Arch. Ryb. Pol.	Archives of Polish Fisheries	Vol. 6	Fasc. 2	233-245	1998

ABUNDANCE AND STRUCTURE OF ROTIFER COMMUNITY IN A HUMIC LAKE SMOLAK TWENTY YEARS AFTER THE EXPERIMENTAL MINERAL FERTILISATION

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ABSTRACT. Liming and supplying with N, P and K of a humic Lake Smolak carried out in 1971-1974 resulted in changes of abundance and composition of the rotifer community. The changes indicated eutrophication of the lake. Discontinuation of treatment caused further changes, which indicated oligotrophication, although 20 years after the fertilisation high species diversity of Rotifera is still observed. The community is dominated by detritivorous species, typical of productive, alkaline waters. Also the number and biomass of rotifers remains high.

Key words: ROTIFERA, HUMIC LAKE, LIMING, FERTILISATION WITH N, P and K.

INTRODUCTION

Rotifers are fairly tolerant to water pH, and most species occur in acidic as well as alkaline waters (Berzins, Pejler 1987). However, rotifer communities of acidic humic lakes usually consist of relatively small number of species, show low diversity, and low total number of individuals (Roff, Kwiatkowski 1977, Brett 1989, Siegfried, Sutherland 1992, Osborne, Jansen 1993).

Lake liming to increase water pH usually results in an enrichment of rotifer community structure and increase of abundance (Hillbricht-Ilkowska et al. 1977a, Keller et al. 1992, Hornstrom et al. 1993). New community resembles those of neutral pH lakes.

Such strong changes are not observed in cases of phosphorus supply alone (without liming). Phosphorus treatment of an acidic reservoir Seatwaite Tarn (English Lake District) in May 1995 increased water pH (by 0.5) and trophy. Despite these changes, species composition of rotifer community did not change, but number of individuals of most species increased.

Liming is rarely accompanied by simultaneous fertilisation with N, P, and K, so it is difficult to assess the effect of such treatment on zooplankton communities.

Treatment of Smolak Lake in 1970-1974 resulted in considerable changes, indicating eutrophication of the lake. Abundance of the community increased, so did species diversity, and some species typical of eutrophy appeared (Węgleńska et al. 1975, Hillbricht-Ilkowska et al. 1977b, Ejsmont-Karabin et al. 1980).

Distinct changes in rotifer community indicating oligotrophication of the lake were observed already in the first years after the treatment. The community, however, did not return to the abundance and structure observed before fertilisation (Ejsmont-Karabin, Węgleńska 1985).

The aim of the present study was a description and evaluation of rotifer communities of Smolak Lake 20-21 years after the fertilisation experiment. The results should reveal whether the trends observed by Ejsmont-Karabin and Węgleńska (1985) 10-15 years ago continue, leading to restitution of rotifer community abundance and structure observed before the fertilisation.

STUDY AREA, MATERIAL, AND METHODS

The study was done in Smolak Lake (Masurian Lakeland, Poland) of total area 5.3 ha, maximum depth 5.1 m, and average depth 2.4 m. In this originally acidic (pH=4.6) lake, liming and supplying with N, P, and K, carried out in 1970-1974, resulted in an increase of water pH to neutral and alkaline values, which were maintained at the level of about 7.0 until 1995. Phosphorus and nitrogen concentration, after initial increase caused by fertilisation, dropped and remained at the level observed in the second year of nutrient supply (Zdanowski, Hutorowicz 1998). Fertilisation caused also 2-3 fold increase of gross primary production, to about 1500 kcal m^{-2} in 1973-1974. Twenty years after the experiment, production is similar to that observed in the last years of fertilisation, and indicates moderate eutrophy of the central part of the lake (Hutorowicz 1998).

Zooplankton was sampled in 1990-1995, 5, 3, 4, 5, 7, and 9 times respectively, from the deepest site of the lake, every 1 m from the surface to the bottom, and pooled. The samples of 30 dm^3 were filtered through a net of mesh size 30 μm. They were preserved with Lugol solution, and after about 30 minutes - with 5% formaldehyde.

Body length of about 10 individuals of each species was measured. Rotifer biomass was calculated using the formulas describing length-weight relationship for each species (Ruttner-Kolisko 1977).

