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FISH COMMUNITY AND PRODUCTIVITY AS AN INDEX OF TROPHIC STATE DIVERSITY IN TWO SHALLOW LAKES

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Summary. Fish community and productivity were investigated in two shallow lakes with different trophic state: eutrophic lake Sumin and hypertrophic lake Syczyńskie. Control fishing was performed three times in 2008 year using multi-mesh gillnet. In total, from 2 to 8 fish species was found, while in eutrophic lake 8 species and in hypertrophic lake 4 species. In both lakes, mainly cyprinids fish was a dominant in the total number of fish: in eutrophic lake – white bream (64.4%), and in hypertrophic lake, bleak (83.2%) and also perch (15.8%). In Sumin Lake in biomass structure the white bream (48.8%), pikeperch (18.4%) and brown bullhead (13.8%) was dominant and in the Syczyńskie Lake, perch (62.8%) and bleak (25.6%). In hypertrophic lake 5-times higher NPUE and almost 2-times higher WPUE then in eutrophic lake was determined. All found species in two lakes characterized the small average total length and biomass, but higher values of coefficient of condition was noted for fish from hypertrophic lake.

Key words: fish community, lake trophic state, fish productivity, shallow lakes

INTRODUCTION

The proper functioning of lake ecosystem is possible only when all his trophic levels are in the right proportions. In the case of disrupting the balance are coming changes leading to the increase the reservoir trophy [Jeppesen *et al*. 2000, Zdanowski 2008].

The main elements are small plantovirous fish, mainly cyprinids and their juvenile forms, which prey on the big filtering zooplankton causes an increase in suspension and turbidity in the water, which leads to the disappearance of macrophytes and in the last stage of the appearance of large quantities of algae and cyanobacteria. The predatory fish represents an important group of whose task is to control the cyprinids fish populations and to maintain the right proportions in the trophic pyramid [Carpenter *et al*. 1985, McQueen *et al*.1986].

Typically, after increasing of the reservoir trophic state the dominance on fish community changes. From the dominance of the valuable economic fish (Coregonidae and Salmonidae) comes to increase of the number of cyprinids fish, which after short time reduces their body's condition and become smaller [Leopold *et al*. 1986, Bninska 2000, Wiśniowolski 2002].

A number of studies concerning the impact of fish fauna on reservoir trophy usually focused on the dam reservoirs [Mastyński and Wojdanowicz 1994, Andrzejewski and Mastyński 2004]. Papers about the ichthyofauna of lakes in Łeczna-Włodawa Lakeland mainly focused on description of the result of monitoring or potential changes in fish community [Kolejko 2006, 2009, Rechulicz 2006, 2008]. For reservoirs of this region is lack of studies whose aim was to determine changes of fish fauna, depending on their trophy status. The aim of present study, was to determine of fish community and productivity, expressed as abundance and biomass of fish, as an indicator of trophic state of two shallow lakes (Łęczna-Włodawa Lakeland).

MATERIALS AND METHODS

Investigations were conducted in two shallow lakes of Łęczna–Włodawa Lakeland (eastern Poland); eutrophic Lake Sumin (51°22'E, 23°08'N; surface area 91.5 ha, maximum depth 6.5 m) and hypertrophic Lake Syczyńskie (51°17'E, 23°14'N; surface area 6.0 ha, maximum depth 2.9 m). The physical and chemical characteristics of water at these lakes are summarized in Table 1.

The characterization of the trophic state of the studied lakes shows that Sumin Lake is eutrophic and the Syczyńskie Lake is extremely hypertrophic lake [Kornijów *et al*. 2002b]. After Harasimiuk *et al*. [1998] Syczyńskie Lake represents the tench – pike fishing type lakes and Sumin Lake belongs to intermediate type: bream-pikeperch fishing type lake.

In both lakes, three times in 2008 year (spring, summer, autumn) control fish catches were carried out. Catches were conducted using standard Norden S multi-mesh gillnet type (10, 60, 30, 6.25, 43, 22, 50, 33, 12.5, 25, 8, 38, 75, 16.5 mm) [Appelberg 2000, CEN document 2005].

