Pol. J. Environ. Stud. Vol. 23, No. 3 (2014), 845-851

Original Research

Long-Term Changes of the Fish Community in a Small Hypertrophic Lake

Jacek Rechulicz*

Department of Hydrobiology, Fishery Laboratory, University of Life Sciences in Lublin,
Dobrzańskiego 37, 20-262 Lublin, Poland

Co-financed by National Fund
for Environmental Protection
and Water Management

Received: 29 October 2013
Accepted: 6 March 2014

Abstract

A study of fish fauna in a small hypertrophic lake was conducted in the spring, summer, and autumn of 2006-10. In total 11 fish species representing 4 families were found. The species richness was low, depending on the season, and ranged from 2 to 7 species. A variation of species dominance, depending on the year and season, was found. Total fish abundance and biomass were varied according to the season, but differences depending on the year had been noted only in fish biomass. The fish fauna was characterized by low values in indices of diversity and the estimated turnover rate of the fauna ranged from 0.09 to 0.56, and the regression analysis showed a significant growth in its upward trend.

Keywords: hypertrophy, small lake, fish, biological diversity

Introduction

Water basins, especially small water bodies, are subject to the continuous effects of eutrophication. This results in increasing the trophic state and changes water parameters, especially total P content (TP) and chlorophyll *a,* and leads to a reduction in visibility [1, 2]. An extreme example of this is hypertrophy, which is usually caused by finding itself in a specific location, a high pollution lake catchment basin, poor fishery management, and a number of other internal factors [3]. This is usually manifested by the destabilization of a food web and changes in communities at different levels of the trophic pyramid [4].

*e-mail: jacek.rechulicz@up.lublin.pl

In recent years, in hypertrophic water basins, observations of the dynamics of change in water quality [5], phytoplankton [6], zooplankton [7-9], and macrophytes [10] were widely conducted.

The fish usually are the last level of the food web and their presence is crucial for the functioning of aquatic ecosystems. Through eating they affect the inorganic nutrient influx and change the proportions between groups of organisms from lower levels of the trophic pyramid [4, 11-13].

In the available literature, fish are often treated as part of groups of organisms present in a more or less eutrophic aquatic ecosystem. There is a lack of studies only with regard to fish, their diversity, dynamics, and composition in highly eutrophic lakes. And good knowledge of the composition and dynamics of the fish community in the long term may be helpful in making future activities related to the restoration of these water bodies. Thus, the aim of the present study is to determine the long-term and seasonal changes in the fish community, which could give an answer to the question whether the hypertrophic small, shallow lake fish species composition is permanent or whether at any disturbance may vary.

Material and Methods

The observation of the fish fauna was conducted in small (5.7 ha) and shallow (max. depth: 2.9 m, mean depth: 0.9 m) Lake Syczyńskie in eastern Poland (51º17'12"N, 23º14'16"E). The characteristics of hydromorphology and the water condition of the lake was already presented in several earlier papers [14-18]. Currently, fishery management is not conducted on the lake. The last fish stocking was more than 10 years previously. The lake is rarely used by anglers and often by poachers.

The control net fishing in Lake Syczyńskie was conducted from 2006 to 2010, three times in each year (spring (V), summer (VII), and autumn (IX)) using a standardized fishing method with multiple mesh (6.25-75 mm) gill net [19]. All collected fish were identified to species and weighed (W, to nearest 0.1 g), and total length (Tl) was measured (to nearest 1 mm) [20]. The obtained in control fishing data were converted to catch per unit effort. For the abundance the NPUE, i.e. number of fish individuals caught in the one net after 12 hours of fishing (ind.×net^{-1}×12h^{-1}), and for fish biomass, WPUE i.e. the biomass (in grams) of the fish caught in one net after 12 hours fishing (g×net^{-1}×12h^{-1}).

The biocenotic dominance index (%*n*) and the stability of occurrence (C_i) for all species was determined by following formulas:

$$\%n = 100 \times n_i/N$$
$$C_i = 100 \times s_i/s_t$$

...where: n_i – number of individuals of "*i*" species, N – total number of fish, s_i – number of samples with "*i*" species present, s_t – total number of samples.

For each season and year the diversity indices such as species richness (*S*), the number of species in each sample, and Margalef species richness index (*R*), are calculated using the following formula:

$$R = S\text{-}1/\ln(N)$$

...where: *S* – species richness, N – total number of fish calculated.

