Long-term changes in the trophic state of Suwalki lakes – an analysis by means of indices based on abundance and composition of their rotifer fauna

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Abstract: Rotifer abundance and species composition in lakes of the Suwalki Landscape Park were studied in the years 1983–1985, 2009, 2012 and 2015. Rotifer trophic state indices (TSI_{ROT}) were used to assess changes in the trophic state of the studied lakes. In most lakes of the Suwalki Landscape Park, there were no changes in rotifer communities over the 25–32 year period to indicate a decline in trophy of the lakes. However, in lakes with the strongest decline in TSI_{ROT} values, the values of indicative parameters widely varied in 2015, which may indicate that the status of rotifer communities in the lakes may be dependent on non-trophic factors.

Key words: Rotifera, zooplankton, lakes, trophic state index

Introduction

Summer communities of rotifers (Rotifera) in harmonic lakes are primarily controlled by availability of food, so they usually react strongly to changes in trophic status of lakes by changes in the community density as well as species composition (Gannon and Stemberger 1978; Ejsmont-Karabin 2012, 2013; Haberman and Haldna 2014; Ochocka and Pasztaleniec 2016). Long-term observations of rotifer fauna in lakes of The Great Masurian Lake system (Ejsmont-Karabin 2013) showed that rotifers are a very sensitive group as regards their response to both increase and decrease in lake trophy. The studies also indicate the high sensitivity of the GML system to anthropogenic changes in their watershed. The aim of the studies concerning rotifer communities in lakes of the Suwałki Landscape Park was to use the above-mentioned features of rotifer zooplankton for assessing the recent trophic status of the studied lakes as well as long-term trends in changes of their trophy.

The region under study is a diverse natural landscape which seems to retain a natural rate of eutrophication not accelerated by agriculture, settlement or tour-

ism (Jekatieryńczuk-Rudczyk et. al. 204). As a result most of the lakes are characterized by low chlorophyll-*a* concentrations and low content of cyanoprokaryotes (Karpowicz et.al. 2016). The process of eutrophication of the lakes situated in this area should, therefore be rather slow. Thus the tested hypothesis proposes that the trophic status of the studied lakes is low and has remained unchanged for the last 30 years.

Material and methods

The studied lakes are as diverse as their watersheds and include typical deep channel lakes, moraine lakes and shallow polymictic lakes. As a result, the set of these lakes is extremely differentiated as regards their area and depth (Table 1).

Samples were taken in July/August 1983–1985, 2009, 2012 and 2015 at the deepest points of the lakes. Rotifer zooplankton was sampled with a 2-l sampler at every 1m depth and pooled for layers of epi-, meta- and hypolimnion in stratified lakes and from the surface to the bottom in shallow lakes. The samples were concentrated with a plankton net of 30 μ m mesh size and fixed in 4% formalin.

Table 1. Morphometric characteristics of lakes of the Suwałki Landscape Park (data according to Borowiak et al. 2016 and Jańczak 1999)

Lake	Geographical coordinates		Area [ha]	Maximum depth [m]	Mean depth [m]
	Latitude	Longitude			
Łuśnin	54°16.7'	22°53.0'	0.47	3.0	1.5
Purwinek	54°16.9'	22°53.9'	0.44	3.3	1.5
Purwin	54°16.8'	22°53.5'	1.41	4.3	2.8
Drainage basin of Czarna Hańcza					
Boczniew	54°15.6'	22°49.3'	19.2	3.9	1.3
Jęgliniszek	54°18.9'	22°51.1'	16.0	2.4	1.2
Hańcza	54°15.9'	22°48.7'	303.6	105.6	39.1
Drainage basin of Szelmentka					
Szelment Wielki	54°13.6'	22°58.6'	356.1	45.0	15.0
Szelment Mały	54°15.4'	23°01.2'	168.5	28.5	7.5
Ilgieł	54°16.3'	23°02.8'	17.1	9.7	4.1
Kupowo	54°18.4'	23°02.6'	32.8	13.2	5.0
Drainage basin of Szeszupa					
Czarne	54°17.6'	22°54.1'	16.2	11.2	2.8
Gulbin	54°15.6'	22°54.0'	7.4	9.1	3.5
Jaczn	54°16.6'	22°52.3'	40.6	25.7	9.8
Jęglówek	54°14.3'	22°53.3'	20.1	27.7	9.3
Kameduł	54°16.0'	22°52.0'	25.3	26.2	7.0
Kluczysko	54°14.0'	22°52.9'	3.7	13.8	5.4
Kojle	54°16.5'	22°53.5'	17.3	32.3	9.7
Kopane	54°14.9'	22°54.3'	16.2	18.8	5.7
Krejwelek	54°16.3'	22°55.1'	5.5	8.8	2.8
Linówek	54°13.4'	22°50.4'	2.9	5.9	2.4
Okragłe	54°16.0'	22°54.4'	15.0	7.4	4.3
Perty	54°16.4'	22°53.9'	19.5	32.6	7.4
Pobondzie	54°18.7'	22°56.8'	53.1	10.0	3.6
Pogorzałek	54°16.4'	22°50.3'	5.8	17.6	5.9
Postawełek	54°17.0'	22°56.6'	3.4	4.0	2.0
Przechodnie	54°16.7'	22°55.5'	23.9	5.4	3.1
Snouda	54°15.1'	22°53.7'	0.47	4.5	2.0
Szurpiły	54°13.8'	22°53.6'	84.4	47.1	11.2
Udziejek	54°15.2'	22°53.3'	7.0	6.9	3.3
Wodziłki	54°14.5'	22°50.9'	3.7	5.4	3.1

