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Planktonic Rotifers as Indicators of Lake Trophy

Wrotki planktonowe jako wskaźniki trofii jezior

Планктоновые коловратки как показатели трофии озер

INTRODUCTION

Trophy of waters means the kind and intensity of supplying lakes with organic substances. This term is used to define the degree of lake trophy in the direction of oligo-, eu- and dystrophy. When the trophy of waters is evaluated, different factors are taken into consideration: the intensity of production, values of conductivity, visibility as well as some selected systematic groups of plants and animals.

Many species of planktonic rotifers react strongly to changes in the number of abiotic environmental factors, and in this way they can be used as bioindicators of trophy and even of saprobity of waters (1, 4, 5, 6, 7, 8, 15). But not all of them are good indicators of trophy, because some of them show a considerable ecological tolerance. Common eurytopic species in particular cannot be used as indicators of the degree of water fertility.

The aim of this work is to evaluate the usefulness of some rotifer species as indicators of lake trophy. This evaluation is based on the results of the investigations obtained on the Łęczna and Włodawa lakes as well on material from Scandinavian lakes.

MATERIAL AND METHODS

Samples were collected in the years 1966—1969 from 66 trophically different waters in the Łęczna—Włodawa lake district situated in the eastern part of Poland. In order to obtain the fullest possible set of the species of rotifers during the summer, in most of the investigated lakes samples were taken twice during the

Table 1. Occurrence and numbers of rotifer trophy — indicators in the Łęczna and Włodawa lakes

Lake	Trophic type	Forms indicating eutrophy											Form indicating humic waters after Pejler
		Pompholyx sulcata	*Trichocerca cylindrica*	*Filinia longiseta*	*Brachionus angularis*	*Keratella cochlearis tecta*	*Brachionus diversicornis*	*Anuraeopsis fissa*	*Trichocerca pusilla*	*Chromogaster ovalis*	*Chromogaster testudo*	*Keratella hiemalis*	*Trichocerca similis*
		1	2	3	4	5	6	7	8	9	10	11	12
Kleszczów	eutrophic	—	—	—	—	—	—	—	—	—	—	—	—
Turowolskie	eutrophic	—	—	—	—	—	—	—	—	—	—	—	1
Pniówno	eutrophic	—	—	—	—	—	—	—	—	—	—	—	—
Święte	dystrophic	—	—	—	—	—	—	—	—	1	—	1	3
Białe Włodawskie	mesotrophic	—	—	—	—	—	—	—	—	1	—	3	1
Piaseczno	mesotrophic	—	—	—	—	—	—	—	—	2	2	1	1
Bialskie	mesotrophic	5	—	—	—	—	—	—	—	—	3	3	2
Uściwierzek	eutrophic	—	—	—	—	—	—	5	—	—	—	—	2
Czarne Gościnieckie	dystrophic	—	4	—	—	—	—	—	—	5	—	—	3
Karaśne	eutrophic-dystrophic	1	—	1	—	—	—	—	—	—	—	—	3
Zagłębocze	mesotrophic	4	—	—	—	—	—	—	—	3	1	2	1
Krasne	mesotrophic	2	2	—	—	—	—	—	—	1	3	1	1
Nadrybie	eutrophic	—	—	—	—	—	—	4	—	—	—	—	4
Orchowo	dystrophic	—	—	2	—	—	—	—	—	—	—	—	1
Łukietek	dystrophic	—	1	—	—	—	—	—	—	2	2	—	1
Brzeziczno	dystrophic	—	3	—	—	—	—	—	—	—	—	—	—
Wereszczyńskie	eutrophic	—	—	3	—	—	—	—	—	—	—	—	1
Spilno	eutrophic-dystrophic	3	—	—	—	—	—	—	—	—	—	—	—
Skomielno	eutrophic-dystrophic	—	—	1	—	—	—	3	—	—	—	—	1
Czarne Sosnowickie	eutrophic-dystrophic	4	4	3	—	—	—	—	—	1	3	4	2
Moszne	eutrophic-dystrophic	—	1	—	1	—	—	—	—	—	—	—	3
Ciesacin	eutrophic-dystrophic	—	—	—	—	1	—	1	—	—	—	—	3
Rogóźno	eutrophic	4	—	—	—	1	—	—	—	2	1	2	1
Gumienek	eutrophic-oligotrophic	—	4	—	—	2	—	1	—	1	—	—	2
Płotycze k. Włodawy	dystrophic	—	4	—	—	2	1	—	—	1	—	3	3
Tarnów	eutrophic	3	—	3	—	—	—	—	—	—	—	—	—
Uściwierz	eutrophic	1	1	—	—	—	—	—	—	—	—	—	3
Chuteckie	eutrophic	1	—	—	1	—	—	—	—	—	—	—	—
Płotycze k. Urszulina	eutrophic	4	—	4	3	5	—	—	—	—	—	—	4
Sumin	eutrophic	3	2	—	—	2	—	1	2	—	—	—	4