Caught fish were determined to species, their total length (Tl) (in cm) and body mass (W) (in g) were measured. The species richness, size structure and the structure of domination in the abundance and biomass of fish were determined. The coefficient of condition of the fish species present in both lakes was estimated by the following formula: $C = W \cdot 100\ 000/Tl^3$; gdzie: C – coefficient of condition, Tl – total length (in mm), W – body mass (in g). The fish data obtained in control fishing were converted to catch per unit effort (NPUE and WPUE). For the abundance, the NPUE, it was the number per unit effort, i.e. number of fish individuals caught in the one net after 12 hour fishing), and for the fish biomass, WPUE, it was weight per unit effort, i.e. fish biomass (in grams) of the fish caught in one net after 12 hour fishing. The share of predatory

fish and small cyprinids fish in the total abundance and total biomass were estimated and also ratio predatory:unpredatory fish was calculated. For the species found in the both lakes the size structure of fish and individuals average weight were compared.

The NPUE and WPUE for lakes, and the total length, weight and coefficient of condition of individual fish species data, noted in the both lakes, were tested for normality of distribution (test W Shapiro-Wilk). Variables NPUE and WPUE had non-normal distribution (NPUE, $W = 0.57272$, $p = 0.0001$; WPUE, $W = 0.88987$, $p = 0.0132$) therefore, for evaluation of statistical significance of group, the Mann-Whitney U test for two independent groups was used. To determine statistical differences in average total length, body mass and coefficient of condition of fish in both lakes, the data was tested using analysis of variance (one-way ANOVA). Upon determination the statistical differences, the post-hoc Tuckey test for unequal of frequencies was used. The all analyzes were performed using program Statistica 6.0, at the significance level $p \leq 0.05$.

RESULTS

The eight fish species (from 6 to 8), was found in eutrophic lake Sumin, while in the hypertrophic lake Szyczyńskie only 4, from 2 to 4 species. In the both lakes the perch, roach, bleak and brown bullhead was found, moreover the pikeperch, bream, white bream and ruffe were noted only in eutrophic lake (Tab. 2). Most of the recorded fish belong to phyto-litophylous and eurytopic, and according IUNC classification belong to the least concern species. Furthermore, it is important that in both lakes the alien species brown bullhead (*Ictalurus nebulosus*) was found (Tab. 2).

An analysis of the fish numbers structure showed that the dominant species in the eutrophic lake was white bream (approx. 64.4%), but also bream (c.a. 10.3%) and brown bullhead (ca 9.0%) had a significant share in the fish abundance (Fig. 1A). In the hypertrophic lake in the abundance structure dominated bleak acting in 83.2% of all caught fish. An important share characterized the perch (15.8%), while the other two species i.e. roach and brown bullhead accounted 0.6% and 0.3% of the total number of fish, respectively (Fig. 1A).

In eutrophic lake in the structure of the biomass the white bream, brown bullhead and pikeperch constituting 48.4%, 18.4% and 13.8% of the total fish biomass. The perch (approx. 62.8%) was a dominant in the total fish biomass in the hypertrophic lake, but a large participation had also a bleak (25.6%). In the same lake also brown bullhead has significant share in the total fish biomass (7.9%) (Fig. 1B).

Estimated variables CPUE and WPUE in the hypertrophic lake reached higher values. The average number of fish caught in Syczyńskie Lake was ca. NPUE 522 and was more than 5 times higher than in eutrophic lake (c.a. 99 NPUE). As showed statistical analysis, the differences were not statistically significant (M-W, $Z = 0.9238$, $U = 53.000$, $p = 0{,}355$) (Fig. 2).

Table 1. Physical and chemical characteristic of water in the investigated lakes (mean values for summer period 2008)

Lake	SD, m	pH	Conductivity, µS cm^{-1}	Total suspension, mg dm^{-3}	Chlorophyll *a*, µg dm^{-3}	Dissolved oxygen, mg dm^{-3}	Total P, mg dm^{-3}	P-PO_4, mg dm^{-3}	N-NH_4, mg dm^{-3}	N-NO_3, mg dm^{-3}
Sumin	0.85	8.10	410	4.23	8.45	12.83	0.097	0.005	0.348	0.182
Syczyńskie	0.45	8.20	536	19.65	132.10	11.41	0.381	0.155	0.189	0.504