Samples were taken once a year, during the summer stagnation period. The period was chosen by Karabin (1985) as best for comparative analysis of the zooplankton because of the stability of summer communities being under the influence of mostly trophic factors.

To assess changes in trophic state of the studied lakes the following rotifer trophic state indices (TSI_{ROT}) were used (Ejsmont-Karabin 2012): (1) rotifer numbers, (2) total biomass of rotifer community, (3) percentage of bacterivores in total rotifer numbers, (4) ratio of biomass to numbers, (5) percentage of the *tecta* form in the population of *Keratella cochlearis*, (6) contribution of species which indicate high trophic state in the indicator group numbers.

TSI_{ROT} values under 45 indicate mesotrophy, TSI_{ROT} values between 45 and 55 – meso-eutrophy, those between 55 and 65 – eutrophy, and those above 65 indicate hypertrophy.

Results and discussion

Rotifer communities in Suwałki lakes studied in 2015 were mostly of extremely low densities, often below 200 ind. dm^{-3} . The communities were dominated by detritophagous *Keratella cochlearis* (Gosse) and algivorous *Polyarthra remata* Skorikov and *P. vulgaris* Carlin. The exceptions were lakes Kluczysko and Udziejek with a high density of small bacteriophage *Anuraeopsis fissa* (Gosse) (Fig. 1).

The communities of rotifers indicative of lake trophy consisted mostly of species that signal low trophy in lakes Boczniew, Kamendul, Perty and Pogorzałek (Fig. 2). Single species indicating a low trophic state were found in lakes Kojle and Łuśnin (*Gastropus stylifer* Imhof) and in Lake Purwinek (*Conochilus hippocrepis* (Schränk)). Six lakes consisted of an indicator set of species dominated by those typical for high trophy. Five

Fig. 1. Rotifer density and species structure in lakes of the Suwalki Landscape Park in summer 2015. In Lakes Kamenduł, Kojle and Perty data are given for epi-, meta- and hypolimnion (from left to right)

lakes were devoid of any rotifer indicators of trophy (Fig. 2).

Data on rotifer abundance and species composition in the epilimnion of the lakes were used to establish values of parameters enabling an assessment of lake trophy (Table 2). The studies covered the years 1983–1985 (Karabin and Ejsmont-Karabin 1993, 1994), 2009 (Jekatierynczuk-Rudczyk et al. 2014) and 2015. The comparison revealed that rotifer densities observed in the years 1983–1985 were often markedly higher than in 2014 or 2015. A particularly strong decrease was noted in lakes: Boczniel, Czarne, Gulbin, Kluczyko,

Kopane, Okrągłe, Postawełek, Szurpiły i Udziejek. Some fluctuations without clear trends together with the highest density achieved in the year 1995 were observed in Lake Perty (Table 2).

Distinct changes within the ca 30 years of the study were also seen in species structure, biomass, mean weight of one individual and the presence of bacteriovores in the community of Rotifera (Table 2). In general, the *tecta* form of *Keratella cochlearis* occurred rarely, and in 2015 in lakes Linówek, Postawełek and Wodзилki both forms (*typica* and *tecta*) of the species were absent.

