27.07), while the dissolved oxygen content ranged from 5.6 (on 01.06) to 20.0 $mgO_2\ dm^{-1}$ (on 27.07). The water pH in Lake Licheńskie during the study period was slightly basic within the range of 8.14 (on 26.04) to 9.26 (on 29.07). The percentage of bottom area overgrown with macrophytes at the study sites in the littoral zone of Lake Licheńskie ranged from 0 to 100%. The least bottom cover was noted at the study stations in April (0-10%). In subsequent months, the amount of bottom cover increased and was at its maximum in September, when it fluctuated from 65 to 100% (mean 76%). The only exception was station 2, located on the beach, at which vegetation density was similar in each month (from 0 to 20%).

## FISH ASSEMBLAGES

A total of 3122 fish belonging to 14 species and 2 families (Table 2) were noted. Among the species identified, the majority were obligatory or facultative phytophils. Stone moroko comprised 32.6% of all the fish caught, and its permanence of occurrence in the samples was 60%. The other dominant species included bleak, *Alburnus alburnus* (L.), at 31.8% and roach, *Rutilus rutilus* (L.), at 15.3%. Although the number share of roach in the catches was lower than that of bleak, it did occur in the catches more frequently (frequancy indices were 50.0 and 36.7%, respectively). The frequency of occurrence of other phytophil species (tench, *Tinca tinca* (L.), rudd, *Scardinius erythrophthalmus* (L.), Prussian carp, *Carassius gibelio* (Bloch)) was high (≥ 30%), but relative density was low. The share of the remaining fish species did not exceed 10%. The rarest (3.3%) and least abundant (< 0.1%) species in the catches included sunbleak, *Leucaspius delineatus* (Heck.), ruffe, *Gymnocephalus cernuus* (L.), and chub, *Leuciscus cephalus* (L.).

TABLE 2

List of species caught in the littoral zone of Lake Licheńskie divided into reproductive groups (D – dominant, V – frequency of occurrence)

| Ecological reproductive group | | Species name | D | V |
|---|---|---|---|---|
| Non-guarding and open substratum egg scattering | | | | |
| Lithophil | Chub | *Leuciscus cephalus* (L.) | < 0.1 | 3.3 |
| Phyto-lithophils | Roach | *Rutilus rutilus* (L.) | 15.3 | 50.0 |
| | Bleak | *Alburnus alburnus* (L.) | 31.8 | 36.7 |
| | White bream | *Abramis bjoerkna* (L.) | 1.8 | 23.3 |
| | Bream | *Abramis brama* (L.) | 0.1 | 6.7 |
| | Ruffe | *Gymnocephalus cernuus* (L.) | <0.1 | 3.3 |
| Phytophils | Rudd | *Scardinius erythrophthalmus* (L.) | 6.4 | 46.7 |
| | Tench | *Tinca tinca* (L.) | 3.5 | 50.0 |
| | Prussian carp | *Carassius gibelio* (Bloch) | 4.1 | 30.0 |
| | Carp | *Cyprinus carpio* L. | 0.2 | 10.0 |
| Nonguarders, brood hiders | | | | |
| Ostracophil | Bitterling | *Rhodeus sericeus* (Bloch) | 3.7 | 13.3 |
| Guarding nesters | | | | |
| Phytophils | Pikeperch | *Sander lucioperca* (L.) | 0.3 | 6.7 |
| | Sunbleak | *Leucaspius delineatus* (Heck.) | <0.1 | 3.3 |
| Phyto-lithophil | Stone moroko | *Pseudorasbora parva* (Temminck and Schlegel) | 32.6 | 60.0 |

The species that occurred in the catches at fairly high frequencies and numerously (stone moroko, bleak) or fairly numerously (roach, rudd, tench) were divided into separate branches of the classification tree (Fig. 2). Another guild was comprised of species that occurred infrequently or in very small numbers. Of these fish, those with fairly high frequency of occurrence were grouped on a separate branch of the classification tree (Prussian carp, bitterling, *Rhodeus sericeus* (Bloch), white bream, *Abramis bjoerkna* (L.)). A third group was comprised of species that occurred in the catches very rarely and in very small numbers (pikeperch, *Sander lucioperca* (L.), bream, *Abramis brama* (L.), carp, *Cyprinus carpio* L., chub, ruffe, sunbleak).

## STONE MOROKO POPULATION

The density of stone moroko in the littoral zone of Lake Licheńskie increased in each subsequent month of the study (Fig. 3). In April, 497 fish were caught, but there were no stone moroko noted. In June, however, 17 of these fish were caught, which was less than 3% of all the fish caught in this month. The most fish were caught in July (968), but stone moroko comprised barely 11% of the fish caught. A distinct increase in

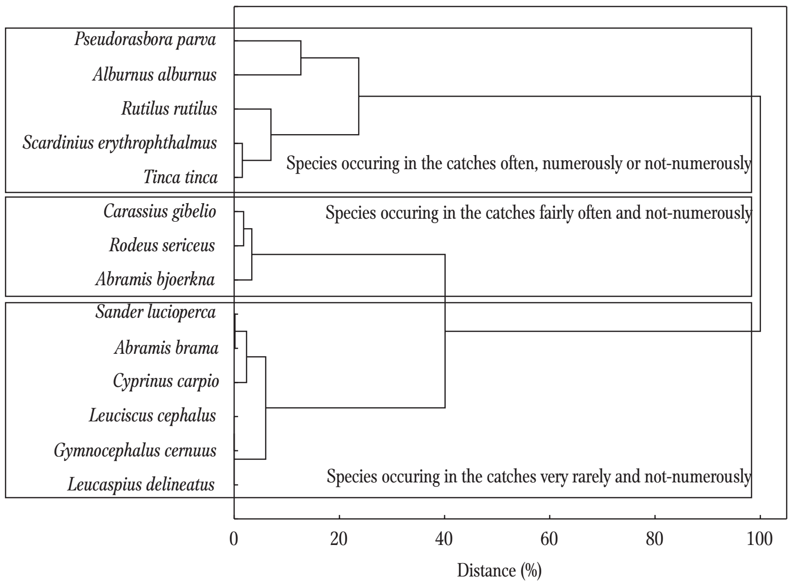


Fig. 2. Hierarchical classification of fish species occurring in the catches made in Lake Licheńskie.

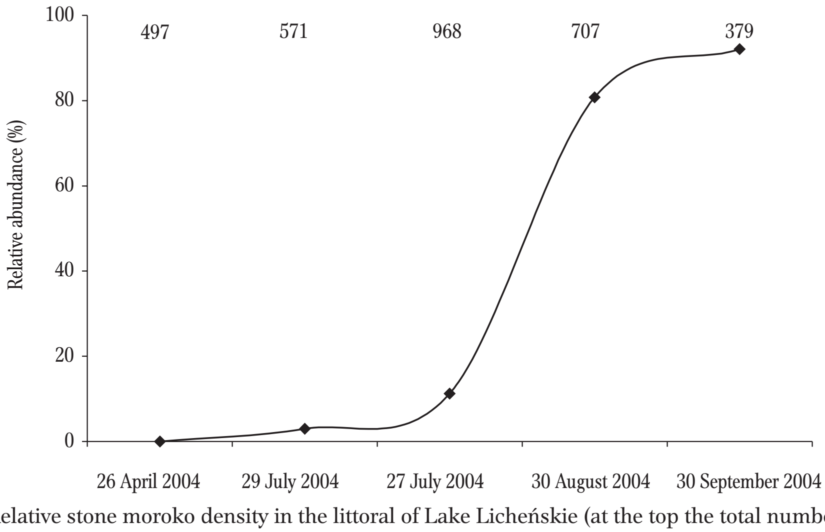


Fig. 3. Relative stone moroko density in the littoral of Lake Licheńskie (at the top the total number of fish caught is given).

the density of stone moroko in the littoral zone of Lake Licheńskie was not noted until August and September (at 80 and 92%, respectively).

The relative density of stone moroko increased along with the development of submerged vegetation (Fig. 4). A significant dependence between the degree of bottom

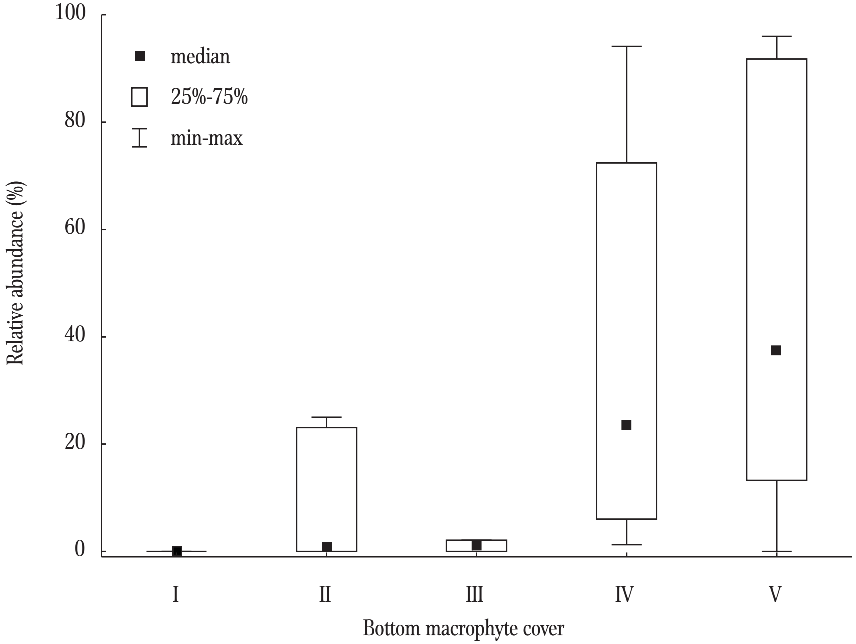


Fig. 4. Comparision of degree of macrophyte bottom cover and the abundance of stone moroko in the littoral zone of Lake Licheńskie. Macrophyte bottom cover: I – no vegetation. II – 1-25%, III – 25-50%, IV – 50-75%, V – over 75%.

macrophyte cover and the occurrence of stone moroko was confirmed (Kruskal-Wallis test: H =11.276, P = 0.024). The results of correlation analysis confirm that as bottom macrophyte cover increased, so too did the relative number of stone moroko (Spearman correlation, r = 0.537, P < 0.05).

The specimens caught in June had the greatest mean total length (Fig. 5). In subsequent months, the mean TL of the fish caught was lower, even if specimens occurred in the catches that were of a maximum body size larger than that in June. This resulted from the appearance in the littoral zone of a large quantity of stone moroko larvae and fry that followed spawning. The largest specimen (66.2 mm in length) was caught on 30.09. The dependence between length (TL) and body weight in stone moroko was described with a polynomial function (Fig. 6). Specimens of a total length of 30-33 mm attain a weight of approximately 0.5 g, while after exceeding a length of 38 mm, they achieve a weight of 1.0 g.

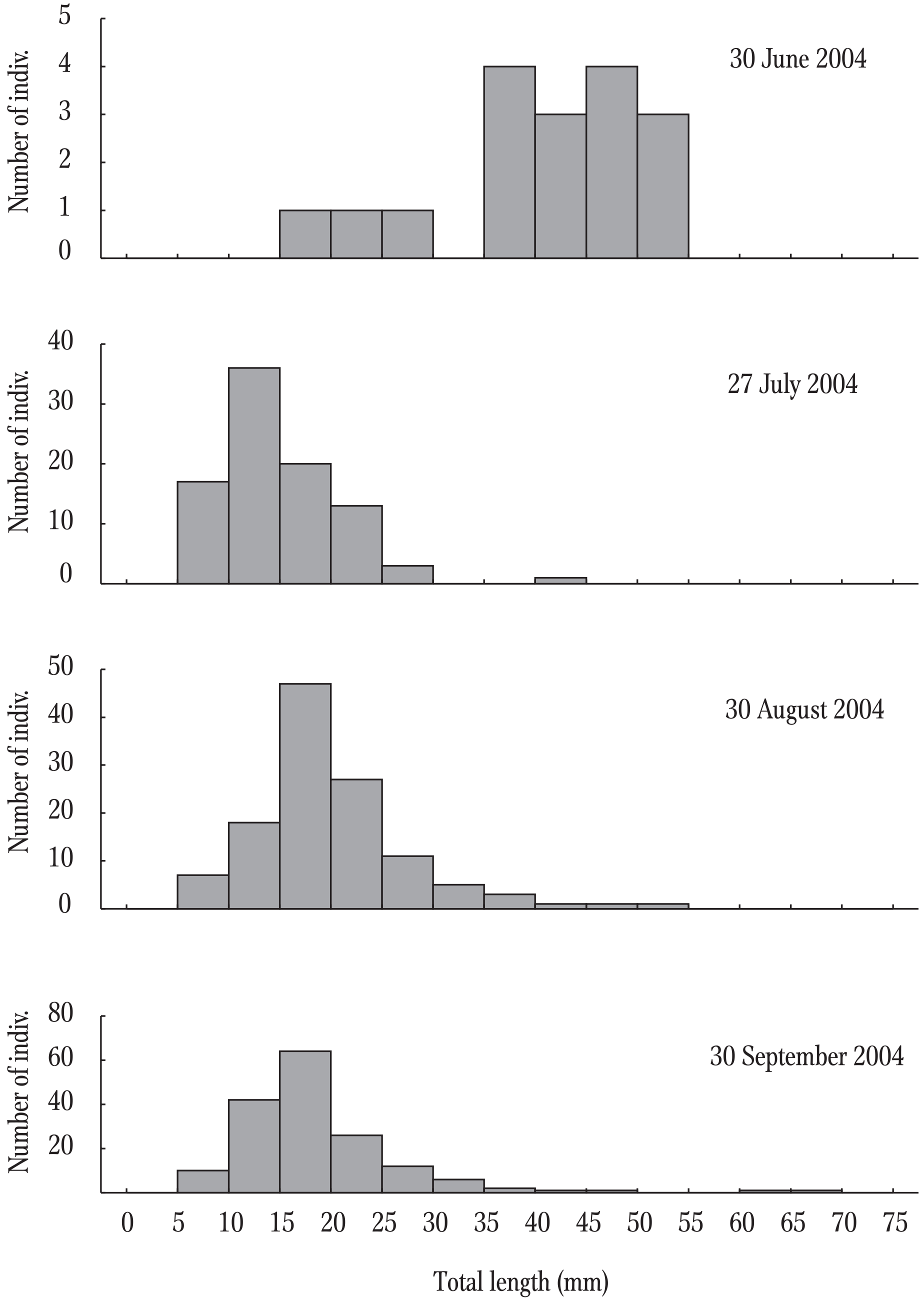


Fig. 5. Total length distribution of stone moroko in the littoral zone of Lake Licheńskie.