To calculate the estimated species richness the "Jackknife 1" procedure was used [21]. The other indices such as Shannon-Wiener index (H') and Simpsons diversity (D) using BiodiversityPro software were determined. In addition, the turnover rate of fish (*t*) according to the formula Brown and Kodric-Brown [22] was calculated:

$$t = (b+c)/(S_1 + S_2)$$

...where: *b* – the number of fish species present only in a previous sample, *c* – the number of fish species present only in the next sample, S_1 – the total number of species found in previous sample, S_2 – the total number of species found in the next sample. This index ranges from 0 to 1 (where 0 – no difference in fish fauna, 1 – complete replacement of the entire fish fauna). Analysis of similarity (Bray-Curtis distance metric) was used to compare the differences among the results of control fishing in each sample and year [23].

Prior to statistical analyses all fish data were log-transformed to reduce the influence of extreme values. Data

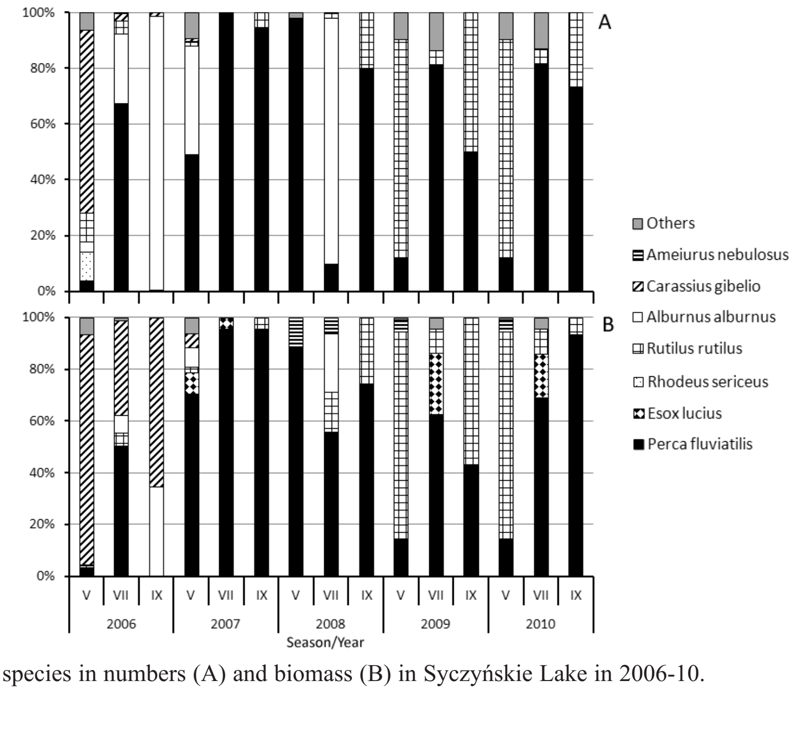

Fig. 1. Dominance of fish species in numbers (A) and biomass (B) in Syczyńskie Lake in 2006-10.

Table 1. Total abundance, stability of occurrence, and morphological characteristics (Tl, in cm; W, in g) of fish from Lake Syczyńskie.

	Species	N	%n±sd	C_i	Total length (Tl)		Body mass (W)	
					Means±sd	Min-max	Means±sd	Min - max
Unpredatory	Crucian carp, *Carassius carassius*	9	0.47±1.63	20.00	14.94±3.34	11.50-21.50	82.28±60.11	27.00-186.00
	Bitterling, *Rhodeus sericeus*	8	0.68±2.61	6.67	4.60±0.43	4.00-5.40	1.00±0.10	1.00-1.20
	Bleak, *Alburnus alburnus*	3145	16.93±33.00	33.33	6.21±0.64	0.50-9.10	2.08±0.96	1.00-25.70
	Roach, *Rutilus rutilus*	811	19.26±27.50	80.00	12.22±2.61	4.60-19.60	24.79±19.85	1.30-89.00
	Rudd, *Scaridinius erythrophthalmus*	43	1.27±2.70	20.00	10.59±3.78	7.20-18.80	19.31±18.65	3.00-72.10
	Sunbleak, *Leucaspius delineatus*	64	1.05±2.76	13.33	6.20±0.81	5.30-7.00	2.75±0.84	2.00-4.00
	Ruffe, *Gymnocephalus cernuus*	16	0.72±1.91	13.33	3.80±0.10	3.70-3.80	1.00±0.10	1.00-1.20
Predatory	Perch, *Perca fluviatilis*	2411	54.09±37.18	100.00	10.38±4.62	4.60-25.30	23.71±33.66	1.00-390.00
	Pike, *Esox lucius*	11	0.37±0.83	26.67	38.91±2.71	33.00-42.50	365.51±48.50	265.50-426.50
Invasive	Prusian carp, *Carassius gibelio*	77	4.75±16.92	26.67	18.12±2.16	14.10-25.50	108.52±48.34	51.00-347.00
	Brown bullhead, *Ameiurus nebulosus*	27	0.41±0.80	26.67	17.33±2.60	15.50 -23.80	95.44±54.74	53.00-252.00