Table 1 continued

		1	2	3	4	5	6	7	8	9	10	11	12
Syczyn	eutrophic	2	—	—	4	1	—	—	—	—	—	—	—
Łukie	eutrophic	—	—	1	5	4	—	1	—	—	—	—	1
Perespa	eutrophic	4	3	1	—	—	—	—	—	—	—	—	2
Głębokie k. Urszulina	eutrophic	2	—	1	3	—	—	—	—	—	—	—	2
Brudzieniec	eutrophic	2	4	3	3	2	2	—	2	1	—	4	5
Uścimowiec	eutrophic-oligotrophic	3	5	1	3	—	4	—	—	1	4	4	2
Czarne Uścimowskie	eutrophic	4	3	1	1	5	—	—	—	—	—	2	2
Głębokie Uścimowskie	eutrophic	4	1	—	1	—	1	—	—	—	—	—	1
Rotcze	eutrophic	1	1	—	1	—	2	—	—	—	—	—	1
Cycowe	eutrophic	1	3	5	5	3	2	—	1	—	—	—	2
Glinki	eutrophic	5	1	1	—	4	—	—	1	—	—	—	2
Liszno	eutrophic	2	—	1	3	—	—	—	—	—	—	—	1
Rogoźno	eutrophic-dystrophic	—	1	4	3	—	—	—	—	—	—	—	—
Mytycze	eutrophic-dystrophic	—	—	4	4	1	2	—	—	—	—	—	4
Lipiniec	eutrophic	1	3	5	1	1	2	—	1	—	—	—	1
Łukcze	eutrophic	—	3	4	5	1	—	—	—	—	—	—	1
Białe Sosnowickie	eutrophic	1	3	1	2	2	2	—	—	—	—	—	3
Ściegienne	eutrophic	5	—	—	—	5	1	3	1	—	—	—	3
Zienkowskie	eutrophic	1	3	5	5	5	3	—	—	—	—	—	1
Wytyckie	eutrophic	1	1	3	5	3	—	2	—	—	—	—	—
Białe Uścimowskie	eutrophic	—	4	2	2	1	—	—	—	—	—	—	1
Brudno	eutrophic	—	2	3	5	4	4	—	1	—	—	—	1
Czarne Włodawskie	eutrophic	1	1	1	—	3	—	1	3	—	—	—	—
Koseniec	eutrophic	1	3	1	1	5	4	1	—	—	—	—	5
Bikcze	eutrophic	1	3	2	3	5	3	—	—	—	—	—	1
Miejskie	eutrophic	5	5	3	4	4	3	2	1	—	—	—	—
Gumienko	eutrophic	1	5	4	1	5	1	1	1	1	—	—	3

Explanations: 1 — individual specimen, 2 — not numerous, 3 — fairly numerous, 4 — numerous, 5 — very numerous.

period between the middle of May and the middle of September. At that time there is the greatest qualitative and quantitative differentation of zooplankton in the waters of the temperate zone. Quality gauze planktonic net No 25 was used to catch rotifers. Samples were always taken in the pelagic zone of a lake, near its maximum depth. The number of individual species was determined according to the accepted evaluation methods. In total 208 planktonic samples were taken and analysed microscopically. At the same time, while the planktonic samples were being taken, the basic physical and chemical factors were determined in the investigated waters and the results were presented in separate publications (12, 13, 14).

RESULTS

Of the 158 forms of rotifers found in the pelagic zone of the Łęczna—Włodawa lakes only 12 can be used as bioindicators in determining the degree of lake fertility. In these lakes the following forms seem to be sensitive indicators of fertile waters: *Anuraeopsis fissa, Brachionus angu-*

laris, Brachionus diversicornis, Filinia longiseta, Keratella cochlearis tecta, Pompholyx sulcata, Trichocerca cylindrica and *Trichocerca pusilla*. The most frequently noted eutrophy indicators were: *Brachionus angularis, Filinia longiseta, Keratella cochlearis tecta, Trichocerca cylindrica* and *Pompholyx sulcata*. They occurred in large or fairly large numbers in all the highly fertile lakes such as: Ściegienne, Białe Uścimowskie, Zienkowskie, Rogoźno, Miejskie, Gumienek (Table 1).