The species diversity index according to Shannon and Weaver (Margalef 1957) was calculated for rotifer numbers and biomass:

$$D = -\sum \frac{n_i}{N} \log n_i / N \quad or$$

$$H_b = -\sum b_i / B \log b_i / B$$

where:

N=total number,

B=total biomass of individuals of all species,

n_i and b_i are number and biomass of individuals of the i species.

Another index used in this paper was percentage similarity of the community (Whittaker, Fairbanks 1958):

$$PSc = 100 - 0.5 \Sigma (a-b) = \Sigma \min.(a,b)$$

where:

a and b=percentage of individuals of each species in total numbers of the communities observed in years A and B, compared in pairs.

The results of earlier studies published in the papers Ejsmont-Karabin et al. (1980) and Ejsmont-Karabin and Węgleńska (1985) were also used in the present paper.

RESULTS

Fertilisation of Smolak Lake in 1970-1974 resulted in considerable increase of rotifer community numbers, to maximum values exceeding 3 thousand individuals dm^{-3}, in 1973 and 1974.

After the end of the treatment, density of rotifers gradually decreased, and in 1976-1978 dropped below the control value. The decrease stopped in 1979-1980 (Ejsmont-Karabin, Węgleńska 1985). Comparison of minimum and maximum values of rotifer density in 1990-1995 (Fig. 1.) does not reveal any tendencies. In 1990 and 1992 the numbers were very low, in 1991 and 1994 – somewhat higher, and the highest values were observed in 1993, although they did not exceed the level noted in the last two years of fertilisation.

Comparison of seasonal dynamics of rotifer density in the control year (1970), the last year of fertilisation (1974), and the last year of this study (Fig. 2) revealed that

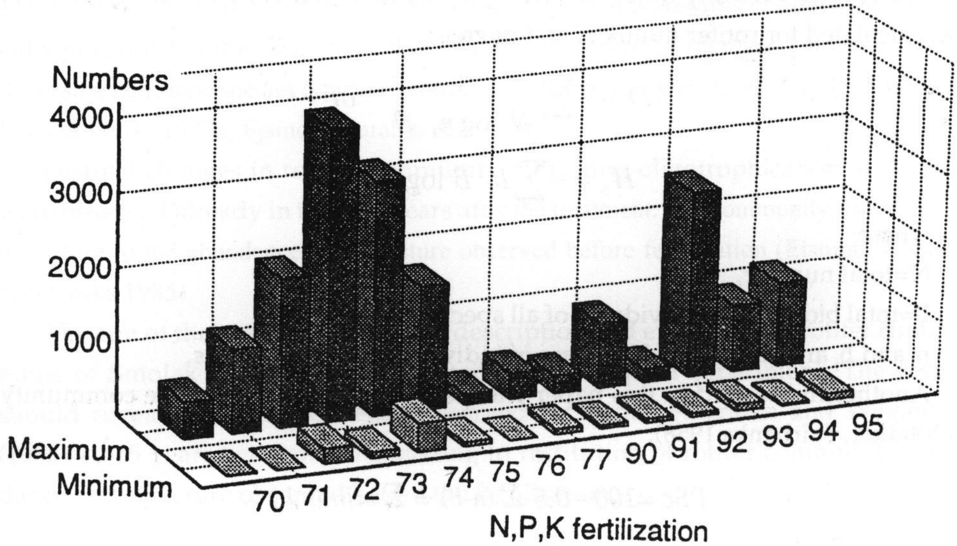

Fig. 1. Minimum and maximum rotifer numbers (ind. dm^{-3}) in the years of study

both: density and its seasonal dynamics considerably differed. In 1970, the density of rotifer community was the lowest and did not exceed 1000 ind. dm^{-3}, and the only peak was observed in autumn. Data for late winter and early spring are lacking, but low rotifer number in May suggests that even if an early spring peak occurred – it probably was low. In 1974, on the contrary, rotifer density was very high, over 3000 ind. dm^{-3}. Two peaks were observed: higher in spring, and lower in summer. In 1995 number of rotifers was much higher than in the control year, but considerably lower than in the fourth year of fertilisation. Two peaks were noted: in late winter and in summer.