N – total numbers, sd – standard deviation

were checked for normality (Shapiro-Wilk test) and homogeneity of variances. To verify the impact of year or season on fish number (NPUE) and their biomass (WPUE) the non-parametrical Kruskal-Walis ANOVA H test by rank was used. To determine changes of the indices of biological diversity and turnover rate of the fish fauna year by year, the analysis of multiple regressions was conducted. The statistical analyses were carried out with Statsoft Statistica software, with a significance level of $p \leq 0.05$.

Results

In Lake Syczyńskie a total of 6,622 specimens representing 11 species and 4 families were collected from 2006 to 2010. Among these, two piscivorous fish species (perch and pike) and two invasive fish species (i.e. brown bullhead and Prussian carp), were found (Table 1). During the whole study period the perch and roach were characterized as having the greatest stability in occurrence at 100 and 80, respectively. In addition, these two species have the highest average share in the numerical structure of fish fauna. Among other species, bleak also has a significant share (16.9%) (Table 1).

Species richness ranged from 2 to 7 (average 3.67±1.68) (Fig. 1). The largest number of species was recorded in 2006 and the lowest in 2008. However, in the spring and summer usually was almost two times greater than in the autumn. Analysis of estimation of species richness (Jackknife 1) showed that the maximum number of species in the lake would be about 13.

The results of control catches showed that perch accounted for over 60% of the total number and composition of fish population in most terms. Dominance was highest between summer 2007 and spring 2008, in the range from 94.4% to 99.7%. Among other species, bleak were characterized, a significant share (up to 98%), especially in autumn 2006 and summer of 2008 (Fig. 1). However, a significant share in the abundance of crucian carp only in the spring of 2006 was reported. Moreover, since autumn 2007 roach have been a regular part of the fish community, whose participation ranged from a few up to more than 78% (i.e. spring 2009 and 2010) (Fig. 1).

In all seasons of 2007 and 2008 and summer and autumn 2010 a significant share of the total biomass was characterized by perch. Prussian carp, a significant share in the biomass, ranged from 36.7% to 89.1%, only in 2006. However, the fish biomass, from spring 2009 to spring 2010 (except summer 2009) was dominated by roach. Additionally, in summer 2009 and 2010 there was a significant share of pike in the biomass and, since 2008, a few percent (especially spring 2008 – 12%) participation of brown bullhead.

Analysis of the results showed that the year did not affect the number of fish caught (Kruskal-Wallis ANOVA, $p = 0.669$), while the variation in the number of fish depending on the season was observed. Significantly fewer ($p < 0.0001$) fish were caught in autumn (Fig. 2C).

Statistical analysis of the biomass of caught fish showed that in 2006 to 2009 fish biomass was in the range of 1066 WPUE to 3276 WPUE. The largest biomass of fish (statistically significant) was caught in 2010 (median 4411 WPUE) ($p = 0.008$) (Fig. 2B). The season also affects the biomass of caught fish. In autumn the biomass of fish was smallest (524 WPUE) ($p <0.001$) (Fig. 2 C, D).

Analysis of similarity showed that most closely related to each other were the results of the catches carried out in 2009 and 2010 (94.9% similarity, Fig. 3A). In other years (2006-08) the degree of similarity was approximately 50%. Moreover, the most closely related net fishing results to each other were in spring 2009 and spring 2010 (99.6%), and summer 2009 and 2010 (Fig. 3B).

Overall, the indices of diversity reached very low average values, i.e. $H' = 0.52±0.09$, $D = 0.69±0.08$, and $R = 0.47±0.15$. Regression analysis of these indicators showed that the period 2006 to 2010 was followed by a slight, non-significant ($p > 0.05$) reduction in their value (Fig. 4B, C, D). In contrast, the calculated turnover rate ranged from 0.09 to 0.55 (average of 0.38±0.13) and its value increased significantly year by year ($r = 0.544$, $p = 0.044$) (Fig. 4A).

Discussion

Fish are a regular component of freshwater ecosystems and their composition depends on the type of environmental conditions of the water basins. More than 30 years ago, Opuszyński [24] proposed a theory of "ichthyoeutrophication" which stated that, in the water bodies, the change of water quality and habitat conditions leads to changes of the fish community. Another factor affecting the fish community can also be a low share of piscivorous fish and waterfowl impact [25], as well as poorly conducted fishery management.