Four indicator forms: *Anuraeopsis fissa, Brachionus diversicornis, Trichocerca cylindrica* and *Trichocerca pusilla* did not occur in the lakes of high calcium concentration. These were: Chuteckie, Liszno, Syczyn and Tarnów, the waters of which contained over 100 mg/l Ca. The lack of rotifers characteristic of eutrophy in the highly fertile Pniówno lake was probably caused by an extreme influx of blue-green algae. We can find some information in literature about the avoidance by some rotifers of high phytoplankton developmental peaks, especially of *Cyanophyta* blooms (10).They probably excrete metabolites which are poisonous to the majority of zooplankton. Two species typical of eutrophy: *Pompholyx sulcata* and *Trichocerca cylindrica* were found in small amounts or in very large amounts in the mesotrophic lakes Bialskie and Krasne. The latter rotifer also occurred, sometimes even abundantly in the dystrophic lakes: Brzeziczno, Łukietek, Czarne Gościnieckie and Płotycze near Włodawa. They had low conductivity amounting to 144—276 $\mu S \cdot cm^{-1}$ and had small quantities of calcium varying from 5,6 to 14,0 mg/l Ca. In Scandinavia homever, *Trichocerca cylindrica* stations are neither of the oligothophic type nor of the dystrophic type (9).

In Swedish and Finnish lakes (1, 6, 7, 8, 9) the following species and forms prefer eutrophic waters: *Anuraeopsis fissa, Filinia longiseta, Keratella cochlearis tecta, Keratella cochlearis hispida, K. quadrata, Trichocerca birostris, T. capucina, T. cylindica, T. porcellus, T. pusilla, Polyarthra euryptera, Pompholyx* sp., *Brachionus angularis* and *B. calyciflorus*. *Polyarthra euryptera* and *Keratella quadrata* which are included by Scandinavian investigators in the large group of typical "eutrophobionts" belong to common rotifers in the Łęczna and Włodawa lakes. *Polyarthra euryptera* occurs both in the waters of low trophy: Łukietek, Brzeziczno, Czarne Gościnieckie, Płotycze near Włodawa, Piaseczno and in the distinctly eutrophic lakes such as: Ściegienne, Sumin, Łukie, etc. One should stress, however, that the more fertile were the waters, the more numerous were their populations. As for *Keratella quadrata*, it is a typical eurytopic species in these waters.

Few species of rotifers show a preference for the waters of low trophy. They have higher abundance and frequency in oligotrophic waters than in eutrophic ones; as a rule, one should suppose that among planktonic

Table 2. Percentage of rotifers water trophy — indicators in the investigated lakes

Lake	Total number of found species	Eutrophy indicators		Indicators of less oligotrophy and humic waters	
		number	%	number	%
1	2	3	4	5	6
Kleszczów	17	—	—	—	—
Turowolskie	17	—	—	—	—
Pniówno	5	—	—	—	—
Święte	20	—	—	2	10.0
Białe Włodawskie	22	—	—	2	9.0
Piaseczno	29	—	—	3	10.0
Bialskie	38	1	2.1	2	5.8
Uściwierzek	30	1	3.3	—	—
Czarne Gościnieckie	21	1	4.8	1	4.8
Karaśne	42	2	4.8	—	—
Zagłębocze	20	1	5.0	3	15.0
Krasne	38	2	5.2	3	7.9
Nadrybie	18	1	5.5	—	—
Orchowo	17	1	6.0	—	—
Łukietek	14	1	7.2	2	14.3
Brzeziczno	14	1	7.2	—	—
Wereszczyńskie	12	1	8.3	—	—
Spilno	12	1	8.3	—	—
Skomielno	22	2	9.0	—	—
Czarne Sosnowickie	31	3	9.7	3	9.7
Ciesacin	19	2	10.5	—	—
Moszne	18	2	11.0	—	—
Rogóźno	18	2	11.0	3	16.7
Gumienek	24	3	12.5	1	4.1
Płotycze k. Włodawy	24	3	12.5	2	8.3
Tarnów	14	2	14.3	—	—
Uściwierz	14	2	14.3	—	—
Chuteckie	14	2	14.3	—	—
Płotycze k. Urszulina	25	4	16.0	—	—
Sumin	31	5	16.1	—	—
Łukie	22	4	18.1	—	—
Perespa	22	3	18.8	—	—
Głębokie k. Urszulina	16	3	18.8	—	—
Uścimowiec	25	5	20.0	3	12.0
Brudzieniec	34	7	20.3	2	6.0
Czarne Uścimowskie	24	5	20.8	2	8.3
Głębokie Uścimowskie	19	4	21.0	—	—
Rotcze	18	4	22.0	—	—
Cycowe	32	7	22.0	—	—
Glinki	22	5	22.7	—	—
Liszno	13	3	23.0	—	—
Rogoźno	13	3	23.0	—	—
Mytycze	17	4	23.5	—	—
Lipiniec	28	7	25.0	—	—
Łukcze	16	4	25.0	—	—
Białe Sosnowickie	24	6	25.0	—	—
Ściegienne	19	5	26.3	—	—
Zienkowskie	22	6	27.3	—	—
Wytyckie	20	6	30.0	—	—
Brudno	20	6	30.0	—	—
Białe Uścimowskie	13	4	30.8	—	—
Czarne Włodawskie	19	6	31.6	—	—
Koseniec	22	7	31.9	—	—
Bikcze	18	6	33.3	—	—
Miejskie	20	8	40.0	—	—
Gumienko	20	8	40.0	—	—