Table 2. Characteristics of fish species found in Sumin and Syczyńskie Lakes

Family	Species	R	A	K	T	Sumin	Syczyńskie
Cyprinidae	White bream – *Blicca bjoerkna* (L.)	Phyto-litophylous	E	LC	I	X	
	Bream – *Abramis brama* (L.)	Phyto-litophylous	E	LC	I	X	
	Roach–- *Rutilus rutilus* (L.)	Phyto-litophylous	E	LC	O	X	X
	Bleak – *Alburnus alburnus* (L.)	Phyto-litophylous	E	LC	I	X	X
Percidae	Ruffe – *Gymnocephalus cernuus* (L.)	Phyto-litophylous	E	LC	I	X	
	Perch – *Perca fluviatilis* (L.)	Phyto-litophylous	E	LC	I/P	X	X
	Pikeperch – *Sander lucioperca* (L.)	Phytophilous	E	LC	P	X	
Ictaluridae	Brown bullhead – *Ictalurus nebulosus* (Lesueur)	Phytophilous	E	A	O	X	X
Species richness (range)						4 (2–4)	8 (6–8)

R – classification of species to reproduction guilds (after Balon [1975]); A – habitat preferences (after Schiemer and Waidbacher [1992]), E – eurytopic fish; K – IUNC categories after Witkowski *et al*. [2009]: LC – least concern species, A – alien species; T – affiliation to a trophic group: I- feeding on invertebrates, O – omnivorous, P – predatory

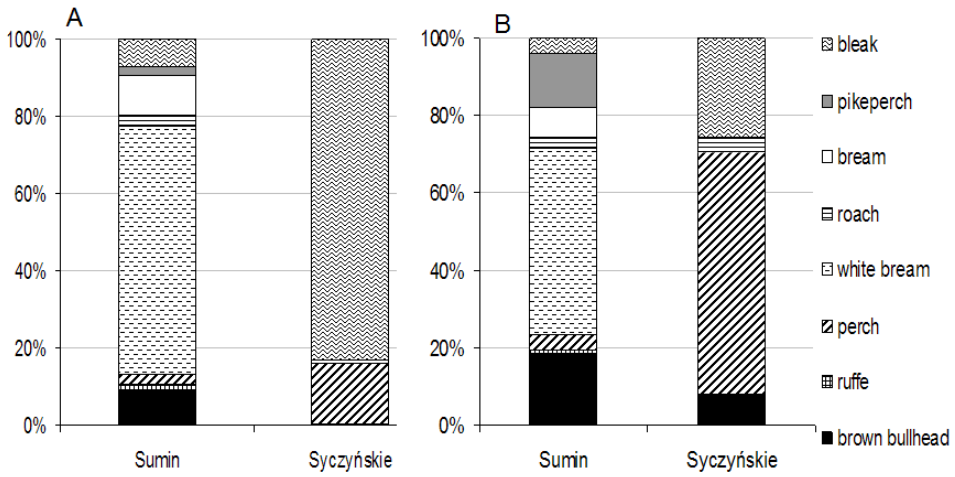

Fig. 1. The structure of dominance in number (A) and biomass (B) of fish in investigated lakes