Observed in recent years, the poor water quality of Lake Syczyńskie has allowed it to be specified as an extremely hypertrophic water body [14, 26]. According to Jeppesen et al. [27] in such waters there can be seen a different response in species richness and biodiversity for the various taxonomic groups. In his research, for most groups of species richness and diversity showed a unimodal relationship with TP, and were also variably related to area and depth of the lake. Lake Syczyńskie is small and shallow, and so like other hypertrophic lakes, was characterized by low species richness (Fig. 1). Earlier studies conducted on this lake by

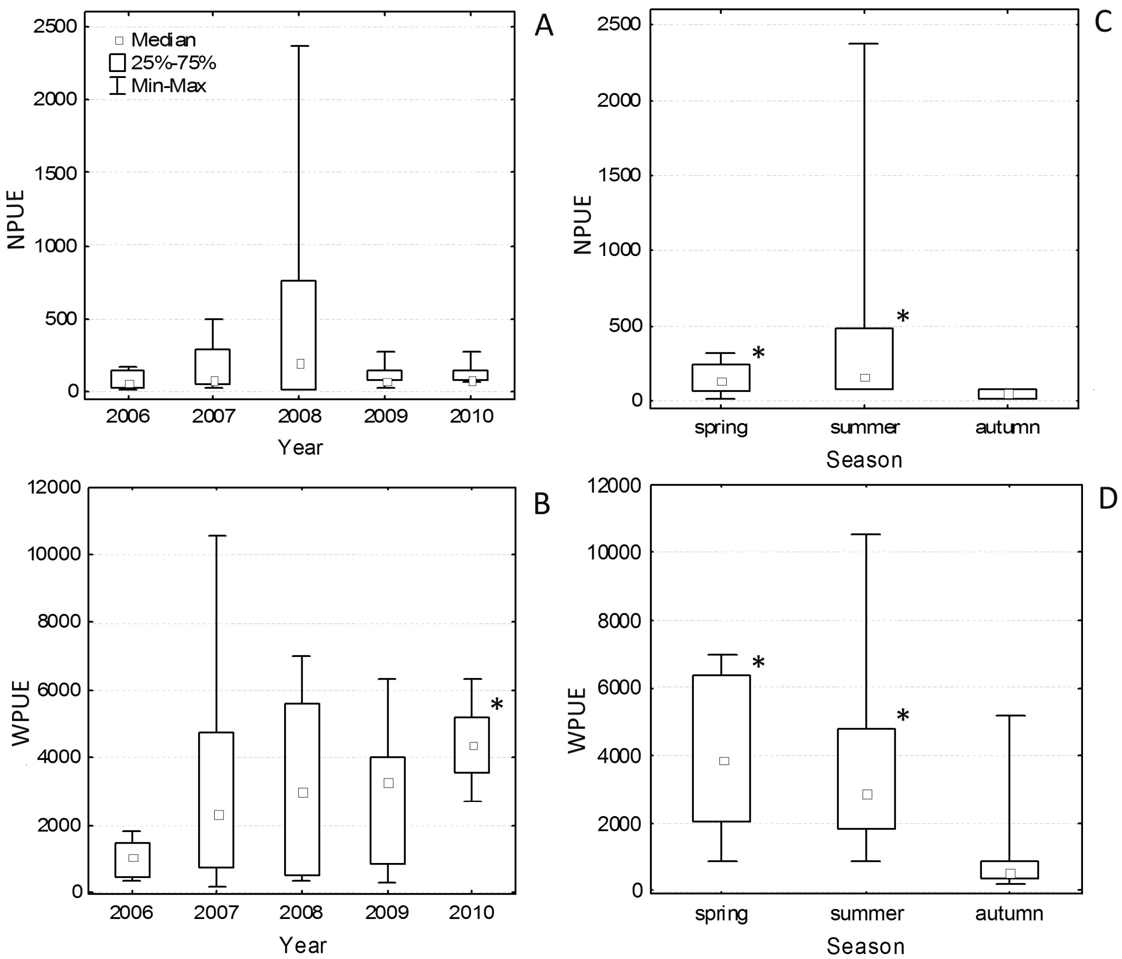

Fig. 2. The total numbers (NPUE) and biomass of fish (WPUE) in years (A, B) and seasons (C, D) in Syczyńskie Lake; *significant differences at p≤0.05