List of lakes according to the increasing percentage of eutrophy indicators.

rotifers species living only in oligotrophic waters do not occur. Pejler (8) also paid attention to this fact, and had a considerable difficulty in distinguishing forms characteristic of low productivity lakes in Southern and Central Sweden. *Ascomorpha ovalis=Chromogaster ovalis, Asplanchna herricki, Synchaeta grandis* and *Ploesoma hudsoni* were regarded by him as species avoiding fertile waters. Berzins (1) also includes *Kellicottia longispina, Conochilus unicornis* and *Ploesoma hudsoni* among the species more common in oligotrophic lakes than in eutrophic ones. However, many investigators are of the opinion that these species are equally frequent in mixotrophic and eutrophic waters (2, 8, 11). Järnefelt (6) thinks that only *Polyarthra dolichoptera* is characteristic of low trophy waters in Finnish lakes. However, on account of its ecological character it cannot be regarded as a wholly good indicator of oligotrophic waters. It is a coldstenothermous species occurring in fairly large numbers in the autumn — winter time, also in eutrophic lakes (2, 11).

In the Łęczna and Włodawa lakes 3 species are closely bound to low trophy waters (weakly oligotrophic and dystrophic): *Chromogaster ovalis, Chromogaster testudo* and *Keratella hiemalis*. These species are found as a rule in waters of smaller conductivity than 600 $\mu S \cdot cm^{-1}$, oxidability below 40 mg/l O_2 and pH smaller than 8.0. To this group of waters belong the deepest lakes of the district: Piaseczno, Białe Włodawskie, Krasne, Zagłębocze, Rogóżno, Bialskie nad Czarne Sosnowickie as well as shallow lakes containing humus acids (water colour 15—18° FU): Czarne Gościnieckie, Święte and Płotycze near Włodawa. They were also found in such lakes as: Brudzieniec, Uścimowiec, Czarne Uścimowskie all containing a high percentage of eutrophy indicators (Table 2). Among them, *Keratella hiemalis* was noted even in a greater number of specimens (Table 1).

Although some of the lakes in the investigated area are defined as dystrophic, among them: Brzeziczno, Czarne Gościnieckie, Łukietek and Płotycze near Włodawa (3), yet species living only in humus waters were not found there. *Trichocerca similis* mentioned by Pejler (8) in the group of indicators of dystrophy appeared to be a rotifer living commonly in different trophic waters (Table 1). It also displayed a high tolerance for some rapidly changing abiotic factors of the environment. It constitutes a firm element in the fauna of the rotifers of this region as it was noted in 80% of the investigated lakes. Three other species preferring dystrophic waters: *Keratella paludosa, K. valga* and *K. ticinensis* were sporadically found (2 to 7% of the lakes) so they are not included in the table of trophy indicators. An important element completing the group of rotifers living in dystrophic waters are *Kellicottia longispina, Conochilus unicornis* and *Gastropus stylifer*.

The percentage share of rotifers characteristic of the individual trophy type waters was differentiated. Great fluctuations were observed among the eutrophy indicators of the investigated lakes. They measured from 2.7 to 40%. The highest indicator measuring over 30% was noted in the lakes: Białe Uścimowskie, Miejskie, Gumienko, Wytyckie, Brudno, Bikcze, Czarne Włodawskie and Koseniec. These lakes can be regarded as very fertile because they have slight visibility (0.32—1.47 m), high oxidability (26.4—42.4 mg/l O_2) and relatively high electrolytical conductivity (298—769 $\mu S \cdot cm^{-1}$). But the smallest values, from 8.7—10% were found in several lakes of limnological character related to weak eutrophy (Table 2). P e j l e r (8) obtained considerably higher values of eutrophy indicators for the lakes in Central Sweden. They were between 29 and 100%. It is probable that a qualitatively richer and a more separated group of rotifers is bound, first of all, to very fertile waters.