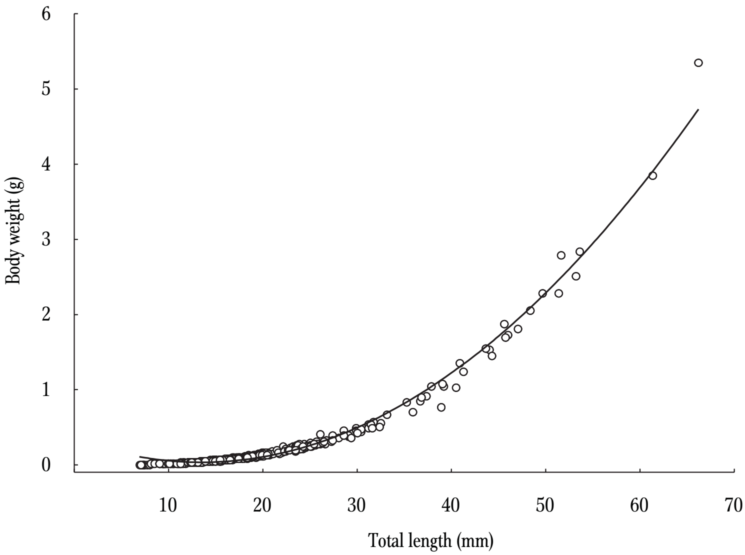


Fig. 6. Dependence between weight and total length of stone moroko.

## DISCUSSION

The analysis of the structure of the ichthyofauna and archival data on the abundance of predatory fish (Wilkońska and Żuromska 1983, Ciepielewski and Dominiak 2004) indicate their impact on the stone moroko population in Lake Licheńskie is minimal. During the current study, the abiotic conditions (water temperature, oxygen content, pH) did not differ significantly. The factors that did differ significantly among the study sites in the littoral zone of Lake Licheńskie were the area of lake bottom cover with macrophytes and the abundance of invertebrate fauna. Spatial differentiation in the occurrence of stone moroko was likely linked to the occurrence of vegetation. The spatial differentiation in the structure of the bottom of the littoral zone in Lake Licheńskie is not significant, and the majority of this bottom zone is sandy or sand covered with a small quantity of organic detritus. Areas with gravel and stones occupy a very small area of the littoral zone. Water temperature, oxygen content, and pH were not factors that differed significantly among the sampling stations during the study. The only factor that was significantly different among the sampling stations was the degree to which the bottom was overgrown with vegetation. The occurrence of macrophytes in lakes in the temperate zone is seasonal. In Lake Licheńskie the dominating species of submerged vegetation is *V. spiralis*, which grows in over 90% of the shallow littoral (Hutorowicz and Dziedzic 2003). The results of the current study confirm that there is a significant dependence between the share of stone moroko in the fish groups and the occurrence of macrophytes – overwhelmingly *V. spiralis*. Increasing bottom cover with submerged vegetation corresponded to an increased share of stone moroko in the fish groups. Pollux and Korosi (2006) presented similar observations from their work in Holland; greater stone moroko frequency was noted in floodplain lakes with dense vegetation than in rivers devoid of macrophytes.

The occurrence of stone moroko has been confirmed in the inland waters of many European countries (Bianco 1988, Marković and Simović 1997, Caiola and De Sostoa 2002, Cakic et al. 2004), although some incidences of its accidental introduction have not been permanent (Copp et al. 2007). This species was first noted in the Konin lakes in 2002 (Kapusta et al. 2006) when the first specimens of it were caught in Lake Licheńskie. In subsequent years this species was noted at increasing density in this lake and it began the gradual colonization of the neighboring lakes. The dispersal of this species has occurred through the system of canals that connect the lakes. The results of catches made in the littoral zones of the Konin lakes in the 2002-2006 period (Kapusta et al. 2006) suggest that locks and cascades and other constructions as well as strong water flow hamper this species in its settlement of other lakes. Of the five lakes comprising the power plant water cooling system, stone moroko has been noted in four. Only in Lake Gosławskie, located to the west of the system and isolated by a series of locks, a pumping station and the direction of water flow in the canals, has stone moroko not been noted. As in Lake Licheńskie, in the other lakes this species prefers littoral zones overgrown with macrophytes.

Stone moroko occurred in the lake littoral zone seasonally. This phenomenon might also be explained by the occurrence of macrophytes. In April, when the littoral zone was nearly devoid of macrophytes, no stone moroko were caught. In subsequent months, however, more and more specimens of this species were caught as the submerged vegetation developed. Length analysis indicates that the majority of these were juveniles from the 2004 spawning. Only in June, did specimens from older age classes (> 0+) dominate the catches. This raises the question of which parts of Lake Licheńskie did these specimens inhabit prior to the development of submerged plants in the shallow littoral zone? Due to the lake's thermal regime (year-round water heating, no ice cover), submerged vegetation does occur in winter, but only in the deeper parts of the littoral zone (> 2 m, Hutorowicz unpublished data). Decreases in water temperature, which are most apparent in the shallow littoral zone (< 1 m), and the occurrence of submerged vegetation in the deeper zones of the lake are the likely causes for the stone moroko to change its place of occurrence. This hypothesis needs to be confirmed with the appropriate research.

The results presented here regard fish caught with selective gear; and since larval fish occurred even in September it was impossible to use any other type of gear. Bearing in mind this limitation, it is tempting to propose that stone moroko plays a significant role in the lake littoral zone. This is confirmed by the analysis of the fish groupings in the littoral zone of Lake Licheńskie. The abundant occurrence of macrophytes in the littoral zone of the lake (Hutorowicz and Dziedzic 2003), offer excellent conditions for phytophils. However, the domination in the catches of the accidentally introduced stone moroko, indicates that *V. spiralis*, an equally exotic species to Polish waters, offers particularly good conditions for *P. parva*. In 2004, it was the most abundant and most frequently occurring species. In terms of numbers, only the bleak stock matched its abundance. The consequences of the dispersal of stone moroko are not difficult to predict. The juveniles of this species are planktivorous (Hliwa et al. 2002), thus, they compete for food with other species subsequently impacting abundance. Additionally, parasites carried by alien ichthyofauna species can lead to declining abundance or even the dying out of other species in a given area (Gozlan et al. 2005, Pinder et al. 2005).

The results of the study showed that the spatial and temporal variation in the occurrence of stone moroko corresponded with the occurrence of macrophytes, and that this fish species finds good feeding and reproductive conditions in this aquatic vegetation. As the area of bottom covered with submerged vegetation increased, so too did the relative density of this fish species. The stone moroko's preferences for inhabiting littoral areas with abundant submerged vegetation suggests that the endemic species of phytophils will be under the greatest impact from *P. parva.*

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## STRESZCZENIE

### ZNACZENIE CZEBACZKA AMURSKIEGO, *PSEUDORASBORA PARVA* (TEMMINCK AND SCHLEGEL) W ZESPOLE RYB NIEWIELKICH ROZMIARÓW W LITORALU PODGRZEWANEGO JEZIORA LICHEŃSKIEGO

Celem badań było określenie sezonowych zmian liczebności czebaczka amurskiego, *Pseudorasbora parva* (Temminck and Schlegel) oraz roli tego obcego gatunku w litoralu podgrzewanego jeziora (rys. 1). W pracy podjęto próbę określenia preferencji siedliskowych oraz scharakteryzowano relacje pomiędzy względną liczebnością czebaczka amurskiego a występowaniem roślinności zanurzonej. Analizie poddano łącznie 329 osobników czebaczka amurskiego (tab. 1). Złowiono ryby należące do 14 gatunków i 2 rodzin (tab. 2, rys. 2). Stwierdzono sezonową zmienność występowania czebaczka amurskiego w litoralu jeziora (rys. 3) oraz istotną zależność pomiędzy stopniem pokrycia dna hydrofitami a jego względnym zagęszczeniem (rys. 4). Czebaczek amurski preferował siedliska obficie porośnięte roślinnością zanurzoną, a unikał siedlisk pozbawionych hydrofitów. Wraz ze wzrostem pokrycia dna hydrofitami wzrastała względna liczebność czebaczka amurskiego. Największą średnią długością całkowitą charakteryzowały się osobniki złowione w czerwcu (rys. 5). W kolejnych miesiącach średnia długość całkowita łowionych ryb była niższa, nawet jeśli w odłowach występowały osobniki o maksymalnych rozmiarach ciała większych niż w czerwcu. Zależność pomiędzy długością a masą ciała opisano za pomocą funkcji wielomianowej (rys. 6). Obfite występowanie tego gatunku w powiązaniu z dostępnością siedlisk i preferencjami pokarmowymi wskazują na duże zagrożenie dla rodzimej ichtiofauny.

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# VARIATIONS IN AGE AND LENGTH GROWTH RATES OF VENDACE, *COREGONUS ALBULA* (L.), FROM SELECTED LAKES IN WESTERN POMERANIA

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ABSTRACT. The aim of the study was to investigate the age and length growth rate of vendace, *Coregonus albula* (L.) from several of the most important commercially exploited lakes in Western Pomerania. Age and length growth rates were determined from scales using back-calculations of the Rosa Lee variant as well as mathematical growth models: Ford-Walford, von Bertalanffy, second degree polynomials, and the modified power function. Fish condition was determined based on the Fulton and Clark factors. The analysis of fish age in the individual lakes indicated that vendace from age class 2+ dominated; this was impacted by the deployment of selective gear (gill-nets with 24 mm mesh size). The most advantageous condition measured with the Fulton and Clark factors was noted in the fish from lakes Drawsko and Komorze. The growth of vendace from lakes Drawsko, Siecino, Komorze, and Pile was average, while that of the fish from Lake Kamienny Jaz was slow. Of the four mathematical models of growth rate, the best fit was obtained with the von Bertalanffy variant.

Key words: VENDACE, GROWTH, MATHEMATIC MODELS OF GROWTH, CONDITION

## INTRODUCTION

Thanks to its fast growth rate, shoaling life strategy, and high quality meat, vendace, *Coregonus albula* (L.), is one of the most valuable fish species caught in the lakes of northern Poland. It exhibits significant phenotype variation which is an indirect reflection of the particular environmental conditions in which it occurs. Gąsowska (1973) reported that each lake had a different variety of vendace that is specific to that basin. The high plasticity of the species is most apparent in its body shape and biological characters that are impacted by, among other factors, maximum depth, surface area, water transparency, and the content of oxygen and nutrients (Thienemann 1933, Kozikowska 1961, Radziej 1973). Of the 1,575 lakes (Filipiak and

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Raczyński 2000) in Western Pomerania, vendace occur in 44, while commercial catches of this species are conducted in just 23 of them (Czerniejewski and Filipiak 2001). Unfortunately, the disadvantageous oxygen conditions render the natural spawning of this species difficult or even impossible, thus necessitating the stocking of lakes with allochthonous material. Since little is known about the most important biological characters of many vendace populations, the stocking material (hatchlings or, less commonly, fry) has substantially lower biological parameters than desired, which impacts the profitability of fisheries. Bearing in mind the rational exploitation of vendace resources in various lakes, it is essential to perform detailed biological studies, especially of growth rate, on the various exploited fish populations. This prompted undertaking the current study, whose aim was to evaluate vendace age and growth rate among fish caught in economically important and morphologically and environmentally varied lakes of Western Pomerania.

## MATERIALS AND METHODS

The vendace used in the study were obtained during nighttime catches conducted with gill-nets (24 mm mesh size) in 2000-2002 in lakes Pile, Kamienny Jaz, Siecino, Drawsko, and Komorze, which all differ environmentally and morphometrically (Table 1).

**TABLE 1**

Limnological and environmental characteristics of the studied lakes

| Parameter | Lake | | | | |
|---|---|---|---|---|---|
| | Drawsko | Kamienny Jaz | Komorze | Pile | Siecino |
| Surface area (ha) | 1781.5 | 27.1 | 416.7 | 980.1 | 729.7 |
| Maximum depth (m) | 79.7 | 11.6 | 34.7 | 43.9 | 44.3 |
| Mean depth (m) | 18.6 | 5.1 | 11.8 | 11.7 | 14.3 |
| Volume (thousand $m^3$) | 331443.4 | 1382.1 | 49372.0 | 115171.4 | 1044441.7 |
| SDI* | 4.97 | 2.0 | 1.57 | 2.80 | 2.54 |
| EI* | 95.8 | 5.3 | 3.1 | 83.8 | 51.0 |
| Purity class | n.d. | II | II | u.w. | II |
| Class of susceptibility to degradation | n.d. | II | I | I | I |

*SDI – shoreline development index, EI – exposure index, u.w. – unclassified water, n.d. – no data*

A total of 503 individuals were evaluated for age, length growth rates, and weight (Table 2).