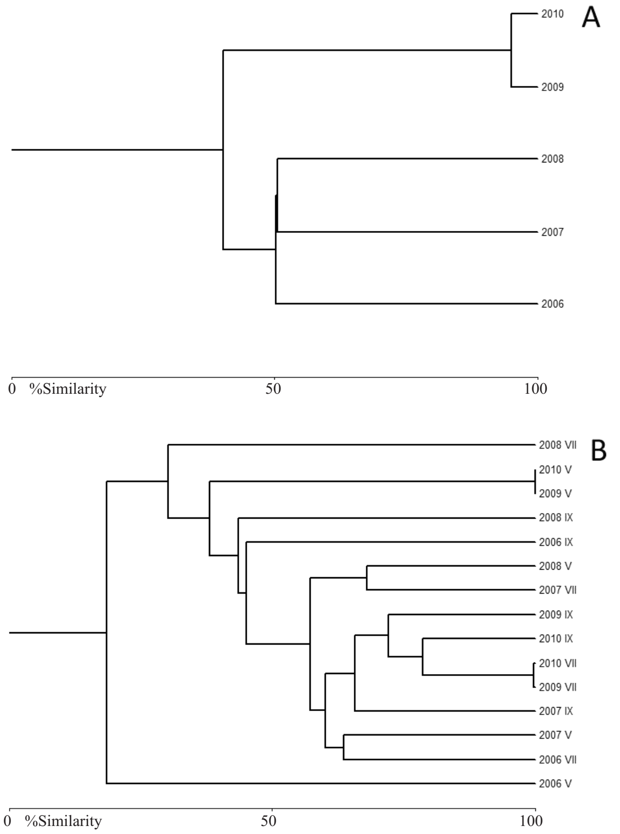

Fig. 3. The similarity (Bray-Curtis cluster analysis) of fishing results in Syczyńskie Lake in years (A) and seasons and years (B).

Kornijów et al. [15] showed only 9 fish species, among which the most numerous were sunbleak, roach, and rudd, whereas in the biomass roach and rudd dominated. In present research, changing the dominant species on the perch, roach, and bleak (Table 1) and differences in the number of species and fish composition in each control fishing (Fig. 1) shows large dynamics of the fish community. This is confirmed by analysis of the turnover rate of fish index, which increased significantly in 2006-10 (Fig. 4A). Changes of the fish community may provide results on the analysis of similarity (Fig. 3A), where the clear similarity between 2006, 2007, and 2008 and 2009 and 2010 was determined. Moreover, diversity indices reached lower values year by year (Fig. 4B, C, D), which may seem typical for hypertrophic water bodies [24, 27]. On the other hand, as reported by Jeppesen et al. [27] after having examined 71 Danish lakes with different trophic levels, estimates of the fish community change along a trophic gradient, by analysis of diversity indices, is not entirely clear.

Considerable impact on the fish composition and values of its diversity may be on the lack of submerged macrophytes in the lake. Often this part of the lake is a spawning ground and a place of refuge for many species of fish [28]. Possibly by this, species such as rudd and crucian carp were relatively rare, and the latter one had a higher abundance and share in total fish biomass only in the initial period of study (Fig. 1). Usually, the fish communities from highly eutrophic or at risk of eutrophication water basins are dom-