Rotifers preferring both oligotrophic and humus waters were noted in 13 lakes. Their percentage share was small, from 4.1—16.7% and only in 3 lakes: Święte, Białe Włodawskie and Piaseczno were oligotrophic indicators found exclusively. These are the lakes of small oxidability, below 15 mg/l O_2 and very small electrolytic conductivity ranging from 146 to 198 $\mu S \cdot cm^{-1}$. The lake Białe Włodawskie, in which fairly high conductivity (403 $\mu S \cdot cm^{-1}$) was found was an exception. This high value was induced by the high level of calcium amounting to 34 mg/l Ca. The highest percentage values of "oligotrophobionts" (12.0—16.7%) were noted in the lakes Zagłębocze, Łukietek, Rogóźno and Uścimowiec. They are lakes of average fertility because they are of high total oxidability ranging from 16.9 to 28.8 mg/l O_2, they have fairly high electrolytic conductivity ranging from 250 to 575 $\mu S \cdot cm^{-1}$ and relatively good visibility ranging from 2.0 m to 6.40 m. Only lake Łukietek is of dystrophic character. The water is brown-yellow (17° FU), visibility amounts to 1.70 m, total oxidability is 27.2 mg/l O_2 and electrolytic conductivity 260 $\mu S \cdot cm^{-1}$,

On the basis of these data one may suppose that species showing preference for oligotrophic and humus waters live mainly in waters of low biological production. They were never found in fertile lakes containing more than 21% of "eutrophobionts".

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STRESZCZENIE

Dokonano oceny przydatności niektórych gatunków i form wrotków jako wskaźników troficzności wód. Na terenie Pojezierza Łęczyńsko-Włodawskiego następujące formy można uważać za wskaźniki eutrofii: *Anuraeopsis fissa*, *Brachionus angularis*, *Brachionus diversicornis*, *Filinia longiseta*, *Keratella cochlearis tecta*, *Pompholyx sulcata*, *Trichocerca cylindrica* i *Trichocerca pusilla* (tab. 1).

Zaledwie trzy gatunki: *Chromogaster ovalis*, *Chromogaster testudo* i *Keratella hiemalis* wykazują pewne upodobanie do wód o niskiej troficzności. W jeziorach Łęczyńsko-Włodawskich nie stwierdzono gatunków zasiedlających wyłącznie wody humusowe. Natomiast *Trichocerca similis*, uważana przez Pejlera (8) za dobry wskaźnik dystrofii, okazała się wrotkiem pospolicie występującym w zbiornikach o różnym stopniu żyzności (tab. 1).

Procentowy udział wrotków charakterystycznych dla poszczególnych typów troficznych wód był zróżnicowany. Szczególnie duże wahania wystąpiły wśród wskaźników eutrofii, których udział w badanych jeziorach wahał się od 2,7 do 40% (tab. 2). W znacznie niższym procencie, zamykającym się w przedziale 4,1—16,7%, występo-

wały gatunki o upodobaniach do wód oligotroficznych i humusowych, przy czym nie poławiano ich nigdy w jeziorach żyźniejszych, w których notowano powyżej 21% „eutrofobiontów" (tab. 2).

РЕЗЮМЕ

Оценивалась пригодность некоторых видов и форм коловраток как показателей трофичности вод. Показателями эвтрофии на территории Ленчиньско-Влодавского приозерья можно считать следующие формы: *Anuraeopsis fissa, Brachionus angularis, Brachionus diversicornis, Filinia longiseta, Keratella cochlearis tecta, Pompholyx sulcata, Trichocerca cylindrica, Trichocerca pusilla* (табл. 1).

Некоторое пристрастие к водам с низкой трофичностью проявляют только 3 вида: *Chromogaster ovalis, Chromogaster testudo, Keratella hiemalis*. Виды, заселяющие исключительно гумусовые воды, в Ленчиньско-Влодавских озерах обнаружены не были. В то же время *Trichocerca similis*, которую Пейлер (8) считает хорошим показателем дистрофии, здесь оказалась широко распространенной коловраткой, выступающей в водоемах с разной степенью трофичности.

Процентное участие коловраток, характеристичных для отдельных трофических типов вод, было дифференцировано. Особенно сильные колебания наблюдались среди показателей эвтрофии, участие которых в этих озерах колебалось от 2,7 до 40% (табл. 2). Значительно меньшим было процентное участие видов с пристрастием к олиготрофичным и гумусовым водам (4,1—16,7%), причем они никогда не ловились в более трофических озерах, в которых отмечалось свыше 21% „эвтрофобионтов" (табл. 2).