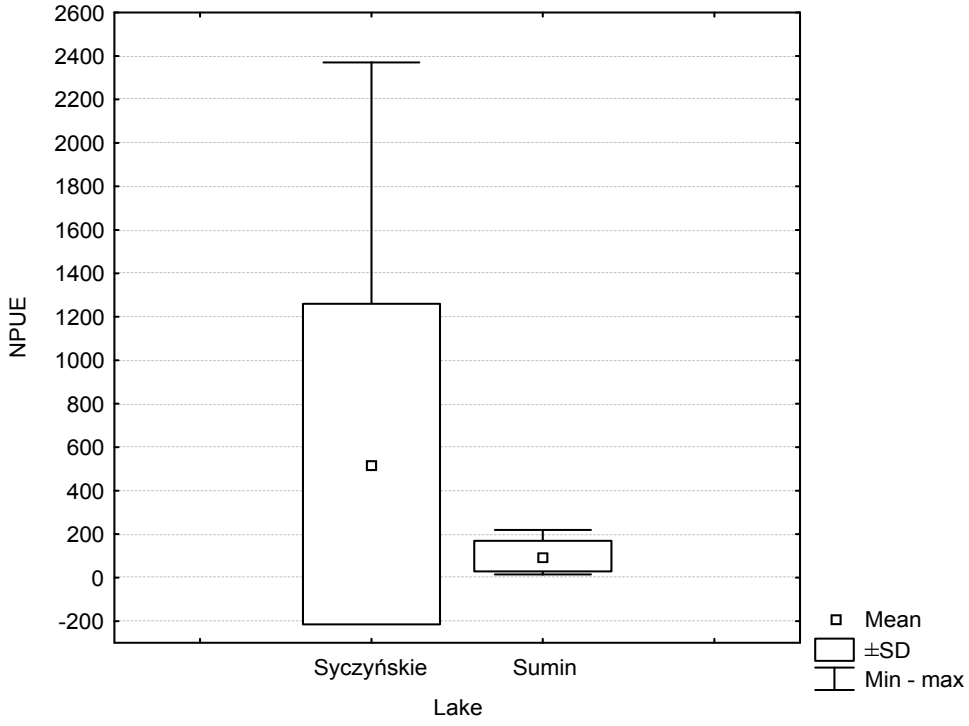

Fig. 2. Fish number (NPUE) in Sumin and Syczyńskie Lakes

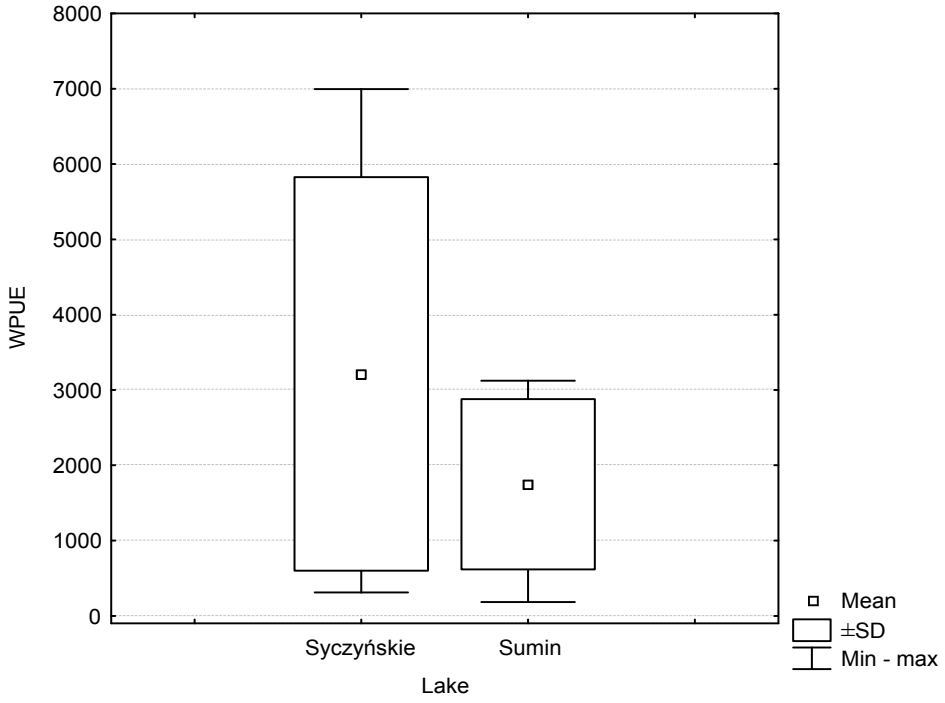

Fig. 3. Fish biomass (WPUE) in Sumin and Syczyńskie Lakes

The biomass of fish caught was almost twice as high in the hypertrophic lake (ca. 3213 WPUE) than in eutrophic lake (ca. 1747 WPUE), but just as in the case of fish abundance, these differences were statistically insignificantly (M-W, U = 53.000, Z = 1.097, p = 0,273) (Fig. 3).

Analysis of results showed that higher value of ratio predatory : upredatory fish, both in numbers and biomass were found for hypertrophic lake than eutrophic lake, and its average value was 1.34 and 1.06, respectively.

The characteristics of the total length, body weight and coefficient of condition of fish from both lakes are presented in Table 3. Analysis of the results showed that a significantly greater total length was observed for perch and bleak in eutrophic lake, while for the brown bullhead and roach in the hypertrophic lake. Similarly, a greater average weight had brown bullhead and roach in the hypertrophic lake, and bleak in eutrophic lake. Only average body weight of perch in the two studied lakes were not different statistically (Tab. 3). The analysis of fish condition showed that brown bullhead, roach and bleak in the hypertrophic lake had higher values of this parameter, and only coefficient of condition of perch were not different statistically (Tab. 3).