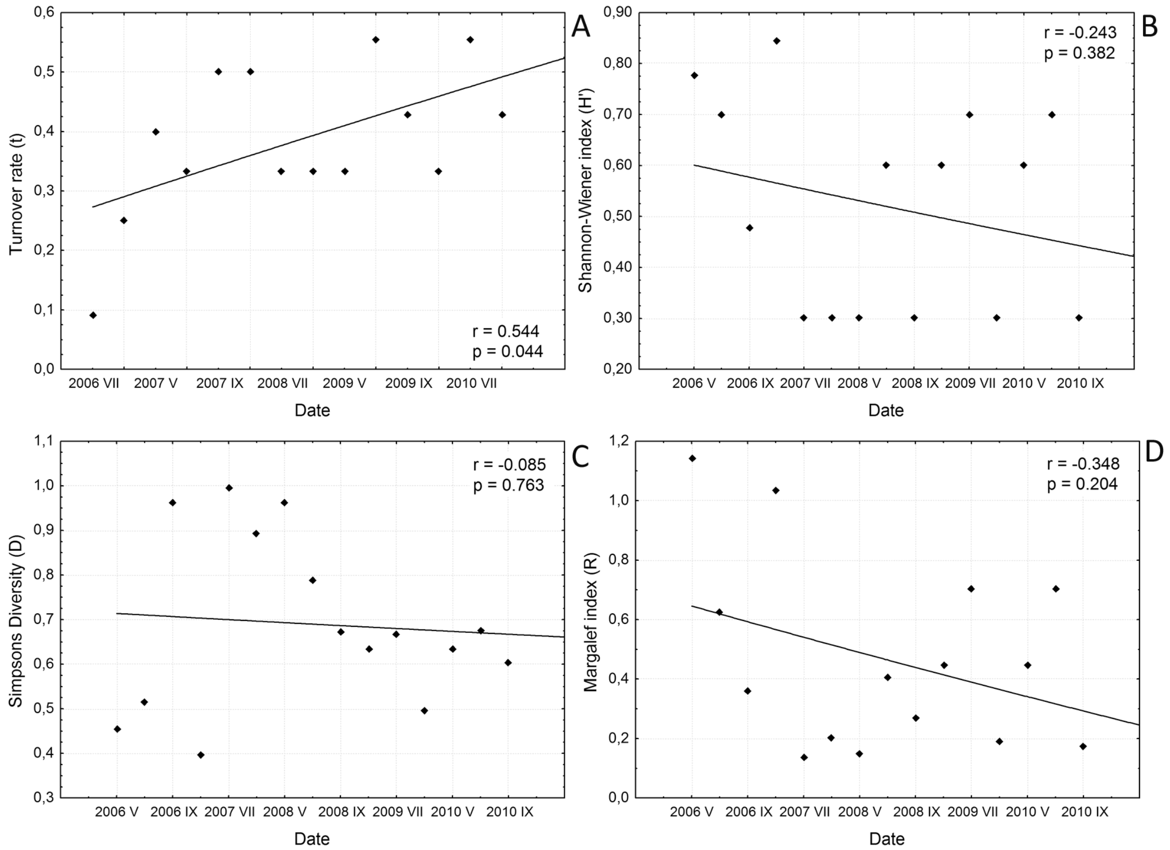

Fig. 4. Results of regression analysis of turnover rate (t) (A) and indices of diversity of fish (Shannon –Wiener (H') – B, Simpsons Diversity (D) – C and Margalef index (R) – D) in Syczyńskie Lake in 2006-10.

inated by omnivorous species and higher density and dominance of smaller-sized fish [29]. As Lawton [30] reported, usually the large population is accompanied by the small-sized body of its individuals. Such a pattern was observed in the studied lake, where the dominant species was perch, roach, and bleak with small body size (Table 1). And that could have implications for the ecosystem level of Lake Syczyńskie, because the dominance of small-sized fish, in a small, shallow lake, leads to higher metabolic and excretion rates, which may be more pronounced at higher temperatures [31]. In addition, the dominance of cyprinids results in increased competition for food for a small perch, which in turn causes a decrease in its average size. As reported by Grimm and Backx [32], this in turn reduces predation on young fish and a decline of large perch in the population.

The increase in total fish biomass and the decline in the percentage of piscivores with increasing TP was reported in the results from studies in temperate and subtropical regions [33-35]. Jeppesen et al. [27] has reported similar results, but in addition according to this author, the biomass of roach and bream was positive, while the biomass of perch was negatively correlated with an increase in TP. Similar was found in perch specimens from Lake Syczyńskie, whose size and biomass were relatively small (Table 1). The perch is a fish species dominant in nutrient-poor lakes [28], but the present study contradicts this. In most control fishing performed in Lake Syczyńskie, perch was the dominant species, despite the fact that the lake is extremely hypertrophic (Fig. 1). Another dominant species was roach, whose share in number and biomass of fish was significant since the spring of 2009. According to Stenson [36], this species has a high plasticity in plankton eating and had an ability to exploit smaller zooplankton prey.

The impact on the composition and change of the fish community in a small lake could be the presence of invasive species such as brown bullhead and crucian carp. These invasive species compete for food with native fish species, prevent reproduction and also feed on fish. Another important aspect is the lack of fishery management on the lake and poaching led by local residents, which is associated with the fish-out of the lakes that are usually the largest specimens of fish. In addition, the presence and high concentrations of cyanobacterial blooms were found in significant quantities almost throughout the year [17, 18]. But to determine the potential impact of cyanobacterial toxins on the health of the fish from Lake Syczyńskie was the subject of other studies [37].

Conclusions

Five years observing the fish community in a small hypertrophic lake has shown that the predominant species in both numbers and biomass were perch and roach, but a large abundance of bleak was characterized occasionally. Most species are characterized by a small average body size. The ichthyofauna has a small species richness and low values of indices of biological diversity and additionally is characterized by significant values of turnover rate. Fish abundance and biomass were varied according to the seasonal changes.

Acknowledgements

The author thanks M. Próchniak, M. Woźny, Ł. Bożek, and M. Blicharz for helpful assistance in our field work. The author also thanks Michael Norman Baczewski for language help.