**TABLE 2**

Vendace age structure in the studied lakes

| Lake | N | Age group | | | | |
|---|---|---|---|---|---|---|
| | | 1+ | 2+ | 3+ | 4+ | 5+ |
| Drawsko | 110 | 23 | 56 | 27 | 4 | - |
| Kamienny Jaz | 80 | 1 | 72 | 7 | - | - |
| Komorze | 97 | 13 | 62 | 22 | - | - |
| Pile | 100 | 10 | 63 | 25 | 1 | 1 |
| Siecino | 116 | 18 | 72 | 26 | - | - |
| Numerical share (%) | 100 | 12.92 | 64.61 | 21.27 | 0.99 | 0.20 |

The fish caught underwent preliminary biological examination: measurements were taken of individual weight (W) (on an electric Axis scale to the nearest 0.1 g) and total length (Lt), with an electronic slide caliper coupled with a microcomputer to the nearest 0.1 mm. With the aid of the power function, this data permitted determining the dependence between total length and the weight of individual fish (Szypuła et al. 2001).

$$W = k\,L^n$$

where:

W – total fish weight - $W_1$ (g);

L – total length - Lt (mm);

k, n – constant parameters, calculated based on empirical data.

Additionally, the weight and length data was used to determine the condition of the vendace using the Fulton and Clark factors (Bolger and Connolly 1989, Ritterbusch-Nauwerck 1995).

Vendace length and weight growth rates were determined from scale readings. The scales were collected with method developed by Bernatowicz (1952). Traces of mucous were cleaned from the scales with ammoniated water and then they were prepared. Age readings and measurements of scale radii (to the nearest 0.001 mm) were done on the oral sections with a computer running MultiScan (Computer Scanning Systems II, Poland), a picture analysis program. In addition to the measurement function, this software allowed enlarging scale pictures, adjusting focus, and improving picture quality. Due to the R-L linear dependence, back-calculations were done with the Rosa Lee variant at the standard length of 30 mm (at which vendace form scales (Grudniewski

1970)). The empirical data obtained with this method were used to present the theoretical vendace length growth determined with the following: von Bertalanffy, Ford–Walford, second degree polynomial, and modified power function (Szypuła et al. 2001).

The statistical analysis of the results was performed with the Statistica (StatSoft Inc., USA). Prior to comparing the body length and condition of the vendace from different lakes, the distribution of the analyzed characteristics was tested with the Shapiro-Wilks test, while the equality of variance was tested with Levene's test (Stanisz 2000). Then ANOVA was performed to verify the hypothesis of the equality of means, and the ad hoc Duncan's test was used.

## RESULTS

Most of the vendace caught belonged to age groups 2+ (64.6%) and 3+ (21.3%), while the least were of age groups 4+ and 5+ (Table 2). Although fish from age class 2+ clearly dominated, significant differences were noted in the mean total lengths and median lengths of the studied populations (ANOVA, P < 0.05, Table 3).

**TABLE 3**

Length and condition characteristics of vendace from the studied lakes

| Lake | Length characteristics | | Condition factors | |
|---|---|---|---|---|
| | Total length (cm) | Range | Fulton | Clark |
| Drawsko | $22.78 \pm 1.72^{a}$ | 19.72-28.49 | $0.84^{a}$ | $0.75^{a}$ |
| Kamienny Jaz | $18.81 \pm 1.45^{c}$ | 16.71-24.36 | $0.82^{b}$ | $0.60^{c}$ |
| Komorze | $20.49 \pm 1.06^{b}$ | 17.87-23.80 | $0.85^{a}$ | $0.76^{a}$ |
| Pile | $20.57 \pm 1.05^{b}$ | 17.90-24.02 | $0.81^{b}$ | $0.72^{b}$ |
| Siecino | $19.60 \pm 0.77^{b}$ | 18.05-21.06 | $0.81^{b}$ | $0.69^{b}$ |

*Values with the same letter superscript in the same column do not differ significantly statistically (P > 0.05)*

The highest values of these parameters were noted in the fish from Lake Drawsko (22.78 and 22.37 cm, respectively), while the lowest were for the fish from Lake Kamienny Jaz (18.81 and 18.42 cm, respectively). Vendace achieve the greatest growth during the first year of life, after which the growth rate slowed (Table 4). The fastest growth in the first year was observed in fish from Lake Drawsko (130.9 mm), and the slowest in those from Lake Kamienny Jaz (115.8 mm).

**TABLE 4**

Growth rate of vendace from the studied lakes by age group determined with the back-calculation method

| Age group (individuals) | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ |
|---|---|---|---|---|---|
| Pile | | | | | |
| I (10) | 13.22 | | | | |
| II (63) | 12.12 | 17.76 | | | |
| III (25) | 11.36 | 16.15 | 19.16 | | |
| IV (1) | 10.33 | 15.37 | 19.67 | 21.88 | |
| V (1) | 10.39 | 14.95 | 17.72 | 20.09 | 22.05 |
| Mean | 12.01 | 17.25 | 19.12 | 20.98 | 22.05 |
| Length growth | 12.01 | 5.25 | 1.87 | 1.86 | 1.07 |
| Kamienny Jaz | | | | | |
| I (1) | 11.32 | | | | |
| II (72) | 11.51 | 15.86 | | | |
| III (7) | 12.28 | 17.28 | 19.92 | | |
| Mean | 11.58 | 15.98 | 19.92 | | |
| Length growth | 11.58 | 4.41 | 3.94 | | |
| Siecino | | | | | |
| I (18) | 13.60 | | | | |
| II (72) | 13.13 | 17.34 | | | |
| III (26) | 12.51 | 17.22 | 19.54 | | |
| Mean | 13.06 | 17.31 | 19.54 | | |
| Length growth | 13.06 | 4.25 | 2.26 | | |
| Drawsko | | | | | |
| I (23) | 15.22 | | | | |
| II (56) | 12.83 | 18.64 | | | |
| III (27) | 12.17 | 17.80 | 21.45 | | |
| IV (4) | 10.63 | 16.41 | 20.40 | 23.48 | |
| Mean | 13.09 | 18.28 | 21.32 | 23.48 | |
| Length growth | 13.09 | 5.19 | 3.04 | 2.16 | |
| Komorze | | | | | |
| I (13) | 14.19 | | | | |
| II (62) | 12.45 | 17.56 | | | |
| III (22) | 11.68 | 16.44 | 19.31 | | |
| Mean | 12.51 | 17.26 | 19.31 | | |
| Length growth | 12.51 | 4.76 | 2.05 | | |

Of the mathematical models of growth applied, the von Bertalanffy model best fit the back-calculated scale readings (Table 5). The comparison of fish growth determined with back-calculations and the von Bertalanffy model indicated that in lakes

TABLE 5

Comparison of vendace growth rates in different lakes determined with various methods

| Age (year) | Method: Back-calculations (1) | Ford-Walford (2) | von Bertalanffy (3) | Second degree polynomials (4) | Modified power function (5) | [1-2] | [1-3] | [1-4] | [1-5] |
|---|---|---|---|---|---|---|---|---|---|
| Pile | | | | | | | | | |
| 1 | 12.01 | 11.83 | 11.28 | 12.72 | 11.89 | 0.24 | 0.79 | 0.65 | 0.18 |
| 2 | 17.25 | 17.33 | 16.85 | 16.29 | 17.31 | 0.08 | 0.40 | 0.96 | 0.06 |
| 3 | 19.12 | 19.89 | 19.71 | 19.07 | 19.58 | 0.77 | 0.59 | 0.05 | 0.46 |
| 4 | 20.98 | 21.08 | 21.18 | 21.06 | 20.88 | 0.10 | 0.20 | 0.08 | 0.10 |
| 5 | 22.05 | 21.63 | 21.93 | 22.26 | 21.75 | 0.42 | 0.12 | 0.21 | 0.30 |
| | Mean absolute difference | | | | | 0.32 | 0.42 | 0.39 | 0.22 |
| Kamienny Jaz | | | | | | | | | |
| 1 | 11.58 | 11.30 | 11.58 | 11.68 | 11.64 | 0.28 | 0.00 | 0.10 | 0.06 |
| 2 | 15.98 | 16.87 | 15.98 | 15.86 | 16.16 | 0.89 | 0.00 | 0.12 | 0.18 |
| 3 | 19.92 | 19.62 | 19.92 | 19.95 | 20.07 | 0.30 | 0.00 | 0.03 | 0.15 |
| | Mean absolute difference | | | | | 0.49 | 0.00 | 0.08 | 0.13 |
| Siecino | | | | | | | | | |
| 1 | 13.06 | 12.96 | 13.06 | 13.24 | 13.00 | 0.10 | 0.00 | 0.18 | 0.06 |
| 2 | 17.31 | 17.66 | 17.31 | 17.07 | 17.51 | 0.35 | 0.00 | 0.24 | 0.20 |
| 3 | 19.54 | 19.37 | 19.54 | 19.62 | 19.40 | 0.17 | 0.00 | 0.08 | 0.14 |
| | Mean absolute difference | | | | | 0.21 | 0.00 | 0.17 | 0.13 |
| Drawsko | | | | | | | | | |
| 1 | 13.09 | 12.79 | 13.08 | 13.14 | 12.94 | 0.30 | 0.01 | 0.05 | 0.15 |
| 2 | 18.28 | 18.86 | 18.21 | 18.09 | 18.57 | 0.58 | 0.07 | 0.19 | 0.29 |
| 3 | 21.32 | 21.74 | 21.43 | 21.51 | 21.41 | 0.42 | 0.11 | 0.19 | 0.09 |
| 4 | 23.48 | 23.11 | 23.45 | 23.42 | 23.25 | 0.37 | 0.03 | 0.06 | 0.23 |
| | Mean absolute difference | | | | | 0.42 | 0.06 | 0.12 | 0.19 |
| Komorze | | | | | | | | | |
| 1 | 12.51 | 12.48 | 12.51 | 12.67 | 12.45 | 0.03 | 0.00 | 0.16 | 0.06 |
| 2 | 17.26 | 17.36 | 17.26 | 17.04 | 17.51 | 0.10 | 0.00 | 0.22 | 0.25 |
| 3 | 19.31 | 19.27 | 19.31 | 19.38 | 19.12 | 0.04 | 0.00 | 0.07 | 0.19 |
| | Mean absolute difference | | | | | 0.06 | 0.00 | 0.15 | 0.17 |

Kamienny Jaz, Siecino, and Komorze the mean average absolute difference was 0.00 cm, while in Lake Pile it was 0.42 cm, and in Lake Drawsko it was barely 0.06 cm. All of the other models fit the back-calculated data quite well; the Ford-Walford model exhibited the worst fit, although the mean absolute values ranged from 0.06 to 0.49 cm (Table 5). The values of the parameters calculated for the other models are in Table 6.

**TABLE 6**

Values of the parameters of the various mathematical models of growth

| Model | Parameter | Lake | | | | |
|---|---|---|---|---|---|---|
| | | Drawsko | Kamienny Jaz | Komorze | Pile | Siecino |
| Ford-Walford | $l_1$ | 12.7898 | 11.2973 | 12.4793 | 11.8315 | 12.9637 |
| | k | 0.4747 | 0.4930 | 0.3911 | 0.4650 | 0.3628 |
| Von Bertalanffy | $l_\infty$ | 26.8455 | 53.6670 | 20.8665 | 22.7266 | 22.0018 |
| | K | 0.4662 | 0.1104 | 0.8403 | 0.6668 | 0.6449 |
| | $t_0$ | -0.4324 | -1.2020 | -0.0890 | -0.0282 | -0.3962 |
| Second degree polynomial | a | 6.6800 | 7.4027 | 6.2816 | 8.3750 | 8.1041 |
| | b | 7.2240 | 4.3269 | 7.3970 | 4.7421 | 5.7802 |
| | c | -0.7600 | -0.0485 | -1.0098 | -0.3929 | -0.6476 |
| Modified power function | A | -33.1754 | 6.8892 | -9.6408 | -15.9488 | -13.4077 |
| | B | -0.2683 | 0.7277 | -1.0724 | -0.5983 | -0.5906 |
| | C | 46.1170 | 4.7497 | 22.0910 | 27.8413 | 26.4096 |

The vendace in lakes Drawsko and Komorze had statistically significantly higher Fulton and Clark condition factors values in comparison to those of the fish from the other lakes (Table 3). This is also confirmed by the L-W dependence determined, where distinctly faster weight growth was noted in the fish from Lake Drawsko (Fig. 1).

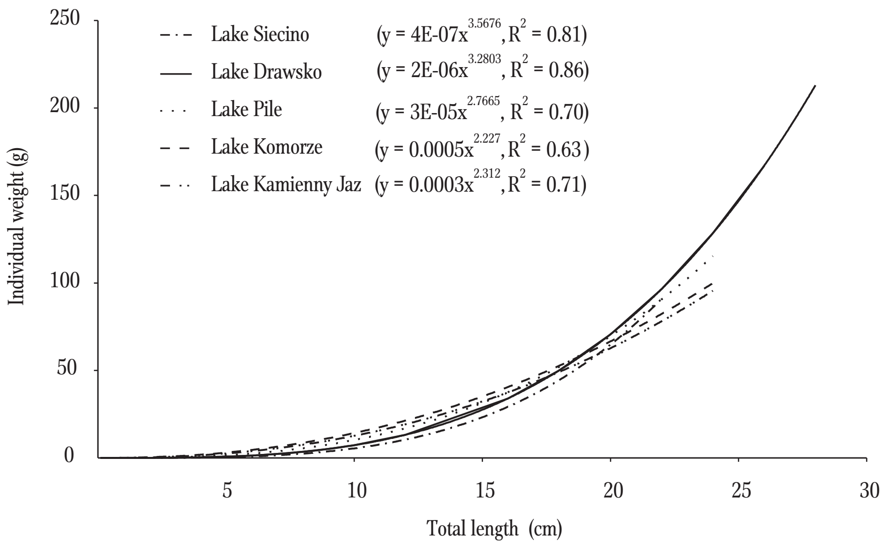


Fig. 1. Dependence between total length and individual weight of vendace from the studied lakes.