Table 3. Characteristics of total length (Tl), body mass (W) and coefficient of condition (C) of fish from investigated lakes

Species / Lake	Brown bullhead		Perch		Roach		Bleak	
	Number of fish (N)							
Sumin	107		28		34		86	
Syczyńskie	10		497		20		2609	
Total length (Tl) (in cm)								
	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range
Sumin	13.96^{B} ±2.85	10.00–20.50	13.20^{A} ±2.09	10.00–17.60	12.11^{B} ±1.73	9.00–15.40	10.81^{A} ±1.05	8.00-12.70
Syczyńskie	20.25^{A} ±2.04	18.00–23.80	11.90^{B} ±2.84	4.7–23.20	14.03^{A} ±2.67	9.00-17.20	6.12^{B} ±0.49	5.00-9.00
Body mass (W) (in g)								
	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range
Sumin	36.07^{B} ±22.76	11.00–104.00	28.11 ±13.96	12.00–63.00	17.76^{B} ±7.36	7.00-39.00	$9,48^{A}$ ±2.63	4.00-15.00
Syczyńskie	153.20^{A} ±52.54	85.00–252.00	24.37 ±24.20	1.00–192.00	34.75^{A} ±15.03	9.00-54.00	1.89^{B} ±0.34	1.00-5.50
Coefficient of condition (C)								
	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range
Sumin	1.20^{B} ±0.14	0.88–1.60	1.14 ±0.05	1.05–1.22	0.97^{B} ±0.15	0.49-1.14	0.74^{B} ±0.12	0.50-1.17
Syczyńskie	1.78^{A} ±0.16	1.46–1.91	1.17 ±0.14	0.80–1.66	1.17^{A} ±0.09	1.06-1.37	0.83^{A} ±0.13	0.54-1.76

$^{A, B}$ for each species means of characteristics designated by the letters in columns differ significantly at $p \leq 0.05$

DISCUSSION

Studied lakes represent different ecological status, as indicated by the physical and chemical parameters (Tab. 1). Due to the values of these parameters Kornijów *et al*. [2002a] classified the lakes according to the theory of alternative stable states of lakes Syczyńskie Lake as a lake phytoplankton (PD) and Sumin Lake, revealing many intermediate features, as a phytoplankton-macrophyte dominated lake (PMD). Overall, in the studied lakes a small number of species (4 and 8) was observed.

Typically, the number of fish species in lakes of Łęczna-Włodawa Disctrict region, ranged from 6 to 12 species, in extreme cases, for example in Skomielno Lake, up to 18 [Rechulicz 2006, 2008]. As reported Kolejko [2009] in the Bikcze and Mytycze, the other reservoirs of this region connected to the Channel Wieprz-Krzna, the number of species ranged from 12 to 13, and in the mesotrophic lakes, up from 18 to 23 species.

The analysis of results showed that in the eutrophic lake the dominant species in the structure of the number was white bream, while in the hypertrophic lake the bleak and perch (Fig. 1A and B). This is interesting, because in most of Europe waters and waters of this region dominant species are roach [Schiemer and Wieser 1992, Kolejko 2009]. On the other hand, not only the dominance of roach, but other cyprinids fish are typically for lakes with higher trophy status, which of course negatively affects their functioning [Carpenter *et al*. 1985, Jeppesen *et al*. 2000].

The most important group of fish in the lakes are the piscivirous fish, which are necessary in the prevention of eutrophication of lakes and are helpful in proper functioning of aquatic ecosystems [Kornijów 1997, Gliwicz 1999, Zdanowski 2008]. In the studied lakes the total participation predators was significant. In the eutrophic lake this group accounted 4.5% in the number structure and 17.5% in the biomass of all fish caught, while in the hypertrophic lake 15.8% and 62.8%, respectively (Fig. 1A and B). It also indicated the high ratio predatory : unpredatory fish, because about 1.0 and 1.3, respectively. However, these predators were in most cases very small (i.e. perch in hypertrophic lake average Tl = 11.9 cm) which despite their large share of had no effect on the improvement of the trophic status. Especially as regards the perch, who requires a slightly larger size, to effectively control the population of cyprinids fish [Dörner *et al*. 1999]. Reverse correlation in the Danish lakes with the various trophic state was observed by Jeppesen *et al*. [2000]. The reduced of nutrient content had effects for increase the number of predatory fish, especially perch. Simultaneously, these studies showed that changes in the structure of fish fauna were unimodally related to the P total.