Biomass dynamics was similar to that of rotifer density. Seasonal pattern of both parameters differed most in 1970, when the greatest pelagic rotifer, *Asplanchna priodonta* Gosse, predominated in the biomass.

In the control year (1970), the four years of fertilisation, and the four years without fertilisation, Smolak Lake was inhabited by 55 species of pelagic rotifers. Among them, 17 species happened to be dominants, and 11 species were found sporadically (Tab. I).

In the control year, rotifer community was poor: only 8 species were found, and 5 of them were dominants (Tab. I). In the fourth year of fertilisation the community

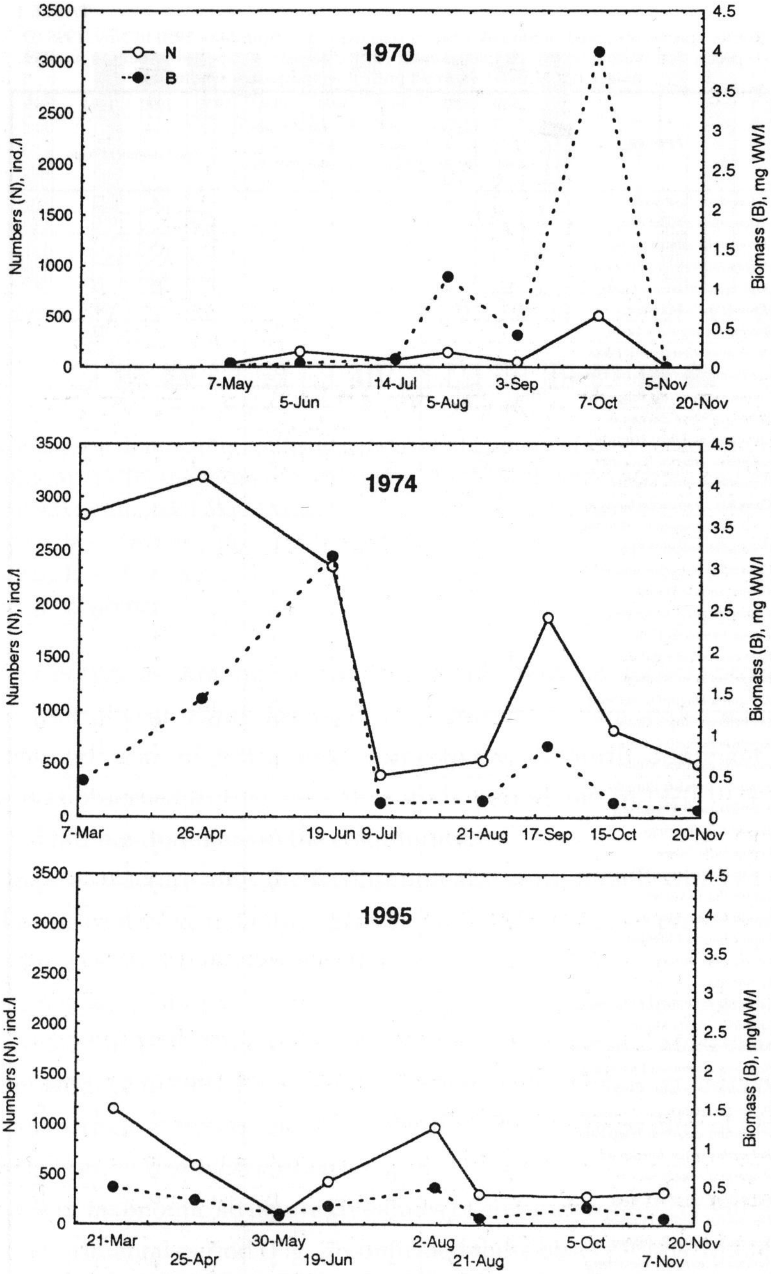

Fig. 2. Seasonal dynamics of numbers and biomass of Smolak Lake rotifer community in the control year, before fertilisation (1970), in the last year of treatment (1974), and 21 years after treatment (1995)

TABLE 1

Rotifer species observed in Smolak Lake in selected years, from May 1970 to Nov. 1995 (D – species dominating in any sample taken in particular year, + - species present in number over 1 ind. dm-3, * - species present as individual specimen)