It should be emphasized that among the five vendace populations analyzed, only in lakes Siecino and Drawsko did parameter "n" of the power function reach a level above 3.0. However, the highest parameter "k" value was noted in the fish from lakes Komorze and Kamienny Jaz (0.0005 and 0.0003, respectively). In the other lakes the value of "k" was less than 0.00001. Among the studied vendace populations, growth in the first years of life can be considered to be average, and in the case of individuals from Lake Kamienny Jaz as slow (Fig. 2).

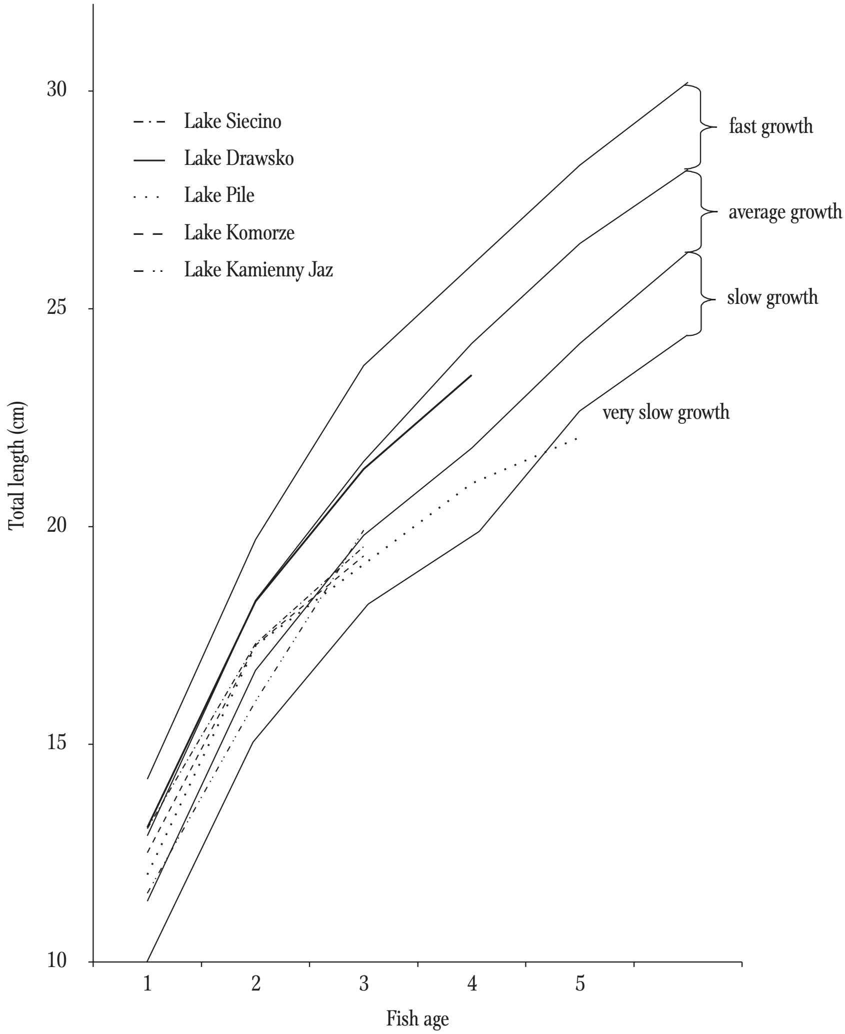


Fig. 2. Evaluation of growth rate of the studied vendace populations (according to the Szczerbowski scale (1978)).

## DISCUSSION

Vendace catches in the lakes of Western Pomerania are most frequently performed with gill-nets with a mesh bar length of 24 mm, and less frequently with hauled gear (Czerniejewski and Wawrzyniak 2006). The deployment of these selective gears permits catching fish measuring from 17.8 to 24.2 cm, and the length of fish caught at maximum effectiveness is 21.0 cm (Ciepielewski 1974). This explains the relatively high continuity of total length and individual weight of the fish obtained from the analyzed populations.

Generally, vendace are pelagic fish with a relatively short life cycle, and commercial catches are comprised in 80-90% of age classes 1+ to 3+ (Viljanen 1988, Christianus 1995, Czerniejewski and Filipiak 2002). However, as suggested by Leopold (1970), in light of the short life of the vendace, maximum fishing pressure should be directed at individuals from age class 2+. In accordance with this, catches of this species in lakes Drawsko, Kamienny Jaz, Komorze, Pile, and Siecino were performed with gill-nets with a mesh bar length of 24 mm, which permitted catching fish from this age group in respective quantities of 11.13, 14.31, 12.33, 12.52, and 14.31% of all the vendace caught. The high percentage of year class 2+ in the catches stems from the fact that vendace growth intensity is the highest in the first three years of life (Bernatowicz et al. 1975). While planning catches, however, it must be remembered that if there are changes in fish growth rates, conducting catches with the same fishing gear or halting fisheries exploitation in a given basin can lead to the aging of the exploited segment of the population (Ciepielewski 1974, Winfield et al. 1996).

The growth rate of vendace varies significantly among lakes. Viljanen (1988) maintains that as latitude increases the length of vendace caught in subsequent years of life clearly diminishes, which is probably the result of lower production in these lakes. Bauch (1961) also suggests that specific environmental conditions play a decisive role in vendace growth, and the highest growth and maximum age are noted in lakes that are rich in crustaceous zooplankton. This is confirmed by the results of studies by Radziej (1973), who stocked Lake Wierzbiczany (maximum depth – 21.6 m, good oxygen and food conditions) with vendace that originated from a slow-growing population from the Mazurian Lake Narie. The first generation of vendace from the stocked basin exhibited faster growth than the population from Lake Narie. In addition to the abundance of zooplankton, growth was also influenced by the size of the lake (Marciak

1970), its depth, water transparency and oxygenation during the summer stagnation period (Bernatowicz et al. 1975), and population abundance. Generalizing, Christianus (1995) maintains that the highest growth rate is usually confirmed in vendace that occur in small basins (28-120 ha) with depths of 21.0 to 42.5 m and good water transparency. In order to evaluate precisely the growth rate of the analyzed populations in Western Pomerania lakes, the criteria proposed by Szczerbowski (1978) were used. Among the five vendace populations studied, individuals from Lake Kamienny Jaz had the slowest growth rate, while that of the other populations was average. The short lengths achieved by the vendace from Lake Kamienny Jaz in subsequent years of life probably resulted from the unstable and disadvantageous hydrochemical conditions prevailing in the summer period when the highest vendace growth is noted. To date, the most commonly applied method for calculating vendace length growth rate has been the von Bertalanffy method (Sandlund 1992, Czerniejewski and Czerniawski 2004). Taking into consideration the calculations made with several mathematical models of growth for the current study, it was confirmed that the von Bertalanffy method was indeed optimal since in three cases the results obtained fully conferred with the data obtained from scale readings and back-calculations (Table 5).

An important element of the study of various fish populations is estimating the condition of individuals. Bolgier and Connolly (1989) reported that the analysis of the degree to which fish feed can be done with the dependency function between length and body weight (Winfield et al. 1996) and the Fulton, Clark, and Le Cren mathematical formulas (Ritterbusch-Nauwerck 1995). The dependency between fish length and weight is usually of a power function character. The value of the exponent of this function depends, among other factors, on fish body shape; in “slimmer” fish it is below 3, while in “stouter” fish it is higher (Wootton 1996). In vendace the value of this parameter is about 3 (Sandlund 1992, Christianus 1995, Czerniejewski and Filipiak 2002), which indicates growth in this species is isometric. In some lakes that are rich in crustaceous zooplankton, this parameter reaches a value of almost 3.5 (Winfield et al. 1996); however, in lakes that have disadvantageous environmental conditions for vendace, the value of this power exponent falls to below 2.5 (Czerniejewski and Flipiak 2002) The mean value of parameter “n” of the dependence of length-weight of the studied vendace from lakes Drawsko, Siecino, and Kamienny Jaz had similar values to the data reported by the authors cited previously. However, in the fish from lakes Komorze and Kamienny Jaz, the value of this was fairly low (2.23 and 2.31, respectively), which indicates that in these two basins the environmental conditions were less advantageous than those in the other lakes.

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## STRESZCZENIE

### ZRÓŻNICOWANIE WIEKU, TEMPA WZROSTU DŁUGOŚCI I MASY CIAŁA SIELAWY, *COREGONUS ALBULA* (L.) Z WYBRANYCH JEZIOR POMORZA ZACHODNIEGO

Celem pracy była analiza wieku, kondycji i tempa wzrostu długości sielawy, *Coregonus albula* (L.) z jezior różniących się warunkami środowiskowymi (tab. 1). Wykonano pomiary długości całkowitej, masy jednostkowej, określono płeć oraz przeprowadzono analizę wieku i wzrostu sielawy metodą odczytów wstecznych oraz matematycznych modeli wzrostu: Forda-Walforda, von Bertalanfy'ego, wielomianu II stopnia i zmodyfikowanej funkcji potęgowej. Dodatkowo oceniono kondycję ryb na podstawie współczynników Fultona i Clarka oraz wykreślono zależność między długością a masą ryb.

W poszczególnych jeziorach zanotowano podobną strukturę wieku ryb, z wyraźną dominacją sielaw w wieku 2+ (tab. 2). Fakt ten wynika z dużej selektywności wontonów o średnicy oczka 24 mm, którymi złowiono ryby. Populacje sielawy z jezior: Drawsko, Komorze, Siecino i Pile charakteryzowały się przeciętnym tempem wzrostu, natomiast w jeziorze Kamienny Jaz wzrostem wolnym (tab. 4, rys. 1). Najbardziej dopasowanym modelem wzrostu w stosunku do odczytów wstecznych okazał się model von Bertalanfy'ego, natomiast najmniej dopasowany był model Forda-Walforda (tab. 5). Najwyższą kondycją charakteryzowały się ryby z jeziora Drawsko i Komorze. Średnia wartość współczynnika kondycji Fultona i Clarka dla sielaw z pierwszego jeziora wyniosłya odpowiednio 0,84 oraz 0,75, natomiast dla jeziora Komorze 0,85 oraz 0,76.

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# METAZOAN PARASITE FAUNA OF FISH SPECIES FROM LAKE KORTOWSKIE

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ABSTRACT. Parasitological studies of fish from Lake Kortowskie were carried out from 2001 to 2004. In the current study, 381 fish representing ten species: perch, *Perca fluviatilis* L., bleak, *Alburnus alburnus* (L.), ruffe, *Gymnocephalus cernuus* (L.), silver bream, *Abramis bjoercna* (L.), pike, *Esox lucius* L., common gudgeon, *Gobio gobio* (L.), tench, *Tinca tinca* (L.), rudd, *Scardinius erythrophthalmus* (L.), bream, *Abramis brama* (L.) and roach, *Rutilus rutilus* (L.) were examined. The aim of the study was to review the parasites of selected fish species and to compare the infestation of bream, perch, and rudd in 1984-88, 1994 and 2001-2003. A total of 51 species of parasites belonging to Monogenea (27), Digenea (6), Cestoda (7), Nematoda (4), Acanthocephala (3), Crustacea (3), and Molusca (1) were recorded. The largest numbers of parasite species were found in roach (18), followed by bleak (14), perch and silver bream (13), bream (11), ruffe and pike (10), and the fewest in common gudgeon (4) and tench and rudd (2). *Tetraonchus monenteron*, *Triaenophorus nodulosus*, *Ergasilus sieboldi*, and molluscs glochidia occurred in 83.3% of the pike. Comparing the bream, perch, and rudd infestation parameters of over twenty years with the current results, it can be concluded that the changes are linked to environmental changes that have occurred as a consequence of the Lake Kortowskie experiment.

Key words: METAZOAN PARASITE, FISH, LAKE KORTOWSKIE

## INTRODUCTION

Metazoan parasites have a harmful effect on both fish health and fisheries. Fish production is affected and fish diseases become serious problem. However, specific species of parasitofauna in fishes from Lake Kortowskie can be used as bioindicators that provide information about the condition of the environment.

Lake Kortowskie is located within the city limits of Olsztyn, and is a bream lake (Waluga and Chmielewski 1996). Its surface area is 90.4 ha, the maximum depth is 17.2 m, and the average depth is 6.4 m (Jańczak et al. 1999). This is a eutrophic lake, and, since 1959, it has been purified; waters from the hypolimnion have been removed by a special pipeline to the Kortówka River. This experiment has been continued up to the present. In

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Lake Kortowskie, 86.6% of the fish population are bream, *Abramis brama* (L.) (23.6%), roach, *Rutilus rutilus* (L.) (22.6%), perch, *Perca fluviatilis* L. (20.3%), and pike, *Esox lucius* L. (20.2%). The share of the remaining 22 species is about 13.4% (Kozłowski pers. inf). This lake is not subject to fisheries exploitation. Only a few parasitological studies have been conducted in this lake: on bream in 1984 (Kukliński 1984, 1994, Dzika 2002), on perch in 1988 (Król and Ochendowski 1988), and on rudd, *Scardinius erythrophthalmus* (L.) in 1984 (Własow et al. 1991). The current study had two objectives: first, to determine the prevalence and intensity of Metazoan parasites in bream, perch, and rudd from Lake Kortowskie; second, to compare current data with relevant data reported in earlier papers.

## MATERIAL AND METHODS

Fish were examined in 2001-2004 in April, May, and June. The study examined a total of 381 fishes, representing ten species (Table 1). Parasitological research included skin, heart, fins, gills, eyes, alimentary tract, liver, spleen, kidney, gall bladder, swim bladder, and brain. Preparations of parasites were made by general methods used in parasitology (Lonc and Złotorzycka 1995). The parasites were identified according to keys by Gusev (1985), Bauer (1987), Pojmańska (1991), and Niewiadomska (2003). Dominant, common, rare, and sporadic species were calculated according to Pojmańska et al. (1980).