The effective possibility of reconstruction of fish community may be carried out biomanipulation by removal planktivorous and bentivorous fish or stocking by large size predatory fish. In addition, it would be important, to give the possibility of natural reproduction of valuable fish species and indirect pro-

tection of predatory fish from excessive angling pressure [Bergman *et al.* 1999, Drenner and Hambright 1999, Lammens 2001, Mehner *et al*. 2001].

To the improving structure of the fish fauna of these lakes the submerged macrophyte could be helpful. According Kornijów *et al*. [2002a] the littorals of both lakes are poorly developed by submerged macrophytes. Due the presences of submerged macrophyte, species such as pike will be reproduce by natural spawning and increase its abundance regardless of fish stock [Buras *et al*. 1996].

The results of control fishing showed that with increased trophy (expressed as total P and $N\text{-}NO_3$, etc.) in the hypertrophic lake the number of fish caught was more than 5 times higher than in eutrophic lake and biomass almost doubled (Fig. 2). But as the analysis shows that, despite clear differences in the values, they proved to be statistically insignificant. The large numbers of fish, depending on the increase in total P has also confirmed by Jeppesen *et al*. [2000]. With the growth of trophy of lake was 10 times more of number of caught fish between the classes of the content of TP. Simultaneously, the author has observed a decrease in the average body length with increasing trophic state of cyprinids fish (roach and bream).

The diversity of trophic lakes may also indicate parameters of fish condition (Tab. 3). Among the species found in both lakes, almost all (except the perch), in hypertrophic lake, had a significantly higher value of coefficient of condition. Typically, with large number of fish in the lake leads to food competition of one trophic level and then decrease of the fish condition. After Kornijów *et al*. [2002a, b], Syczyńskie Lake, classified as typically phytoplankton dominated lake and bleak (planktivorous fish), which dominate here, has a lot of food and thereby the greater value of body condition.

CONCLUSIONS

The ichthiofauna of investigated lakes characterized by a small number of fish species, mainly cyprinids.

The cyprinids fish were dominant in abundance structure in both lakes, white bream in eutrophic lake and bleak in the hypertrophic lake.

In the structure of the biomass in the eutrophic lake the white bream was dominated, but also a significant share had a pikeperch. In the hypertrophic lake largest share of biomass had perch, but his small size (average Tl ca. 12 cm) does not allow to effectively control the population of cyprinids fish.

The number of fish (NPUE) was five times higher, and the biomass (WPUE) almost twice higher in hypertrophic lake than in eutrophic lake (no statistical differences at $p \leq 0.05$), however, the fish from hypertrophic lake had higher value of coefficient of condition.

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STRUKTURA ICHTIOFAUNY I PRODUKTYWNOŚĆ RYBACKA JAKO WSKAŹNIK ZRÓŻNICOWANIA TROFICZNEGO DWÓCH PŁYTKICH JEZIOR

Streszczenie. Strukturę ichtiofauny i jej produktywność badano w dwóch jeziorach o zróżnicowanym statusie troficznym: jezioro Sumin – eutroficzne oraz jezioro Syczyńskie – hipertroficzne. Odłowy kontrolne ryb przeprowadzono w trzech sezonach w 2008 r. za pomocą sieci multimesh gillnet. Ogółem odnotowano od 2 do 8 gatunków ryb, z czego w jeziorze eutroficznym stwierdzono 8 gatunków, zaś w jeziorze hipertroficznym 4 gatunki. W strukturze liczebności ryb w obu jeziorach dominowały ryby karpiowate: krąp (64,4%) w jeziorze eutroficznym oraz ukleja (83,2%) i okoń (15,8%) w jeziorze hipertroficznym. W strukturze biomasy dominowały odpowiednio: krąp (48,8%), sandacz (18,4%) i sumik karłowaty (13,8%) oraz okoń (62,8%) i ukleja (25,6%). W jeziorze hipertroficznym odnotowano ponad 5-krotnie wyższą liczebność ryb (w NPUE) i prawie dwukrotnie większą biomasę (w WPUE) niż w jeziorze eutroficznym. Wszystkie gatunki ryb odnotowane w obu jeziorach charakteryzowała niewielka średnia długość całkowita i masa ciała, natomiast ryby z jeziora hipertorficznego wykazywały istotnie lepszą kondycję.

Słowa kluczowe: struktura ichtiofauny, status troficzny jeziora, produktywność rybacka, płytkie jeziora