Although the 30–32-year changes in the species structure of rotifer communities were generally significant, they did not usually lead to the total replacement of species, instead the changes occurred in their participation in the total densities (Fig. 3). Exceptions were Lake Kluczyko, where *Gastropus stylifer*, *Filinia longiseta* (Ehrenberg) and *Keratella cochlearis* were replaced by *Anuraeopsis fissa*, and Lake Postawełek, where *A. fissa* and *K. cochlearis* were replaced by *Squatinella* sp. and *Conochiloides dossuarius* (Skorikov).

According to rotifer indices of lake trophy, most of the lakes surveyed in the years 2009–2015 are now meso-eutrophic. They represent 77% of the lakes, while 14% can be considered as mesotrophic, and 9% are eutrophic. However, even in the latter there is still relatively moderate eutrophy. The trophic state of the lakes studied in 1983–1985, estimated by means of the same method, was much higher (Fig. 4). At that time lakes with low eutrophy dominated (48% of the lakes), but the share of meso-eutrophic lakes was similarly high (43%). Only two lakes: Hańcza and Szelment Wielki were mesotrophic.

Over the 25–32 years there were no changes in the structure and abundance of rotifer communities in 75% of the lakes of the Suwalki Landscape Park that

Fig. 2. Contribution (%) of species indicating low and high trophic state in the indicator group numbers

Table 2. Parameters used to assess trophic status of lakes (Ejsmont-Karabin 2012) and based on density and species composition of rotifer communities. Explanations: N – rotifer numbers (ind. dm⁻³); B – total biomass of rotifer community (mg ww dm⁻³); BAC – percentage of bacterivores in total rotifer numbers (%); TECTA – percentage of the *tecta* form in the population of *Keratella cochlearis* (%); B:N – ratio of biomass to numbers (µg ww ind.⁻¹); IHT – contribution of species which indicate high trophy in the indicator group numbers (%)

Lake	Year	Parameter					
		N	B	BAC	TECTA	B:N	IHT
Łuśnin	2015	159	0.02802	77.4	0.0	0.176	0.0
Purwinek	2015	36	0.00936	77.8	0.0	0.260	–
Purwin	2015	81	0.01649	72.8	9.1	0.204	87.5
Drainage basin of Czarna Hańcza							
Boczniew	1984	2743	0.62413	22.3	0.0	0.228	46.6
	2009	36	0.01829	30.6	0.0	0.508	6.7
	2015	477	0.14983	37.7	0.0	0.314	0.4
Jegliniszki	1984	2112	0.31127	45.3	0.0	0.147	100.0
Hańcza	1983	56	0.02704	1.8	0.0	0.483	0.0
	1995	1644	0.42422	39.4	0.0	0.258	1.5
	2002	153	0.06553	11.1	0.0	0.428	0.0
	2009	255	0.08907	32.9	0.0	0.349	0.0
	2015	163	0.10022	28.7	0.0	0.615	0.0
Drainage basin of Szelmentka							
Szelment Wielki	1985	57	0.03292	3.5	0.0	0.578	0.0
Szelment Mały	1985	466	0.16532	28.8	0.8	0.355	1.5
Ilgiel	1985	1726	0.27149	59.2	21.5	0.157	96.2
Ślepe	2015	8	0.00399	37.5	0.0	0.499	–
Kupowo	1985	2037	0.42459	29.2	36.3	0.208	72.1
Drainage basin of Szeszupa							
Czarne	1985	1946	0.55874	23.1	0.9	0.287	8.7
	2014	120	0.02723	26.7	0.0	0.227	66.7
Gulbin	1983	2033	0.55963	45.2	40.9	0.275	56.3
	2009	496	0.15219	74.0	27.8	0.307	93.9
Jaczno	1984	206	0.05189	31.6	0.0	0.252	9.7
	2009	25	0.00687	24.0	0.0	0.275	50.0
	2015	113	0.04003	71.1	0.0	0.354	18.8
Jeglówek	1983	850	0.22922	14.1	0.0	0.270	0.0
	2009	438	0.10950	39.7	0.0	0.250	0.0
Kamendul	1984	447	0.12188	22.1	9.5	0.273	39.0
	2009	72	0.02088	61.1	42.3	0.290	86.3
	2015	177	0.04462	39.5	0.0	0.252	30.8
Kluczysko	1983	1948	0.41748	47.2	1.6	0.214	58.8
	2009	95	0.02153	61.1	23.5	0.227	94.1
	2015	749	0.03894	96.8	30.0	0.052	100.0
Kojle	1984	268	0.06317	17.9	0.0	0.236	0.0
	2009	79	0.01844	39.2	0.0	0.233	14.3
	2015	97	0.02868	49.5	0.0	0.296	0.0
Kopane	1983	1022	0.27937	20.5	6.4	0.273	16.3
	2009	23	0.00488	52.2	0.0	0.212	100.0
Krajwelek	1983	3826	1.02632	43.0	37.3	0.268	62.2
	2009	178	0.04272	91.0	35.3	0.240	98.3
	2015	187	0.03904	49.2	9.1	0.209	86.7
Linówek	2009	417	0.09866	39.1	0.0	0.237	12.7
	2015	11	0.00236	18.2	–	0.215	–
Okragle	1983	1434	0.37741	36.3	21.6	0.263	54.1
	2009	462	0.09486	71.4	33.1	0.205	98.5
	2015	201	0.04663	69.7	7.4	0.232	83.9