**TABLE 1**

Characteristic of the studied fish

| Species | N | Infested fishes (%) | Lenght range (cm) | Weight range (g) |
|---|---|---|---|---|
| *Abramis bjoercna* (L.) | 76 | 72.4 | 10 - 21 | 8.4 - 122.1 |
| *Rutilus rutilus* (L.) | 66 | 89.4 | 11 - 21 | 12.0 - 98.6 |
| *Perca fluviatilis* L. | 56 | 85.7 | 7 - 31 | 3.7 - 554.8 |
| *Gymnocephalus cernuus* (L.) | 55 | 100.0 | 9 - 14 | 6.7 - 25.9 |
| *Abramis brama* (L.) | 48 | 25.0 | 11 - 33 | 10.3 - 399.6 |
| *Alburnus alburnus* (L.) | 46 | 87.0 | 11 - 15 | 7.6 - 21.3 |
| *Gobio gobio* (L.) | 13 | 76.9 | 5 - 13 | 7.5 - 21.6 |
| *Scardinius erythrophthalmus* (L.) | 10 | 60.0 | 11 - 13 | 15.3 - 31.4 |
| *Esox lucius* L. | 6 | 100.0 | 40 - 50 | 462.2 - 933.7 |
| *Tinca tinca* (L.) | 5 | 100.0 | 9 - 12 | 9.6 - 27.4 |

## RESULTS

A total of 51 parasite species were recorded from the fish necropsies. The parasites represented seven higher taxa: Monogenea (27 species), Digenea (6), Cestoda (7), Nematoda (4), Acanthocephala (3), Crustacea (3), and Mollusca (1). The lowest numbers of parasite species were recorded in gudgeon, *Gobio gobio* (L.), tench, *Tinca tinca* (L.) and rudd (Table 2). The parasite fauna of roach from this lake was definitely the most abundant (18 species). Of the 11 Monogenea species found on gills, *Dactylogyrus caballeroi*, *D. crucifer* (18.5%), *Paradiplozoon megan* (23.1%), and *P.h. homoion* (20.5%) were the most abundant. The remaining species were found sporadically. Metacercariae of *Diplostomum* sp., (28.2%), *Tylodelphys clavata* (43.6%), tapeworm *Paradilepis scolecina* (25.6%), and copepods *Caligus lacustris* (10.2%) occurred commonly. Gills hosted *Ergasilus sieboldi*, *Postodiplostomum cuticula* (mc.), and molluscs glochidia were found on the fins.

The parasite fauna of bleak, *Alburnus alburnus* (L.) from Lake Kortowskie was represented by 14 species. Monogenea were represented by 7 species. The specialist species *D. parvus* (11.9%) occurred commonly on gills, but the remaining species occurred rarely and sporadically. Metacercariae of *Diplostomum* sp. (9.5%) were found in eye lenses. Tapeworms *P. scolecina* (45.2%) were the most numerous in the examined material (713 specimens were found in bleak livers). One specimen of *Proteocephalus* sp. was found in the intestine of one fish. *Caligus lacustris*, *Argulus foliaceus*, and *Glochidium* occurred on fins, and *E. sieboldi* was noted on gills.

In the case of perch, 13 parasite species were recorded. Metacercariae of *Diplostomum* sp. were found in the eye lens of one fish only, while *T. clavata* (33.9%) occurred most abundantly (518 specimens were found). Tapeworms *Proteocephalus percae* (248 specimens) and plerocercoids of *Triaenophorus nodulosus* (12 specimens) were found in the intestine and liver. *Camallanus lacustris* occurred rarely in the intestine, and one *Desmidocercella numidica* larvae was found in the vitreous humour of the eye of one fish. *A. anguillae* was numerous and 159 specimens were found in intestines. Copepods *E. sieboldi*, *Caligus lacustris*, and *Argulus foliaceus* were found on gills and fins, while molluscs glochidia (63 specimens) were found on fins.

In silver bream, *Abramis bjoercna* (L.) 13 species of parasites were found. Monogenea were represented by 6 species. Monogenean worms occurred rarely and sporadically on the gills of fish. The metacercariae of *Diplostomum* sp. were the most prevalent (52.6%) and abundant (mean intensity 19.92) In eye lenses, 797 specimens were found. The remaining parasites, metacercariae digenean flukes, tapeworms, and copepods, settled in different organs of the fish and occurred rarely and sporadically.

All of the ruffe, *Gymnocephalus cernuus* (L.) (55 specimens) examined were infected with parasites. A total of ten species of parasite were noted. *Dactylogyrus amphibotrium* occurred commonly on gills (34.5%). The most prevalent were metacercariae of *Diplostomum* sp. (76.5%) and *Tylodelphys clavata* (70.9%). Metacercariae of *Ichthyocotylurus platycephalus* (12.7%) were found in the heart, while *Proteocephalus percae* (69.1%), one specimen of nematode (1.8%), *Acanthocephalus anguillae* (43.6%), and *A. lucii* (5.5%) were noted in the alimentary tract. The copepod *Ergasilus sieboldi* (45.4%) occurred commonly and molluscs glochidia (1.8%) sporadically. In total, this fish hosted 1205 specimens of countable parasites, of which 515 were *Tylodelphys clavata*.

All of the pike, *Esox lucius* L. (6) examined were infected with parasites. The gills were infected by *Tetraonchus monenteron* and *Ergasilus sieboldi*. The intestine hosted *Triaenophorus nodulosus* and *Raphidascaris acus*, and the fins hosted molluscs glochidia. These were the most prevalent parasite in the present study. The prevalence of infection was 83.3% for *Tetraonchus monenteron, Ergasilus sieboldi*, glochidia larvae and 50% for *Raphidascaris acus*. The remaining parasites, *Diplostomum* sp., *Tylodelphys clavata, Argulus foliaceus,* and *Caligus lacustris*, occurred less than abundantly. Adult 2 specimens of *Azygia lucii* were found in branchial chamber. In total, the fish hosted 691 specimens of parasites, of which there were 124 specimens of *Tetraonchus monenteron*, 219 specimens of *Ergasilus sieboldi*, and 138 specimens of *Triaenophorus nodulosus*.

Twelve specimens of bream were infected with eleven species of parasites. Five monogenetic worms occurred rarely and sporadically on bream gills. Digenetic flukes were represented by the metacercariae of *Diplostomum* sp., *Tylodelphys clavata*, and *Posthodiplostomum cuticola*. *Caryophyllaeus laticeps* was prevalent in the intestine (58.3%), and *Paradilepis scolecina* occurred rarely in the liver. In total, 333 parasites were collected (Table 2).

**TABLE 2**

Parasites of fish in Lake Kortowskie and basic infection parameters (2001-2004)

| | Perch n=56 | | Bleak n=46 | | Ruffe n=55 | | Silver bream n=76 | | Pike n=6 | | Gudgeon n=13 | | Tench n=5 | | Rudd n=10 | | Bream n=12 | | Roach n=66 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parasite species | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | No of para-sites |
| *Dactylogyrus amphibotrium* | | | | | 34.54 | 2.10 | | | | | | | | | | | | | | | 40 |
| *D. auriculatus* | | | | | | | | | | | | | | | | | 2.77 | 4 | | | 4 |
| *D. caballeroi* | | | | | | | | | | | | | | | | | | | 18.52 | 4.2 | 210 |
| *D. cornoides* | | | | | | | 2.63 | 2.5 | | | | | | | | | | | | | 5 |
| *D. cornu* | | | | | | | 1.31 | 2 | | | | | | | | | | | | | 2 |
| *D. crucifer* | | | | | | | | | | | | | | | | | | | 18.52 | 5.2 | 260 |
| *D. difformis* | | | | | | | | | | | | | | | | | | | 3.7 | 2 | 2 |
| *D.distinguendus* | | | | | | | 5.26 | 1.25 | | | | | | | | | | | | | 5 |
| *D. falcatus* | | | | | | | | | | | | | | | | | 5.55 | 1 | | | 2 |
| *D. fallax* | | | 2.4 | 1 | | | | | | | | | | | | | | | 3.7 | 1 | 2 |
| *D. fraternus* | | | 7.76 | 1 | | | | | | | | | | | | | | | | | 2 |
| *D. minor* | | | 4.76 | 1.5 | | | | | | | | | | | | | | | | | 17 |
| *D. nanus* | | | | | | | | | | | | | | | | | | | 3.7 | 1 | 1 |
| *D. parvus* | | | 11.9 | 3.4 | | | | | | | | | | | | | | | | | 17 |
| *D. similis* | | | | | | | | | | | | | | | | | | | 11.11 | 1.33 | 4 |
| *D. sphyrna* | | | | | | | 5.26 | 4.5 | | | | | | | | | | | | | 26 |
| *D. suecicus* | | | | | | | | | | | | | | | | | | | 3.7 | 4 | 4 |
| *D. wunderi* | | | | | | | | | | | | | | | | | 5.55 | 4.5 | | | 9 |
| *D. zandti* | | | | | | | | | | | | | | | | | 11.11 | 4 | | | 16 |
| *Gyrodactylus arcuatus* | | | 2.4 | 2 | | | | | | | | | | | | | | | | | 2 |
| *G. decorus* | | | | | | | | | | | | | | | | | | | 3.7 | 4 | 4 |
| *G. elegans* | | | | | | | 5.26 | 5.25 | | | | | | | | | 8.36 | 7.66 | | | 44 |
| *G. laevis* | | | | | | | | | | | | | | | | | | | 3.7 | 1 | 1 |
| *Paradiplozoon bliccae* | | | | | | | 1.31 | 2 | | | | | | | | | | | | | 2 |
| *P. homoin* | | | 9.52 | 1 | | | | | | | 23.07 | 2.33 | | | | | | | 20.51 | 1 | 11 |
| *P. megan* | | | 4.16 | 1 | | | | | | | 7.69 | 1 | | | | | | | 23.07 | 1 | |
| *Tetraonchus monenteron* | | | | | | | | | 83.33 | 24.8 | | | | | | | | | | | 124 |

**Cont. TABLE 2**

Parasites of fish in Lake Kortowskie and basic infection parameters (2001-2004)

| | Perch n=56 | | Bleak n=46 | | Ruffe n=55 | | Silver bream n=76 | | Pike n=6 | | Gudgeon n=13 | | Tench n=5 | | Rudd n=10 | | Bream n=12 | | Roach n=66 | | No of para- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parasite species | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | P(%) | Int. mean | sites |
| *Diplostomum* sp. (mc.) | 1.78 | 13 | 9.52 | 1 | 76.54 | 8.68 | 52.63 | 19.92 | 33.33 | 2 | | | | | 60 | 2.66 | 41.66 | 34 | 28.20 | 11.54 | 1489 |
| *Tylodelphys clavata* (mc.) | 33.92 | 26 | | | 70.90 | 13.35 | 18.42 | 4.85 | 50 | 15.33 | | | | | | | 33.33 | 5.25 | 43.58 | 18.11 | 1482 |
| *Ichthyocotylurus platycephalus* met. | | | | | 12.72 | 8.14 | | | | | | | | | | | | | | | 57 |
| *Posthodiplostomum cuticula* (mc.) | | | | | | | | | | | | | | | | | 8.33 | 1 | 2.56 | 1 | 2 |
| *Rhipidocotyle campanula* (mc.) | | | | | | | 9.21 | 1.86 | | | | | | | | | | | | | 13 |
| *Azygia lucii* | | | | | | | | | 16.66 | 1 | | | | | | | | | | | 2 |
| *Paradilepis scolecina* (pler.) | | | 45.23 | 37.52 | | | 6.57 | 10 | | | 15.38 | 5.5 | | | | | 8.33 | 10 | 25.64 | 16.8 | 1042 |
| *Triaenophorus nodulosus* (pler.) | 5.36 | 4 | | | | | | | | | | | | | | | | | | | 12 |
| *Triaenophorus nodulosus* | | | | | | | | | 83.33 | 27.6 | | | | | | | | | | | 138 |
| *Caryophylloides fennica* | | | | | | | 1.32 | 2 | | | | | | | | | | | | | 2 |
| *Caryopyllaeus laticeps* | | | | | | | | | | | | | | | | | 58.33 | 12 | | | 84 |
| *Proteocephalus percae* | 44.64 | 9.92 | | | 69.09 | 3.97 | | | | | | | | | | | | | | | 399 |
| *Proteocephalus* sp. | | | 2.4 | 1 | | | | | | | | | | | | | | | | | 1 |
| *Desmidocercella numidica* (lar.) | 1.78 | 1 | | | | | | | | | | | | | | | | | | | 1 |
| *Camallanus lacustris* | 7.32 | 3.25 | | | | | | | | | | | | | | | | | | | 13 |
| *Rhapidascaris acus* | | | | | | | | | 50 | 1.33 | | | | | | | | | | | 4 |
| Nematoda sp. | | | | | 1.81 | 1 | | | | | | | | | | | | | | | 1 |
| *Acanthocephalus anguillae* | 23.21 | 12.23 | | | 43.63 | 1.45 | | | | | | | 20 | 1 | | | | | | | 196 |
| *A. lucii* | 3.57 | 2 | | | 5.45 | 1.33 | | | | | | | | | | | | | | | 6 |
| *Acanthocephalus* sp. | 3.57 | 2 | | | | | | | | | | | | | | | | | | | 2 |
| *Argulus foliaceus* | 3.57 | 1 | 2.38 | 1 | | | | | 16.66 | 8 | | | | | | | | | | | 11 |
| *Caligus lacustris* | 7.14 | 1 | 28.3 | 1.4 | | | 7.86 | 1.16 | 16.66 | 1 | | | | | 10 | 2 | | | 10.25 | 3.75 | 43 |
| *Ergasilus sieboldi* | 17.86 | 4.4 | 4.76 | 1 | 45.45 | 2.32 | 6.57 | 1 | 83.33 | 43.8 | 7.69 | 1 | 80 | 8.5 | | | 16.66 | 2 | 5.12 | 1 | 367 |
| *Glochidium* | 25 | 4.5 | 7.14 | 1 | 1.81 | 3.0 | | | 83.33 | 14.2 | | | | | | | | | 5.12 | 1 | 142 |

*n- no of fish examined*
*P- prevalence (%)*
*Int. mean – mean intensity*

## DISCUSSION

Of the 51 parasite species found in Lake Kortowskie, the Monogenea, which are highly specific for particular host species, occurred on the gills and fins of the examined fish and formed a very large group (27 species). Among the factors impacting the presence of these parasites, water temperature is of major importance. According to Dzika and Dubas (1988), species of *Dactylogyrus* react to changes in temperature; rapid increases of water temperature increases their reproductive activity and their expansion on the host, while a sudden drop in temperature inhibits reproduction. This corresponds with the results of the present study as samples were collected only during the spring months (April, May, June). On the other hand, increasing water temperature increases the resistance of fish to these parasites, which could be a mechanism reducing the numbers of parasites on individual host specimens during the summer and fall (Dzika 1987).