Species	1970	1971	1972	1973	1974	1975	1990	1994	1995
	year	1st year of fertilisa-tion	2nd year of fertilisa-tion	3rd year of fertilisa-tion	4th year of fertilisa-tion	post-treatment years			
Anuraeopsis fissa Gosse		+	D	+	+	+	+	D	+
Ascomorpha ecaudis Perty			+	+		+			
Ascomorpha saltans Bartsch					*	*	+		
Asplanchna brightwelli Gosse			+						
Asplanchna priodonta Gosse	D	+	+	+	+	+	D	D	+
Bipalpus hudsoni Imhof								+	+
Brachionus angularis Gosse			+	*			+	D	D
Brachionus diversicornis Dada			+						
Brachionus quadridentatus Hermann			*						
Chromogaster ovalis Bergendal			+		*				
Collotheca libera Zacharias							*		
Collotheca mutabilis Hudson			+	+		+			D
Collotheca pelagica Rousselet			+		+		+		+
Colurella uncinata Mülller				*					*
Conochilus dossuarius Hudson				+	+	D	+	+	D
Conochilus hippocrepis Schrank						+			
Conochilus natans Seligo					+				*
Conochilus unicornis Rousselet				+			+		
Filinia cornuta Weisse		+	+		+				
Filinia longiseta Ehrenberg		+	+	+	D	+	+	D	D
Filinia terminalis Plate			+	+	+	+	+		+
Gastropus stylifer Imhof	D			+	+		+		
Hexarthra mira Hudson			D	+		+			
Kellicottia longispina Kellicott		+	+	+	+	+			
Keratella cochlearis Gosse	+	+	D	D	D	D	D	D	D
Keratella hiemalis Carlin							+	D	+
Keratella quadrata Müller	D	D	D	D	D	+			+
Keratella serrulata Ehrenberg									*
Keratella valga Ehrenberg									+
Lecane acus Harring									*
Lecane bulla Gosse							+		
Lecane closterocerca Schmarda					*				*
Lecane flexilis Gosse					*		*		*
Lecane furcata Murray				*					
Lecane lunaris Ehrenberg							+		*
Lecane luna Müller		+						+	
Lecane ungulata Gosse	*								
Lepadella acuminata Ehrenberg									*
Lepadella patella Müller									*
Macrochaetus subquadratus Perty					+				
Notholca acuminata Ehrenberg			*						
Notholca squamula Müller				*					
Polyarthra dolichoptera Idelson		D	D	D	+		+	+	D
Polyarthra euryptera Wierzejski								+	
Polyarthra major Burckhardt					+		+		
Polyarthra remata Skorikov	D		D	D	+	+	+		+
Polyarthra vulgaris Carlin			+	+	D	+	D		D
Pompholyx sulcata Hudson		+	+	D	+	+			
Synchaeta kitina Rousselet	+		+	+	+	+			
Synchaeta pectinata Ehrenberg		*	+	+	+	+	+	+	+
Synchaeta sp.	D			+	+	+	+		
Trichocerca capucina W.&Z		*		+	+		+	+	
Trichocerca cylindrica Imhof		+	*	D	+	+	+	+	
Trichocerca porcellus Gosse					*				
Trichocerca similis (Wierzejski)		+	+	+	+	+		+	