References

1. KRISTENSEN P., HANSEN H. O. European rivers and lakes: assessment of their environmental state. Copenhagen (Denmark): European Environment Agency. **1994**.
2. OECD. Eutrophication of waters: monitoring, assessments and control. Paris: OECD. **1982**.
3. OTT I., KÕIV T., NÕGES P., KISAND A., JÄRVALT A., KIRT E. General description of partly meromictic hypertrophic Lake Verevi, its ecological status, changes during the past eight decades, and restoration problems. Hydrobiologia. **547**, 1-20, **2005**.
4. CARPENTER S. R., KITCHELL J. F. The Trophic Cascade in Lakes. University Press, Cambridge. **1993**.
5. ÇELIK K. Spatial and seasonal variations in chlorophyll-nutrient relationships in the shallow hypertrophic Lake Manyas, Turkey. Environ. Monit. Assess. **117**, 261, **2006**.
6. ÇELIK K., ONGUN T. Spatial and temporal dynamics of the steady-state phytoplankton assemblages in a temperate shallow hypertrophic lake (Lake Manyas, Turkey). Limnology. **9**, 115, **2008**.
7. JÜRGENS K., JEPPESEN E. The impact of metazooplankton on the structure of the microbial food web in a shallow, hypertrophic lake. J. Plankton Res. **22**, (6), 1047, **2000**.
8. KŰBAR K., AGASILD H., VIRRO T., OTT I. Vertical distribution of zooplankton in a strongly stratified hypertrophic lake. Hydrobiologia. **547**, 151, **2005**.
9. ZINGEL P. Vertical and seasonal dynamics of planktonic ciliates in a strongly stratified hypertrophic lake. Hydrobiologia. **547**, 163, **2005**.
10. MÄEMETS H., FREIBURG L. Long- and short-term changes of the macrophyte vegetation in strongly stratified hypertrophic Lake Verevi. Hydrobiologia. **547**, 175, **2005**.
11. JEPPESEN E., SØNDERGAARD M., LAURIDSEN T. L., DAVIDSON T. A., LIU Z., MAZZEO N., TROCHINE C., ÖZKAN K., JENSEN H. S., TROLLE D., STARLING F., LAZZARO X., JOHANSSON L. S., BJERRING R., LIBORIUSSEN L., LARSEN S. E., LANDKILDEHUS F., EGEMOSE S., MEERHOFF M. Biomanipulation as a restoration tool to combat eutrophication: recent advances and future challenges. Adv. Ecol. Res. **47**, 411, **2012**.
12. HA J.-Y., SANEYOSHI M., PARK H-D, TODA H., KITANO S., HOMMA T., SHIINA T., MORIYAMA Y., CHANG K.-H., HANZATO T. Lake restoration by biomanipulation using piscivore and Daphnia stocking; results of the biomanipulation in Japan. Limnology. **14**, (1), 19, **2013**.
13. VAŠEK M., PRCHALOVÁ M., PETERKA J., KETELAARS A. M. H., WAGENVOORT A. J., ČECH M., DRAŠTÍK V., ŘÍHA M., JŮZA T., KRATOCHVÍL M., MRKVIČKA T., BLABOLIL P., BOUKAL D. S., DURAS J., KUBEČKA J. The utility of predatory fish in biomanipulation of deep reservoirs. Ecol. Eng. **52**, 104, **2013**.