Of the ten fish species from Lake Kortowskie examined in the present study, previous studies focused on bream, perch, and rudd. During 1984 and 1994, the parasites of bream were studied by Kukliński (1984) and Dzika (2002) (Table 3). In 1984 and 1994, 14 species of parasites (excluding Protozoa) were recorded. From among five species of Monogenea found in the present study, in 1994 three (*Dactylogyrus auriculatus, D. wunderi, D. zandti*) and additionally *Gyrodactylus* sp. were found. In 1984, however, only *Gyrodactylus* sp. was noted. During all three periods of study, the eye digenean flukes *Tylodelphys clavata* and *Diplostomum* sp. were found. The extensity of infection with *Diplostomum* sp. in 1984 and 1994 was similar at 88% and 90.9%, respectively, while in the current study it decreased by half to 41.7%. The prevalence of occurrence of *Tylodelphys clavata* changed from 15.0% in 1984 to 67.2% in 1994 and then 33.3% during the 2001-2003 period. While *Paracenogoninus ovatus* (mc.), *Posthodiplostomum cuticola* (mc.), *Sanguinicola* sp. (ova), and *Sphaerostomum maius* were noted in 1984, they were not present in 1994. During the current study, only metacercariae of *Posthodiplostomum cuticola* were present and its prevalence increased eightfold. In 1994, *Ichthyocotylurus platycephalus* (mc.) and *Phyllodistomum elongatum* were noted, but they were not found during the current study. In all three study periods *Caryophyllaeus laticeps* was present and its extensity was similar in 1984 and 1994 at 26.6% and 21.8%, respectively. In the current study its prevalence doubled to 58.3%. In 1984, plerocercoids of *Ligula intestinalis* were found, which were not found in the later studies, while in 1994 and in the present study plerocercus forms of *Paradilepis scolecina* appeared. The extensity of infestation of fish with that tapeworm decreased threefold as compared to 1994. In 1994 only one species of Acanthocephala, *Acanthocepalus lucii*, was recorded; however, it was not recorded in the present study. *Philometra* sp. was present in 1984 at an extensity of 13.3%, later, in 1994 its extensity decreased threefold to 5.4%, and then this species was absent from the 2001-2003 study. Among the three species of Crustacea found in 1984, in 1994 and in the present study, only one, *Ergasilus sieboldi*, was found. The extensity of infestation with this parasite decreased gradually from 43.3% in 1984 to 21.8% in 1994 and 16.6% at present. Larvae of molluscs glochidia were present with similar extensity (1.7% and 1.8%) in 1984 and 1994, while in the present study they were not found on the fish. For bream, a total of 23 parasite species were noted with 14 species in 1984 and 1994 and only 11 currently. During the years of study, the number of internal parasite species decreased from 9 to 5.

The second species of fish from Lake Kortowskie that was studied earlier was perch (Król and Ochendowski 1988; Table 3). During the current study, no Monogenea were found in perch, although in 1988 *Gyrodactylus* sp. was present. Eye digenea flukes were present in both 1988 and during the present study, but the extensity of infestation changed drastically with an eightyfold decrease in the presence of *Diplostomum* sp. and a threefold decrease in the prevalence of *Tylodelphys clavata*. During the current study, no *Bunodera luciopercae* were found. Among tapeworms, the plerocercoid of *Triaenophorus nodulosus* was present with similar extensity in both 1988 and during the current study, while *Proteocephalus percae* appeared during the present study only (44.6%). In both years, *Desmidocercella numidica* was present with similar prevalence while that of *Camallanus lacustris* decreased fourfold. In 1988, one species of Acanthocephala, *Acanthocephalus lucii* (16.3%), was present. In the current study *Acanthocephalus lucii* was also present but its prevalence decreased fivefold. On the other hand, *Acanthocephalus anguille* and *Acanthocephalus* sp. appeared. Of the three species of Crustacea, the prevalence of *Argulus foliaceus* decreased fourfold, while *Caligus lacustris* and *Ergasilus sieboldi* appeared. A tenfold increase in the infestation of perch with *Glochidium* larvae was observed. During the present study no leeches was observed, while in 1988 *Piscicola geometra* was present.

**TABLE 3**

Changes of parasite occurrence in bream, perch, and rudd in Lake Kortowskie during 1984-2003

| | Bream | | | | | | Perch | | | | Rudd | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1984 n=60 | | 1994 n=55 | | 2001-2003 n=48 | | 1988 n=92 | | 2001-2003 n=56 | | 1983-1984 n=40 | | 2002-2003 n=10 | |
| Parasite species | P% | Intensity (range) | P% | Intensity (range) | P% | Intensity (range)/ mean intensity | P% | Intensity (range) | P% | Intensity (range) | P% | Intensity (range) | P% | Intensity (range) |
| *Dactylogyrus auriculatus* | - | - | 5.4 | 1 | 2.77 | 4 | | | | | | | | |
| *D. falcatus* | - | - | - | - | 5.55 | 1 | | | | | | | | |
| *D. wunderi* | - | - | 9.1 | 1-4 | 5.55 | 4.5 | | | | | | | | |
| *D. zandti* | - | - | 12.7 | 1-6 | 11.11 | 4 | | | | | | | | |
| *Dactylogyrus* sp. | | | | | | | | | | | sporadically | - | - | - |
| *Gyrodactylus elegans* | - | - | - | - | 8.36 | 7.66 | | | | | | | | |
| *Gyrodactylus* sp. | 1.7 | single | 1.8 | 1 | - | - | 2.2 | 1 | - | - | | | | |
| *Diplostomum* sp. (mc.) | 88 | 1-80 | 90.9 | 1-157 | 41.66 | 6-75 | 85.5 | 1-68 | 1.78 | 0-1 | 35 | - | 60 | 1-6 |
| *Tylodelphys clavata* (mc.) | 15 | 1-8 | 67.2 | 1-97 | 33.33 | 1-11 | 98.9 | 1-66 | 33.92 | 1-152 | 8 | - | - | - |
| *Ichthyocotylurus platycephalus* (mc.) | - | - | 1.8 | 1 | - | - | | | | | | | | |
| *Paracoegonius ovatus* (mc.) | 35 | 1-28 | - | - | - | - | | | | | | | | |
| *Posthodiplostomum cuticola* (mc.) | 1.7 | 0-3 | - | - | 8.33 | 0-1 | | | | | 15 | - | - | - |
| *Sanguinicola* sp. | 1.7 | - | - | - | - | - | | | | | | | | |
| *Sphaerostomum maius* | 5 | 1-93 | - | - | - | - | | | | | | | | |
| *Bunodera luciopercae* | | | | | | | 19.6 | 1-6 | - | - | | | | |
| *Phyllodistomum elongatum* | - | - | 7.2 | 1-7 | - | - | | | | | | | | |
| *Caryophyllaeus laticeps* | 26.6 | 1-73 | 21.8 | 1-50 | 58.33 | 1-18 | | | | | 28 | - | - | - |
| *Proteocephalus percae* | | | | | | | - | - | 44.64 | 1-65 | | | | |
| *Paradilepis scolecina* (pler.) | - | - | 27.8 | 1-12 | 8.33 | 0-10 | | | | | | | | |
| *Ligula intestinalis* (pler.) | 8.3 | - | - | - | - | - | | | | | | | | |
| *Triaenophorus nodulosus* (pler.) | | | | | | | 6.5 | 1-5 | 5.36 | 1-6 | | | | |
| *Acanthocephalus lucii* | - | - | 5.5 | 1-6 | - | - | 16.3 | 1-23 | 3.57 | 0-2 | | | | |
| *Acanthocephalus anguillae* | | | | | | | - | - | 23.21 | 1-72 | | | | |
| *Acanthocephalus* sp. | | | | | | | - | - | 3.57 | 0-2 | | | | |
| *Philometra* sp. | 13.3 | 1-4 | 5.4 | 0-3 | - | - | | | | | | | | |
| *Camallanus lacustris* | | | | | | | 30.4 | 1-16 | 7.14 | 1-8 | | | | |
| *Desmidocercella numidica* | | | | | | | sporadically | | 1.78 | 0-1 | | | | |
| *Ergasilus sieboldi* | 43.3 | 1-25 | 21.8 | 1-3 | 16.64 | 1-3 | - | - | 17.86 | 1-20 | 37 | - | - | - |
| *Tracheliastes maculatus* | 8.3 | 1-8 | - | - | - | - | | | | | | | | |
| *Argulus foliaceus* | 5 | 1-2 | - | - | - | - | 14.1 | - | 3.57 | 0-1 | | | | |
| *Caligus lacustris* | | | | | | | - | - | 7.14 | 0-1 | - | - | 10 | 0-2 |
| *Glochidium* lar. | 1.7 | single | 1.8 | 1 | - | - | 2.2 | 1-67 | 26 | 1-24 | | | | |
| *Piscicola geometra* | | | | | | | 8.7 | 1-3 | - | - | | | | |

*Explanation see in table 2*

The last species from Lake Kortowskie studied earlier was rudd (Własow et al., 1991; Table 3). Comparing the fauna of parasites from 1983-1984 with those from 2002-2003, it can be seen clearly that the number of parasite species decreased. According to Własow et al. (1991), six species of parasites were found on rudd (excluding Protozoa): *Dactylogyrus* sp.; *Diplostomum* sp.; *Tylodelphys clavata*; *Posthodiplostomum cuticola*; *Caryophyllaeus laticeps*; *Ergasilus sieboldi.* During the present study, only two species were found: *Diplostomum* sp. and *Caligus lacustris*, a new species. The prevalence of rudd infestation with *Diplostomum* sp. increased twofold.

The comparison of present infestation of bream and perch with that of 1984 and 1994, clearly shows that there has been a decrease in the number of species, decreases in prevalence or increases (sometimes dramatic), and the disappearance of some species and the appearance of new ones. In the case of perch parasites, during the current study no *Bunodera lucioperca* were recorded, the prevalence of *Camallanus lacustris* decreased fourfold, and *Protecephalus percae* appeared. On the other hand, in the case of bream no *Paracoenogonimus ovatus, Sphaerostomum maius, Sanguinicola sp., Phyllodistomum elongatum,* nematode *Philometra ovata* or tapeworm *Ligula intestinalis* were observed, while the prevalence of *Posthodiplostomum cuticola* increased eightfold and that of *Caryophyllaeus laticeps* twofold. The decrease in the number of parasites in rudd could be the consequence of the small number of fish examined.

The absence of *Bunodera lucioperca, Phyllodistomum elongatum, Sphaerostomum maius* (*Sphaerostomum bramae* according to Niewiadomska 2003), the tapeworm *Ligula intestinalis*, and the nematode *Philometra ovata* indicates the absence of invertebrates that had earlier been present in that lake. The appearance of *Proteocephalus percae* increased the prevalence of *Posthodiplostomum cuticola*, while the appearance of *Caryphyllaeus laticeps* indicate the restoration and diversity of flora and fauna, particularly plankton crustaceans (Moczarska 2003) and benthic oligochaeta (Rozentalski 2003) as well as fauna of the *Planorbis* family of snails.

This is most likely related to the Lake Kortowskie experiment and the resulting environmental changes as well as advantageous nesting and feeding conditions for piscivorous birds, which are the final hosts for many parasite species with complex developmental cycles.

## CONCLUSIONS

1. The fish parasite fauna of Lake Kortowskie is diversified with respect to its specific composition and quantities. In 2001-2004, 51 species of parasite belonging to dif-

ferent systematic groups were noted, as follows: Monogenea (27), Digenea (6), Cestoda (7), Nematoda (4), Acanthocephala (3), Crustacea (3), Mollusca (1).

2. Roach and ruffe were the most infected species and prevalence was highest among pike. *Tetraonchus monenteron*, *Triaenophorus nodulosus*, *Ergasilus sieboldi*, and mollusc glochidia occurred in 83.3% of pike. Gudgeon and rudd were the least infected.
3. The majority of the parasites studied during the current project were non-specific (generalists) and were able to infect almost all fish species inhabiting Lake Kortowskie.
4. From the comparison of the bream, perch, and rudd infestation parameters of 1984 and 1994 with the current results, it can be concluded, that changes are linked to changes in the environment occurring in Lake Kortowskie as a consequence of the Lake Kortowskie experiment.

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## STRESZCZENIE

PASOŻYTY (METAZOA) RYB Z JEZIORA KORTOWSKIEGO

W latach 2001-2004 przeprowadzono badania parazytologiczne ryb z Jeziora Kortowskiego. To eutroficzne jezioro leży w granicach miasta Olsztyna. Od 1959 roku w jeziorze tym przeprowadzany jest eksperyment polegający na usuwaniu wód hipolimnionu. Obecnie zbadano 381 ryb reprezentujących 10 gatunków. Zanotowano 51 gatunków pasożytów należących do: Monogenea (27), Digenea (6), Cestoda (7), Nematoda (4), Acanthocephala (3), Crustacea (3) i Molusca (1). Stwierdzono 6334 pasożyty w badanych rybach, wśród których 3045 to przywry digeniczne. Najwięcej gatunków pasożytów zanotowano u płoci (18), następnie u uklei (14), okonia i krąpia (po 13), leszcza (11), jazgarza i szczupaka (10), a najmniej u kiełbia (4) oraz lina i wzdręgi (po 2). Porównano i przedyskutowano zarażenie leszcza, okonia i wzdręgi w odniesieniu do lat 1984-1988, 1994 i 2001-2003.