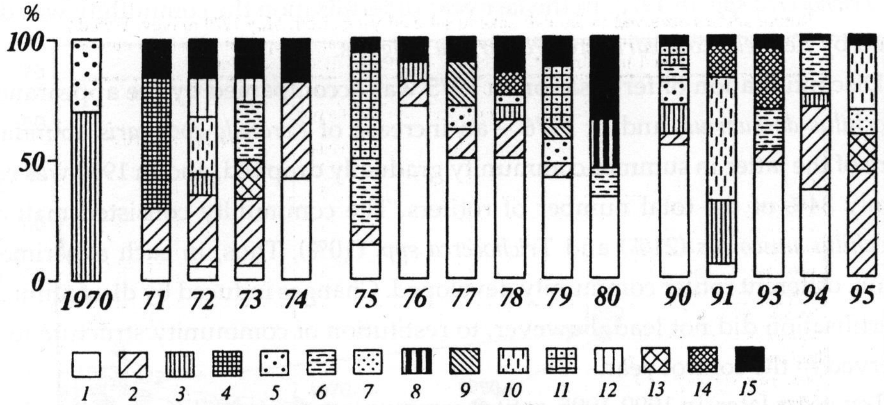

Fig. 3. Percentage of dominating rotifer genera in total number of summer communities in the control year (1970), the years of fertilisation (1971-1974), and after the end of treatment (1975-1995) in Smolak Lake. Explanation: 1- *Keratella*, 2 – *Polyarthra*, 3 – *Asplanchna*, 4 – *Synchaeta*, 5 – *Gastropus*, 6 – *Trichocerca*, 7 – *Brachionus*, 8 – *Conochilus unicornis*, 9 – *Kellicottia*, 10 – *Anuraeopsis*, 11 – *Conochilus dossuarius*, 12 – *Hexarthra*, 13 – *Filinia*, 14 – *Collotheca*, 15 – other

consisted of 29 species. Among the dominants, only *Keratella quadrata* predominated also in the control year. *Filinia longiseta* and *Polyarthra vulgaris* appeared in the first and the second year of fertilisation respectively. A fourth dominant, *Keratella cochlearis*, was observed during the entire study period, but in 1970-1974, although abundant, it did not dominate in the community.

Dominance structure after the fertilisation also considerably differed from that observed in the control year. Only *Asplanchna priodonta*, a species present in all years, dominated in 1990 and 1994 communities.

26 species were observed in 1995, among which 7 were dominants. None of them dominated in 1970. Nine species were found sporadically. Most characteristic was the appearance in 1994-1995 of high numbers of detritivorous *Brachionus angularis*, and an increase of two species that appeared after the beginning of fertilisation: *Filinia longiseta* and *Conochilus dossuarius*.

Analysis of taxonomic structure dynamics of summer rotifer communities over the entire experimental period (Fig. 3) confirmed these observations. Induced by fertilisation lack of *Asplanchna priodonta* and *Gastropus stylifer* (dominating in 1970) in summer was accompanied in 1971-1974 by an increase of *Polyarthra spp.* Also other taxa temporarily dominated, such as *Synchaeta spp.* in 1971, *Anuraeopsis fissa* in 1972, and *Trichocerca spp.* in 1973. In the last year of fertilisation the community was dominated by *Keratella cochlearis* and *Polyarthra vulgaris.*

Discontinuation of fertilisation in 1975 was accompanied by the appearance of *Conochilus dossuarius,* and in 1976 – an increase of *Keratella cochlearis* abundance. Share of the latter in summer community gradually dropped, and in 1980 was equal to only 34% of the total number of rotifers. The community consisted mainly of *Conochilus unicornis* (21%) and *Trichocerca spp.* (10%). Thus, in each experimental season, different rotifer community developed. Changes induced by discontinuation of fertilisation did not lead, however, to restitution of community structure to that observed in the control year.

Ten years later, in 1990-1995, rotifer community remained different from the one noted before fertilisation (1970) (Fig. 3). It was still more abundant in codominant species, and similarly as in 1976-1980, dominated by *Keratella cochlearis* and *Polyarthra spp.,* although accompanied by some species which were not observed 10 years earlier: *Brachionus angularis, Filinia longiseta, Anuraeopsis fissa, Collotheca spp.,* and *Trichocerca spp.* This indicates higher share of eurytopic species, feeding on detritus or nannophytoplankton. In summer communities such species as *Brachionus angularis, Anuraeopsis fissa,* and *Filinia longiseta,* typical for eutrophic waters, became important. Scarce individuals of spine-lacking *Keratella cochlearis* (*tecta* form) were also observed confirming the increase of trophic status of the lake (Karabin, 1985, Ejsmont-Karabin, Hillbricht-Ilkowska 1994).

These observations were also confirmed by the analysis of percentage similarity of community index, calculated for each year in two series: (1) for pairs: control year –the following years, and (2) for pairs: last year of study – the preceding years. Index values were calculated for spring and summer communities (Fig. 4).