14. KORNIJÓW R., PĘCZUŁA W., LORENS B., LIGĘZA S., RECHULICZ J., KOWALCZYK-PECKA D. Shallow Polesie lakes from the view point of alternative stable states theory. Acta Agrophisica. **68**, 61, **2002**.
15. KORNIJÓW R., SMAL H., PĘCZUŁA W., LORENS B., RECHULICZ J., SUGIER P., PALEOLOG-DEMETRAKI A., LIGĘZA S., TARKOWSKA-KUKURYK M., KOWALCZYK D., SZAFRAN K., HALKIEWICZ A. Hypertrophication of Lake Syczyńskie (Eastern Poland). Limnol. Review. **2**, 209, **2002**.
16. SMAL H., KORNIJÓW R., LIGĘZA S. The effect of catchment on water quality and eutrophication risk of five shallow lakes (Polesie region, Eastern Poland). Pol. J. Ecol. **53**, 313, **2005**.
17. TOPOROWSKA M., PAWLIK-SKOWROŃSKA B., KRUPA D., KORNIJÓW R. Winter versus summer blooming of phytoplankton in a shallow lake: effect of hypertrophic conditions. Pol. J. Ecol. **58**, (1), 3, **2010**.
18. WIŚNIEWSKA M., KRUPA D., PAWLIK-SKOWROŃSKA B., KORNIJÓW R. Development of toxic Planktothrix agardhii (Gom.) Anagn. Et Kom. and potentially toxic algae in the hypertrophic Lake Syczyńskie (Eastern Poland). Oceanol Hydrobiol St. **35**, (1), 173, **2007**.
19. APPELBERG M. Swedish standard methods for sampling freshwater fish with multi-mesh gillnets. Fiskeriverket Information, 1, **2000**.
20. BRYLINSKA M. Freshwater fish of Poland. PWN Warsaw, pp. 23-67, **2000** [In Polish].
21. MAGURRAN A. E. Measuring Biological Diversity. Blackwell Publishing. **2004**.
22. BROWN J. H., KODRIC-BROWN A. Turnover rates in insular biogeography: effect of immigration on extinction. Ecology. **58**, 445, **1977**.
23. CLARKE K. R. Non-paramertic multivariate analyses of changes in community structure. Aust. J. Ecol. **18**, 117, **1993**.
24. OPUSZYŃSKI K. The role of fishery management in counteracting eutrophication processes. Hypertrophic Ecosystems. Developments in Hydrobiology. **2**, 263, **1980**.
25. BLANCO S., ROMO S., VILLENA M.-J., MARTÍNEZ S. Fish communities and food web interactions in some shallow Mediterranean lakes. Hydrobiologia. **506–509**, 473, **2003**.
26. KORNIJÓW R., PĘCZUŁA W. Ecosystem of a small shallow lake suffering from cyanobacterial blooms - hypereutrophic, phytoplankton dominated or both? Verh. Internat. Verein. Limnol. **29**, 1015, **2005**.
27. JEPPESEN E., JENSEN J. P., SØNDERGAARD M., LAURIDSEN T., LANDKILDEHUS F. Trophic structure, species richness and biodiversity in Danish lakes: changes along a phosphorus gradient. Freshwater Biol. **45**, 201, **2000**.
28. JEPPESEN E., SØNDERGAARD M., JENSEN J. P., HAVENS K. E., ANNEVILLE O., CARVALHO L., COVENEY M. F., DENEKE R., DOKULIL M. T., FOY B., GERDEAUX D., HAMPTON S. E., HILT S., KANGUR K., KÖHLER J., LAMMENS E. H. H. R., LAURIDSEN T. L., MANCA M., MIRACLE M. R., MOSS B., NÕGES P., PERSSON G., PHILLIPS G., PORTIELJE R., ROMO S., SCHELSKE C. L., STRAILE D., TATRAI I., WILLÉN E., WINDER M. Lake responses to reduced nutrient loading – an analysis of contemporary long-term data from 35 case studies. Freshwater Biol. **50**, 1747, **2005**.
29. TEIXEIRA-DE MELLO F., MEERHOFF M., PEKCAN-HEKIM Z., JEPPESEN E. Substantial differences in littoral fish community structure and dynamics in subtropical and temperate shallow lakes. Freshwater Biol. **54**, 1202 , **2009**.
30. LAWTON J. H. Species richness and population dynamics of animal assemblages: patterns on body size : abundance space. Philos. Trans. R. Soc. Lond. B, **330**, 283, **1991**.
31. GILLOOLY J. F., BROWN J. H., WEST G. B., SAVAGE V. M., CHARNOV E. L. Effects of size and temperature on metabolic rate. Science. **293**, 2248, **2001**.
32. GRIMM M. P., BACKX J. The restoration of shallow eutrophic lakes and the role of northern pike, aquatic vegetation and nutrient concentration. Hydrobiologia. **200:201**, 557, **1990**.
33. BACHMAN R. W., JONES B. L., FOX D. D., HOYER M., BULL L. A., CANFIELD D. E. Relations between trophic state indicators and fish in Florida (U.S.A.) lakes. Can. J. Fish. Aquat. Sci. **53**, 842, **1996**.
34. PERSSON L., ANDERSSON G., HAMRIN S. F., JOHANSSON L. Predation regulation and primary production along the productivity gradient of temperate lake ecosystems. In: Complex Interactions in Lake Communities (ed. S.R. Carpenter), pp. 45-65. Springer, New York. **1988**.
35. QUIROS R. Factors related to variance of residuals in chlorophyll – total phosphorus regressions in lakes and reservoirs of Argentina. Hydrobiologia. **200:201**, 343, **1990**.
36. STENSON J. A. E. Predatory-prey relations between fish and invertebrate prey in some forest lakes. Rep. Inst. Freshw. Ecol. Drottningholm. **58**, 166, **1979**.
37. SKOWROŃSKA B. TOPOROWSKA M. RECHULICZ J. Simultaneous accumulation of anatoxin-a and microcystins in three fish species indigenous to a lake affected by cyanobacterial blooms. Oceanol Hydrobiol St. **41**, (4), 53, **2012**.