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***Short communications***

# A SIMPLE TRAP FOR THE CAPTURE NEW-EMERGENT SALMONID FRY IN STREAMS

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ABSTRACT. A simple trap was built for capturing salmonid fry emerging from natural spawning redds in streams. The trap is shaped like a cap with a vertical PVC tube. Since the trap is not attached permanently to the substrate, settled debris can be cleaned out regularly, and the trap can be deployed in streams with large amounts of drifting organic material. Its simple construction means that it is easy to use. Based on the comparison of the effectiveness of two types of traps on artificial redds, the catch efficiency of the newly constructed trap was determined to be 37%.

Key words: SALMONIDS, FRY EMERGENCE, FRY TRAPS

Relatively little is known regarding various aspects of salmonid (*Salmonidae*) fry emergence from natural redds. This is mainly due to methodological difficulties with deploying appropriate traps. The basic problem is constructing traps that do not disturb water flow through redd substrates thus allowing fry to emerge from the redds freely.

The simplest method for capturing emerging fry is to deploy drift traps (Garcia de Leaniz et al. 1993), but they can only be used in streams in which small quantities of organic material drift on the water current. Earlier experiments conducted in the drainage area of the upper Wda River indicated that large quantities of drifting plant debris make the use of such traps very problematic (Radtke 2005).

Good results were obtained in streams using a net trap that encircles the entire redd and forms a type of cap with the edges buried into the surrounding gravel (Philips and Koski 1969, Porter 1973, Field-Dodgson 1983, Fraley et al. 1986). Unfortunately, this type of trap deployed permanently in the stream bottom can only be used success-

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fully when there are small quantities of mobile sediments (McMichael et al. 2005), and when the net is not subjected to large quantities of drifting organic debris or if it does not become overgrown with algae. Blocked mesh openings require that the trap is cleaned regularly, but its permanent deployment on the stream bottom limits trap manipulation possibilities. Additionally, there is also the danger that sand and mud will accumulate on the net that is buried under the gravel at the edges of the redd, which can increase mortality among the eggs and fry (Reiser et al. 1998).

The large quantities of floating organic debris encountered during earlier experiments in the Wda and Trzebiocha rivers as well as the substantial amount of sand on the bottom required building a trap that encompasses the entire redd just like the cap trap. However, its lower edge was not be buried permanently in the gravel, but was attached to a metal hoop surrounding the redd. Depending on the trap size, from one to three arch handles made of thick wire were mounted on the hoop. The construction was covered with a cap of polyester twine netting with a mesh bar length of 2 mm (Photo 1, Fig. 1). The second part of the trap was a vertical tube made of PVC 10 cm in diameter that was attached to the end of the netting with a PVC t-joint that was closed off from the bottom. The back

Photo 1. Medium cap trap with a vertical tube (metal hoop circumference – 75 cm).

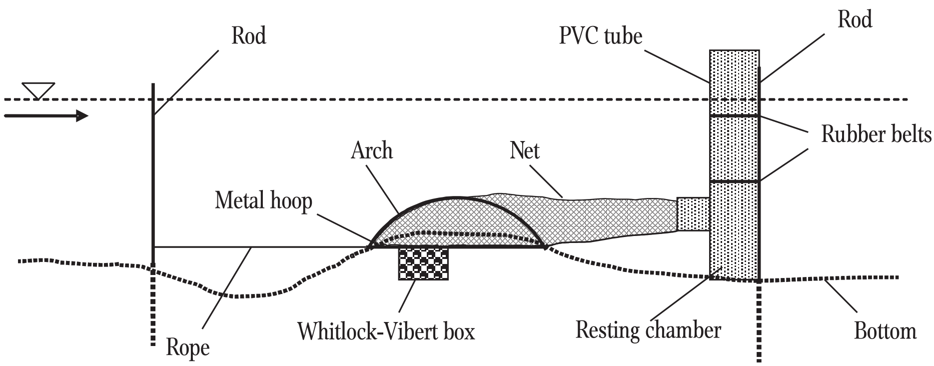


Fig. 1. Deployment and construction of the cap trap and vertical tube on an artificial redd.

wall of the t-joint was perforated. This created a resting chamber for the fry in the lower part of the tube, and also provided the fry free contact with the water surface for swim bladder inflation. The hoop was attached by rope to metal rods that were driven into the stream bottom. The vertical PVC tube was attached to a second vertical metal rod with two rubber belts (Fig. 1). This construction permitted easy monitoring access, for example, to empty it of its contents, and the lack of permanent contact with the substrate made it easy to clean the net of accumulated sediment. While servicing the trap, however, care must be taken to not disturb the structure of the redd.

In spring 2007 an attempt was made to determine the catchability of the new trap construction on artificial redds. Unfortunately, not all the specimens placed as eggs or fry in artificial redds emerge, which is why the number of individuals placed in the redd compared to the fry caught in the trap does not accurately reflect trap catchability. For this reason, the best way of evaluating the catchability of the tested trap is to compare the number of fry it catches to the number of fry caught in traps that catch all emergent fry under the same environmental conditions. In order to do this, six artificial redds that were shaped similarly to natural ones were constructed in the Trzebiocha (approximately 20 m downstream from the weir at Grzybowski Młyn). These redds had similar parameters, which means they were of the same size (redd tail diameter of approximately 0.5 m), and the same substrate (gravel diameter range of 16-32 mm). The depth of the stream was about 0.25 m, and the water current was within the 0.6-0.7 $ms^{-1}$ range. A Whitlock-Vibert box containing 100 fry of lake trout, *Salmo trutta* m. *lacustris* L. from Lake Wdzydze with approximately 75% yolk sac resorption was placed in each redd. The fry came from the hatchery at Grzybowski Młyn, and they were released through rubber hoses into the W-V boxes after it had been placed on the redd.

Two types of traps were used. Three redds were fitted with cap traps with a vertical tube (described above) in three different circumferences (small – 0.5 m, medium – 0.75 m, large – 1 m). For comparison, the three other redds were fitted with three boxes of perforated metal that caught all the fish emerging from the redd (Photo 2, Fig. 2). The dimensions of the boxes were as follows: height – 0.30 m, length – 0.6 m, width – 0.23 m. The size of the perforations was 2 mm. With this type of trap, the W-V box with the fry was placed in plastic baskets with 2 mm perforations and gravel. The main part of the box was fitted with an opening in the bottom along the edge of the plastic basket so that all of the emerging fry could reach the trap. The rear section of the box trap had

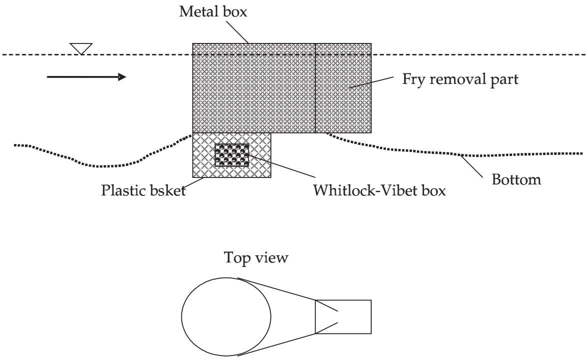


Fig. 2. Deployment and construction of the metal box trap on an artificial redd.

Photo 2. Metal box trap with a removable resting chamber for the fry.

a separate, removable module that provided a resting chamber for the fry (Photo 2, Fig. 2).

Two experiments were conducted in May 2007 on the three cap traps and the three box traps described above. The mean catch from six attempts with the metal boxes was 49.8 fry individuals while with the cap traps it was 18.5 fry individuals (Table 1).

**TABLE 1**

Number of fry deployed and caught in traps on artificial redds (SD – standard deviation)

| Trap type | Number of traps | Number of fry released per 1 trap | Number of fry caught (mean ± SD) |
|---|---|---|---|
| Cap trap | 6 | 100 | $18.5^{a} \pm 16.2$ |
| Metal box trap | 6 | 100 | $49.8^{b} \pm 20.2$ |

*Values with a different letter index in the same column differ significantly statistically (test t, P< 0.05)*

Assuming that the metal box catches all the emergent fry, the measure of catchability of the cap trap was taken as the ratio of the number of fry caught in it to the number of fry caught in the metal box. This proportion was 0.37 (SD = 0.24). The difference in the mean number of fry caught in these two trap types was statistically significant (Student's t – test, P < 0.05). In practical terms it seems that the number determined can be taken to be the approximate catchability of the cap trap.

The lower catchability of the cap trap recorded during the experiment can be explained by the migration of the emerging fry outside of the substrate area covered by the trap. The phenomenon of horizontal migration in redd substrates was observed in

Atlantic salmon (Garcia de Leaniz et al. 1993). In practice, one way of preventing trap aversion by emerging fry is to use an additional perforated hoop pushed into the gravel bottom to encircle the eggs or fry. However, this carries with it the risk of sediment accumulation and reduced water flow through the center of the redd.

Although the model cap trap described above does not encircle the entire redd and does not catch all the fry emerging from it, it can be deployed successfully in natural salmonid spawning grounds where there are large quantities of floating organic debris.

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## STRESZCZENIE

PROSTA PUŁAPKA DO POŁOWU WYCHODZĄCEGO Z GNIAZD WYLĘGU RYB ŁOSOSIOWATYCH W POTOKACH

Celem badań było określenie łowności pułapki do połowu wylęgu ryb łososiowatych wychodzącego z naturalnych gniazd tarłowych. Pułapka własnej konstrukcji tworzy formę czapki zakończonej pionową rurą PVC (fot. 1, rys. 1). Uzyskane wyniki porównano z rezultatami osiągniętymi z zastosowaniem pułapki z perforowanej blachy, w której umieszczono aparat z wylęgiem (fot. 2, rys. 2). Brak stałego umocowania pułapki w podłożu umożliwia jej regularne czyszczenie z naniesionego osadu, dzięki czemu można ją stosować w rzekach z dużą ilością dryfującej materii organicznej. Prosta konstrukcja umożliwia łatwą

obsługę pułapki. Na podstawie porównania efektywności dwóch rodzajów pułapek na sztucznych gniazdach określono łowność nowo skonstruowanej pułapki na 37%. Średnia ilość larw troci jeziorowej, *Salmo trutta* m. *lacustris* L. złowionych w porównywane typy pułapek różniła się istotnie statystycznie (test t, $P < 0,05$; tab. 1).

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***Short communications***

# DESCRIPTION OF PIKEPERCH, *SANDER LUCIOPERCA* (L.), SEMEN OBTAINED FROM MALES HELD UNDER DIFFERENT REARING CONDITIONS


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ABSTRACT. The aim of the study was to determine the concentration and motility of sperm and the osmotic pressure and total protein in the seminal plasma of pikeperch, *Sander lucioperca* (L.). The samples investigated were milt from males held under various rearing conditions (ponds, tanks of a closed recirculating systems, cages). The highest percentage of motile sperm was noted in the semen samples from males held in basins, while the lowest percentage of motile sperm and the highest protein content was confirmed in the samples from spawners held in ponds. Sperm motility and the osmolality of the seminal plasma were low in all the spawner groups; this may indicate contamination with urine. As the content of protein rose in the plasma and the sperm concentration increased, so did their motility.



Key words: PIKEPERCH, MILT, HCG, SEMINAL PLASMA, CONTAMINATED SEMEN


The quality of milt is as crucial as that of spawn for the success of both natural and artificial spawning. The basic quality parameters of semen that determine the ability of the sperm to fertilize are motility following activation and concentration (Kruger et al. 1984). Based on the quantity of sperm in a unit measure, conclusions can be drawn regarding testicular development and functioning (Król et al. 2006), among other factors, while the parameters of sperm motility differ among species and individuals


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(Glogowski et al. 2007). Sperm concentration is not a constant value for this phylum of animal (Ciereszko and Dąbrowski 1993).

The quantity of some of the seminal components are key in predicting the fertilization capability of a semen sample or its suitability for short- or long-term storage. Not all of the seminal components are secreted; some come from damaged sperm or cells from the testes and the vas deferens (Glogowski et al. 2007). Sertoli cells or blood are the source of the protein in seminal plasma (Loir et al. 1990), and the protein content in the seminal plasma is much lower in comparison with the seminal plasma of other vertebrates. The factor that either activates or halts sperm motility in teleost fish is the osmotic pressure in the seminal plasma (Alavi and Cosson 2006).

Among the endemic freshwater fish of Poland, pikeperch, *Sander lucioperca* (L.), is unquestionably a valuable species economically thanks to its rapid growth rate and high-quality meat. As a predator, it also plays an important role in maintaining ecological equilibrium. The progressive eutrophication of waters in Poland is leading to disadvantageous environmental changes, and pikeperch spawners are caught in open waters and then held and spawn artificially under controlled conditions with the application of the appropriate hormonal substances (Demska-Zakęś and Zakęś 2002, Zakęś and Szczepkowski 2004, Zakęś and Demska-Zakęś 2005). The advantages of artificial reproduction under controlled conditions include the possibility of monitoring the course of spawning and choosing gametes of the highest quality. This is reflected in the results obtained and the decision-making process of the use of the sex products obtained. The aim of the current study was to describe the basic parameters of the semen of pikeperch held under various rearing conditions, with a specific focus on the osmotic pressure of the seminal plasma.