Spring and summer rotifer communities of Smolak Lake in all years of fertilisation and after its end differed considerably from those observed in the control year (Fig. 4). Spring community of 1970 was still in 40% similar to that of 1971, but in the following years the similarity was below 20%. Similarity of species composition of summer communities in comparison to that of 1970 was in all cases very low and did not exceed 5%, only in 1980 and 1990 it was slightly higher.

Spring community species structure in 1995 was most similar to that observed in 1975 (the second year after fertilisation) (Fig. 4). Summer community structure in 1995 was, on the other hand, completely different from those observed in all previous years: species similarity did not exceed 25%.

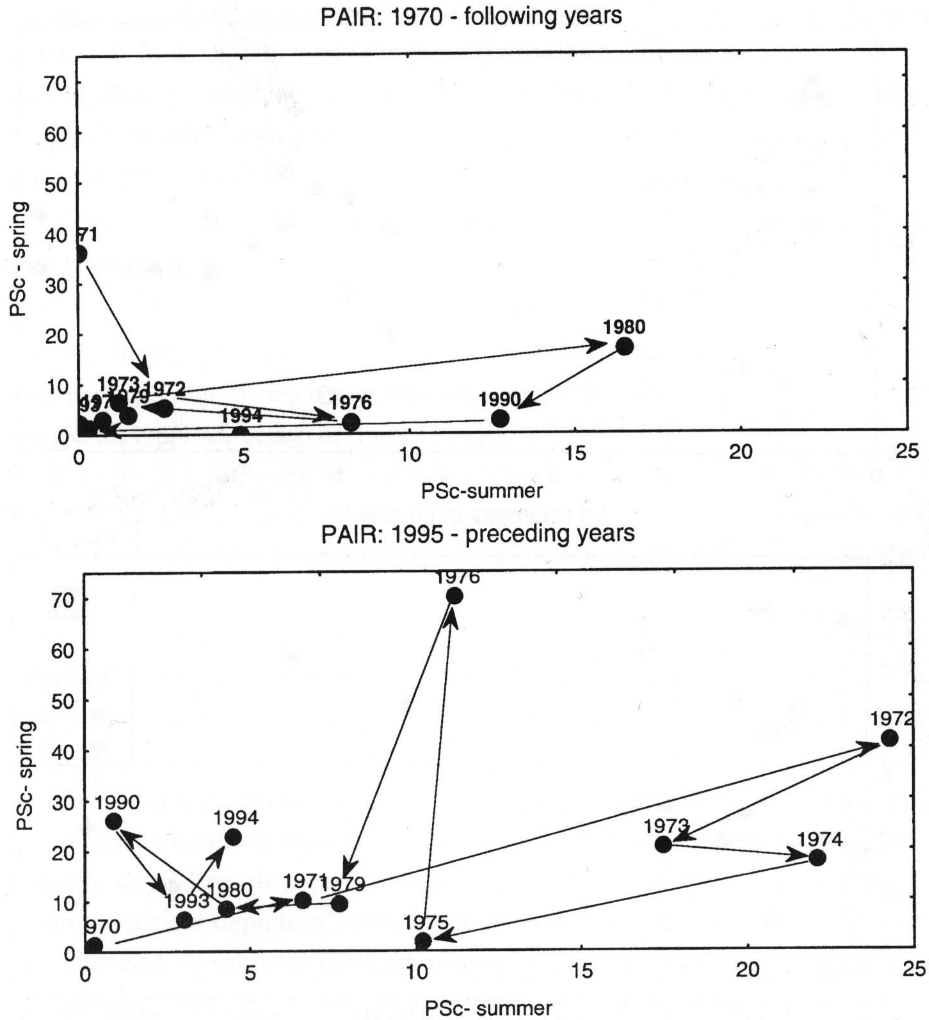

Fig. 4. Long-term changes of spring/summer value ratio of percentage similarity of community calculated for pairs: rotifer communities in 1970 versus communities of the following years, and: rotifer communities in 1995 versus communities of the preceding years

Spring communities of 1970 and 1995 were similar in 1.4% of species composition. PSc index for both summer communities was even lower and equal to 0.3%. This comparison indicates that discontinuation of nutrient supply and liming did not result, even after 20 years, in restitution of the primary rotifer community structure observed before the experiment, in 1970.