Lake	Year	Parameter					
		N	B	BAC	TECTA	B:N	IHT
Perty	1984	224	0.06249	17.9	0.0	0.279	0.0
	1995	631	0.13941	41.9	4.2	0.221	78.9
	2009	170	0.04125	41.8	0.0	0.243	53.3
	2012	139	0.04668	38.1	0.0	0.336	30.9
	2015	176	0.05284	43.8	0.0	0.300	16.7
Pobondzie	1983	1833	0.33739	49.4	13.9	0.184	94.8
Pogorzałek	2009	127	0.02467	81.1	2.4	0.194	91.3
	2015	483	0.10501	70.0	0.0	0.217	14.9
Postawelek	1983	2730	0.78706	56.1	39.9	0.288	94.4
	2009	61	0.01252	72.1	12.1	0.205	91.7
	2015	8	0.00269	12.5	–	0.336	–
Przechodnie	1983	1638	0.30300	64.3	24.4	0.185	86.5
Snouda	2009	80	0.02296	62.5	10.9	0.287	50.0
	2015	36	0.00586	58.3	0.0	0.163	95.0
Szurpiły	1983	972	0.25994	10.3	2.1	0.267	10.3
	2009	117	0.02798	51.3	3.4	0.239	12.5
	2015	140	0.05278	57.6	0.6	0.377	7.9
Udziejek	1983	1673	0.42510	46.7	27.6	0.254	63.7
	2009	714	0.13714	87.3	15.2	0.192	97.3
	2015	353	0.05682	53.5	51.7	0.161	98.1
Wodziłki	2015	10	0.01120	40.0	–	1.120	–

would indicate a decline in trophicity of the lakes under study (Fig. 4). However, in lakes where the strongest decline of these values was recorded, values of individual indicative parameters greatly varied in 2015, which resulted in very high values of standard deviation. This seems to point to certain processes currently affecting the trophic state of lakes, which may suggest that the status of rotifer communities in these lakes is dependent on non-trophic factors. In this case the assessment of the trophic status of lakes would not sufficiently illustrate their ecological status. According to Kratz et al. (1987) taxa that exhibit large variability among sites are sensitive indicators of change in an ecosystem. Rotifers

are among such taxa (Ejsmont-Karabin 2012). This has also been demonstrated in long-term studies on Lake Vortsjarv (Haberman and Haldna 2014), where rotifer indices increased in parallel with increasing trophic level. The complicated character of factors influencing the productivity of the lakes under study, as described by Górniak et al. (2016), and especially the important role of hydrology, is reflected in both long- and short-term changes in rotifer indices of lake trophicity. The relatively high water retention time noted in 2015 (due to an exceptionally warm and dry summer), and good oxygenation of the hypolimnion zones, made internal phosphorus input impossible (Górniak et al. 2016).

Fig. 3. Comparison of species structure of rotifer communities in the epilimnion of lakes in the years 1983–1985 with the communities noted in the years 2009 or 2015

Fig. 4. Long-term changes in rotifer index of trophic state of Suwałki lakes

This may explain the recently observed low trophicity of the studied lakes as reflected in the values of rotifer indices.

Conclusions

The results of the 30-year studies confirmed to some extent the tested hypothesis as the trophic status of the lakes remained relatively low, and some of them are currently even lower than noted 30 years earlier. Most of the lakes recently studied are meso-eutrophic or moderately eutrophic. However, high deviation of particular rotifer indices may result from impact of environmental factors other than trophic ones.

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