Pikeperch spawners were caught in the Martwa Wisła River in spring 2006. In the summer of the same year, they were divided into three rearing groups: I – fish held in ponds with a surface area of 10 are; II – fish held in basins with a volume of 1 $m^3$ connected to a closed recirculation system; III – fish held in cages with a volume of 8 $m^3$. The conditions in the two types of ponds were similar with regard to light regime and temperature, while in the basins conditions were created that approximated the natural ones. After about nine months, in spring 2007, when the water temperature in the ponds reached 12°C, all of the fish were moved to basins connected to a recirculating system.

The fish were acclimatized to a temperature of 15°C for several days, then individual fish were examined and stimulated hormonally with human chorionic gonadotropin (HCG) at a dose of 450 IU kg $^{-1}$ (Biogonadyl, Biomed Lublin, Poland). The doses of this preparation were the same for both sexes and were administered once through an injection to the peritoneum. During manipulation, the fish were anesthetized with a dose of 1 ml $l^{-1}$ Propiscin (Inland Fisheries Institute in Olsztyn). The water temperature during manipulation was 15°C, and the period between obtaining the milt and the analyses was three to four hours. Thirty hours after the injection, semen samples were collected with a syringe. The samples were transported on ice (2-4°C) to the Department of Molecular Andrology, PAS in Olsztyn. In the laboratory, the motility of the sperm was determined with the subjective method under magnification of 400 × with 119 mM $NaHCO_3$ + 0.5% albumin or $H_2O$ as the activating agent. After dilution (1000 × in 0.7 % NaCl), the sperm concentration in the semen was determined with the spectrophotometric method as described by Ciereszko and Dąbrowski (1993). The total protein content was determined (Lowry et al. 1951), and the seminal plasma osmotic pressure was determined with a WESCOR® Vapor Pressure osmometer 5520.

Pearson's correlation coefficient was applied to determine the dependencies between the characters of samples from the three groups analyzed (GraphPad Prism 4 Demo, GraphPad Software Inc., USA). The significance of differences of the characters among the three fish groups studied was verified with Tukey's post-hoc test ($P < 0.05$).

A higher percentage of motile sperm was noted in the milt samples that were activated with $H_2O$ than in those activated with 119 mM $NaHCO_3$ with 0.5% albumin (Table 1). The highest percentage of motile sperm was noted in the fish reared in cages (47.50%, N = 4), and the lowest in the fish reared in ponds (33.16%, N = 4). Regardless of the activating fluid applied, sperm motility was positively correlated with concentration (Fig. 1).

Sperm concentrations ranged from 4.28 to 5.26 mld $ml^{-1}$, depending on which group the fish came from, among which the highest sperm concentration was noted in samples from fish that had been reared in ponds (group I; Table 1). In the samples examined for sperm motility, the mean concentration of sperm was similar for all groups (group I – 7.14; group II – 5.63; group III – 6.64 mld $ml^{-1}$. In the samples with non-motile sperm, the sperm concentrations were also similar among the groups although decidedly lower (group I – 3.76; group II – 2.03; group III – 2.78 mld $ml^{-1}$).

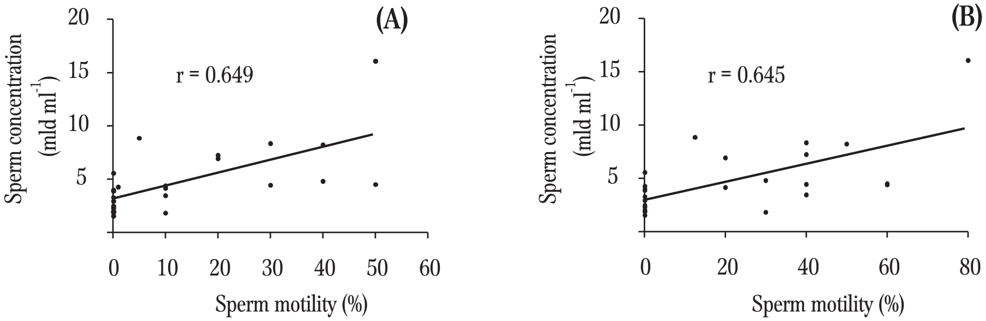


Fig. 1. Dependency between the concentration and motility of sperm activated with 119 mM $NaHCO_3$ + 0.5% albumin (A) or with $H_2O$ (B).

**TABLE 1**

Basic quality parameters of pikeperch semen obtained from fish reared under different conditions (mean ± SD)

| Group | N | Sperm motility (%) 119 mM $NaHCO_3$ | Sperm motility (%) $H_2O$ | Sperm concentrations (mld $ml^{-1}$) | Osmotic pressure (mOsm $kg^{-1}$) | Concentrations of total protein (mg $ml^{-1}$) |
|---|---|---|---|---|---|---|
| Group I | 9 | 7.22±10,93 | 14.72±21.81 | 5.26±2.31 | 178±74.87 | 2.43±1.94 |
| Group II | 8 | 17.50±17.52 | 25.00±21.38 | 4.28±2.41 | 227±75.27 | 1.38±1.24 |
| Group III | 8 | 15.12±21.94 | 23.75±31.14 | 4.71±4.74 | 192±90.03 | 1.01±0.69 |

The highest mean value of seminal plasma osmotic pressure was noted in the fish from group II, while the lowest was from group I (Table 1). Samples in which no sperm motility was observed had the lowest values of this parameter (means for groups: I - 123; II - 144; III - 126 mOsm $kg^{-1}$) in comparison to samples that had a certain percentage of motile sperm (means for groups: I - 247; II - 277; III - 258 mOsm $kg^{-1}$). In previous studies (Kowalski et al. 2003, Glogowski et at. 2007) higher osmotic pressure values were obtained in European pikeperch (221-287 mOsm $kg^{-1}$). The seminal plasma protein content ranged from 1.01 to 2.43 mg $ml^{-1}$ (Table 1). It was demonstrated that the concentration of sperm increased along with increasing levels of protein in the plasma ($r = 0.611$, $P < 0.05$). Similarly, with increased seminal plasma osmotic pressure the motility of the sperm increased (Fig. 2).

The lowest percentage of motile sperm and the highest protein contents were noted in the samples obtained from the spawners held in ponds. The motility of sperm as well as the seminal plasma pressure exhibited low values in all fish groups, and this may

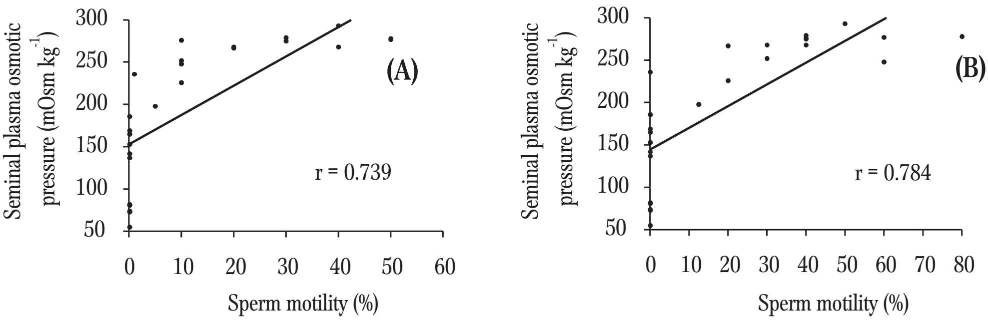


Fig. 2. Dependency between seminal plasma osmotic pressure and sperm motility in pikeperch sperm activated with 119 mM $NaHCO_3$ + 5% albumin (A) or with $H_2O$ (B).

indicate that the milt was contaminated with urine. This problem occurs when stripping milt from many fish species. This can be largely eliminated by collecting semen directly from the vas deferens with a catheter (Glogowski et al. 2000).

The concentration of sperm in the pikeperch groups that were studied was lower than values determined in previous studies of this same species (Kowalski et al. 2003, Glogowski et al. 2007). The concentration of sperm that was determined in European perch, *Perca fluviatilis* L., (Lahnsteiner et al. 1995, Król et al. 2006) and yellow perch, *Perca flavescens* (Mitch.) (Ciereszko and Dąbrowski 1993) also differed and was higher than the values presented herein. In comparison to other semen quality parameters, only the content of total protein in the seminal plasma of group I (mean 2.43 mg $ml^{-1}$) can be considered as close to the levels reported in the literature for perch (Lahnsteiner et al. 1995) or pikeperch (Kowalski et al. 2003). A positive statistically significant relationship between this parameter and the concentration of sperm may indicate that this protein comes from damaged or dead sperm.

The seminal plasma osmotic pressure in Chondrostei fish, such as the sturgeons, is much lower than that of the Teleostei fish, such as the cyprinids, salmonids, or percids. In addition to variation in genera and species, this parameter can also differ among individuals (Alavi and Cosson 2006). It is worth emphasizing that the value of seminal plasma osmotic pressure also appears to be an indicator, among other things, of semen contamination with urine, which results in its poor quality and the lack of its ability to fertilize or to be stored for short periods or cryopreserved. This situation also occurs when stripping milt under controlled conditions and has been observed in species such as carp, *Cyprinus carpio* L. (Perchec et al. 1995), tench, *Tinca tinca* (L.) (Rodina et al.

2004), European pikeperch (Bokor et al. 2007), and rainbow trout, *Oncorhynchus mykiss* (Walbaum) (Glogowski et al. 2000).

The statistically significant dependency between sperm motility and seminal plasma osmotic pressure confirms that the latter is indeed a milt quality parameter. It appears that urine contamination is responsible for the high variability observed during the present study. Bokor et al. (2007) also noted when collecting milt samples from European pikeperch that it is impossible to avoid entirely the contamination of the milt with urine. In the current study, the milt samples in which the sperm exhibited no motility had seminal plasma osmotic pressure within the range of 55 to 186 mOsm $kg^{-1}$.

Inducing reproduction with hormonal substances can influence a variety of milt quality parameters including seminal plasma osmotic pressure (Redondo-Muller et al. 1991). It would appear, however, that weak motility or the lack thereof is more likely to result from an inappropriate period between hormonal administration and semen stripping than from the hormone used to stimulate spermiation. HCG is indeed a substance that is both recommended and used widely and one that produces excellent results in the reproduction of this fish species (Demska-Zakęś and Zakęś 2002, Zakęś and Szczepkowski 2004).

From a practical point of view, any contamination of the sex products (water, urine, stool, blood) should be eliminated. One alternative for achieving this is to ensure that the bladder is emptied prior to semen collection as is widely applied when stripping spawners (with abdomen massage) (Perchec et al. 1995). Another method is to use catheters, or solutions to immobilize sperm motility. Using immobilizers leads to the stabilization of the ambient pH, which is crucial when freezing semen (Rodina et al. 2004) or for its short-term storage. Successful sperm revitalization was achieved in carp (Perchec et al. 1995) and other species, and in the case of pikeperch semen, which is often contaminated with urine (during collection), it is recommended to investigate the effectiveness of this procedure in the future.

Studies of the characteristics of semen from various fish species indicate that there is significant variation among individuals in the biochemical parameters of seminal plasma, sperm concentration, and sperm motility. This is impacted by both genetic factors as well as the aging of sperm, seasonality, the type and dose of the hormonal substances administered, and the method of obtaining milt, which could have impacted the results of the current study. Future studies should either address the problem of semen collection techniques that permit obtaining milt with good motility (in excess of 50%), or those for revitalizing sperm.

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## STRESZCZENIE

CHARAKTERYSTYKA NASIENIA SANDACZA, *SANDER LUCIOPERCA* (L.) POZYSKANEGO OD SAMCÓW PRZETRZYMYWANYCH W RÓŻNYCH WARUNKACH CHOWU

Celem badań było określenie koncentracji i ruchliwości plemników, ciśnienia osmotycznego i białka ogólnego w plazmie nasienia sandacza *Sander lucioperca* (L.). Próby mlecza pozyskano od samców podzielonych na trzy grupy tarlaków, tj. ryby przetrzymywane w stawach, basenach i sadzach, które poddano stymulacji hormonalnej przy użyciu HCG.

Wyniki prezentowanych badań świadczą o istnieniu zmienności osobniczej pod względem badanych parametrów jakości mlecza sandacza. Najwyższym odsetkiem ruchliwych plemników oraz najwyższymi wartościami ciśnienia osmotycznego cechowały się próby mlecza sandaczy, które przetrzymywano w basenach (grupa II; tab. 1). Najwyższą z kolei koncentrację plemników oraz zawartość białka całkowitego w plazmie nasienia stwierdzono w próbach, które pozyskano od samców przetrzymywanych w stawach (grupa I). Najwyższe współczynniki korelacji wyznaczono pomiędzy ruchliwością plemników a ciśnieniem osmotycznym plazmy nasienia i to bez względu na zastosowany roztwór aktywujący ruchliwość plemników (119 mM $NaHCO_3$ + 0,5% albumina lub $H_2O$), co świadczy o istotnym związku pomiędzy badanymi parametrami. Niski odsetek ruchliwych plemników i znaczna ilość prób z zerową ruchliwością może sugerować zanieczyszczenie mlecza moczem podczas jego pozyskiwania, co uwidocznione jest stosunkowo niskimi wartościami ciśnienia osmotycznego plazmy nasienia.

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Perrone S.J., Maede T .L. 1973 - Protective effect of chloride to nitrite toxicity in coho salmon - J. Fish. Res. Bd. Can. 34(2): 486-492.

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Rybicki J. 1988 - Microbiological decomposition of phosphoric compounds in surface waters - Proc. XV Com. Inter. Microbiol. Assoc., The Hague 5-10.09.1987, Academic Press, N. York: 258-265.

W przypadku cytowania prac zawartych w wydawnictwach książkowych należy także podać tytuł książki, redaktora (ów) oraz nazwę wydawnictwa, np.:

Zawisza J., Backiel T. 1970 - Gonad development, fecundity and egg survival in Coregonus albula L. - In: Biology of coregonid fishes (Eds.) C.C. Lindey and C.S. Woods, Univ. Manitoba Press, Winnipeg: 363-397.

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