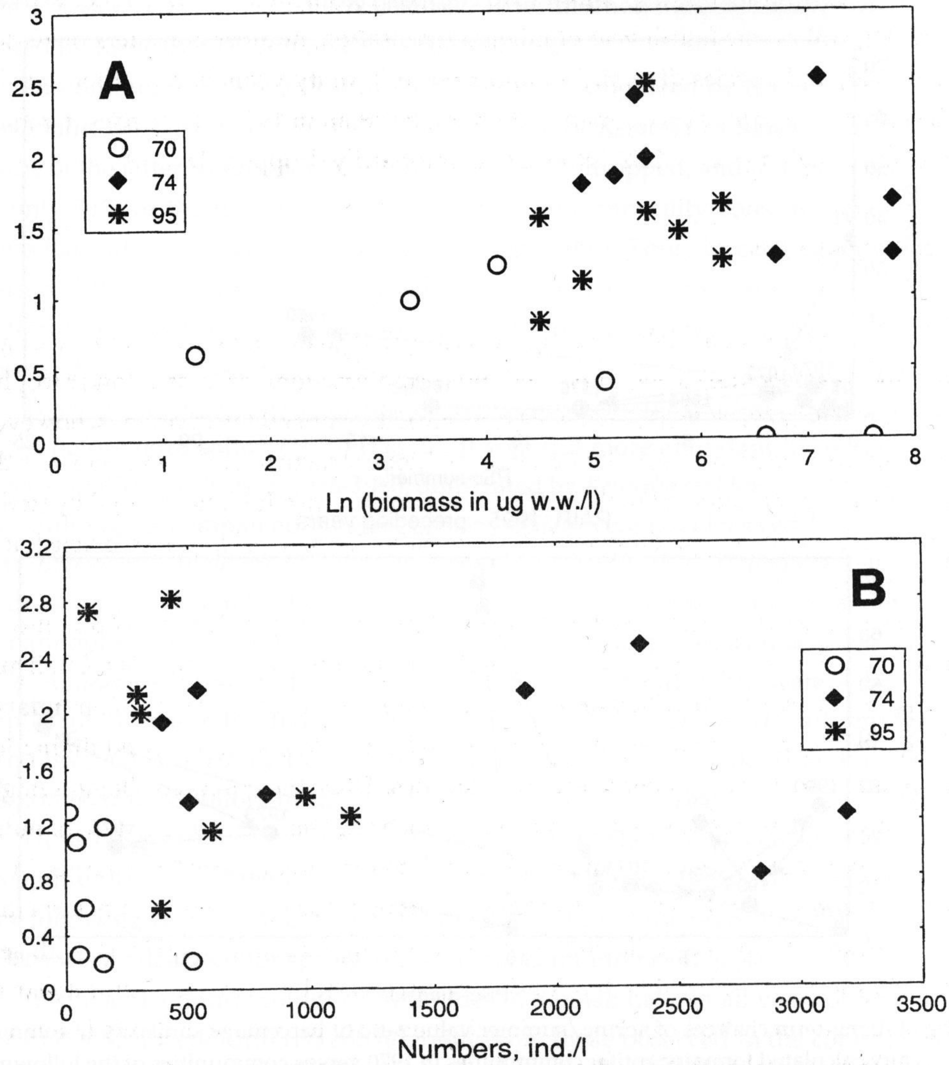

Fig. 5. Relation between: A – rotifer community biomass and its species diversity (HB), and B – total number of rotifers and its diversity (D) in Smolak Lake in 1970, 1974, and 1995

Smolak Lake in 1970, similarly as most acidic lakes (Roff, Kwiatkowski 1977), had highly variable rotifer biomass and low species diversity (Fig. 5A). Fertilisation caused considerable increase of both: biomass and species diversity. Twenty years after the fertilisation, diversity remains high, and similar to that observed in 1974, and so does the biomass (although slightly lower than in 1974).

Very low rotifer density in 1970 (control) was accompanied by low species diversity (Fig. 5B). In the fourth year of mineral fertilisation, number of rotifers increased manifold, and species diversity – almost twice. Twenty years later, rotifer density decreased to a value approximately twice higher than in 1970, but species diversity remained high, up to D=2.82, although it temporarily dropped (D=0.59).

DISCUSSION

Small, oligotrophic lakes are highly susceptible to any manipulations, as oligotrophy may promote strong direct and indirect interactions, at least at lower trophic levels (Neill, 1988). Direction of changes induced by mineral fertilisation is, however, difficult to predict, and usually depends on biotic structure of the ecosystem at the moment of manipulation (Neill, 1988). Increase of lake productivity caused by fertilisation may, according to Fretwell (1977), amplify biocenotic changes by extension of the food chains.

The main subject discussed in the present paper is the problem of reversibility of deep changes in rotifer community caused by fertilisation and liming of a small and poorly productive lake. Changes of species composition, and increase of abundance and diversity resulting from the treatment, indicate that fertilisation and liming led to an increase of the number of ecological niches. Thus, the observed changes might have involved alterations in the food web. In such situation, discontinuation of nutrient supply should result not in „a come back to the initial status" but rather in „a reaction to nutrient depletion". Another important issue were community structure changes caused by unpredictable environmental fluctuations interfering with seasonal dynamics. Taking this into consideration, reversal of rotifer community structure to that observed before the fertilisation should not be expected, even if productivity level of the lake dropped to the control value.

Analysis of abundance and taxonomic structure of rotifers of Smolak Lake, indicating persistence of changes induced by fertilisation of the lake in 1971-1974, confirms this hypothesis. Species composition of the community remained high, and dominance of detritivorous species, typical of productive, alkaline waters was observed. Density and biomass of the community also remained high.

These observations indicate that ecosystem of a small, forest lake affected by mineral fertilisation may not return to the initial situation, even if change-inducing factor is withdrawn. Thus, any attempts of manipulation in natural water bodies should be always accompanied by the awareness of possible irreversibility of the induced changes.

Contribution to the research project No 6 P205 032 04

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STRESZCZENIE

OBFITOŚĆ I STRUKTURA ZESPOŁU WROTKÓW (*Rotifera*) W HUMUSOWYM JEZIORZE SMOLAK PO DWUDZIESTU LATACH OD ZAKOŃCZENIA EKSPERYMENTU NAWOŻENIA MINERALNEGO

Badaniami objęto płytkie, humusowe, śródleśne jezioro Smolak. Jezioro to w latach 1970-1974 zostało poddane zabiegom nawożenia N, P i K i wapnowania, symulującym proces eutrofizacji.

Zabiegi te spowodowały wyraźny wzrost liczebności zespołu Rotifera. Po zaprzestaniu nawożenia zagęszczenie wrotków stopniowo spadało, by w 20 lat po zakończeniu eksperymentu osiągnąć wartości zbliżone do notowanych w początkowym okresie nawożenia (Fig. 1). Zarówno liczebność wrotków, jak i jej dynamika w roku kontrolnym (1970), ostatnim roku nawożenia (1974) i w ostatnim roku niniejszych badań (Fig. 2) były całkowicie odmienne. Dynamika zmian biomasy wrotków była we wszystkich trzech latach badań podobna do zmian liczebności wrotków (Fig. 2).

Zarówno nawożenie, jak i jego zaprzestanie spowodowały szereg drastycznych zmian w strukturze gatunkowej zespołu Rotifera, przy czym zmiany te w dużym stopniu dotyczyły gatunków dominujących (Tabela l, Fig. 3). W rezultacie zespoły zarówno wiosenne, j ak i letnie, wrotków j eziora Smolak we wszystkich latach pn nawożeniu i jego zaprzestaniu różniły się bardzo silnie od zespołów obserwowanych w roku kontrolnym, podobnie jak różniły się też one od zespołów obserwowanych w roku 1995 (Fig. 4). 20 lat po zaprzestaniu nawożenia zróżnicowanie gatunkowe zarówno liczebności, j ak i biomasy zespołu wrotków j est nadal wysokie i zbliżone do notowanego w roku 1974 (Fig. 5).

Wyniki powyższe świadczą, że ekosystem małego, śródleśnego jeziora zmieniony w swym funkcjonowaniu przez zabieg nawożenia mineralnego nawet w 20 lat po zaprzestaniu tego zabiegu nie powrócił do sytuacj i wyjściowej.

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