Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznań, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wrocław.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

1999
Volume 2
Issue 1
Series FISHERIES

SZLAUER B. 1999. ZOOPLANKTON–BASED ASSESSMENT OF THE LAKE MIEDWIE (NORTH–WESTERN POLAND) TROPHIC STATUS
Electronic Journal of Polish Agricultural Universities, Fisheries, Volume 2, Issue 1.
Available Online http://www.ejpau.media.pl

ZOOPLANKTON–BASED ASSESSMENT OF THE LAKE MIEDWIE (NORTH–WESTERN POLAND) TROPHIC STATUS

Barbara Szlauer
Department of Hydrobiology, Agricultural University of Szczecin, Poland

ABSTRACT

Studies on the Lake Miedwie zooplankton, associated with measurements of water temperature, dissolved oxygen content, and transparency showed the presence of at least 35 rotifer, 10 cladoceran, and 10 copepod species as well as the occurrence of mesotrophic lake indicators: *Bythotrephes longimanus*, *Cyclops scutifer*, and *Daphnia cristata*. The mesotrophic status of the lake is documented also by the structure of the zooplankton community and by the results of the *Daphnia magna* test for water fertility. All the data demonstrate the improvement in the lake's condition, compared to that in the 1980s. The results obtained attest to the need of biotic parameters to be incorporated into Lake Miedwie monitoring.

Key words: Lake, eutrophication, Rotatoria, Crustacea, zooplankton structure, *Daphnia magna* test.

PRINT

INTRODUCTION

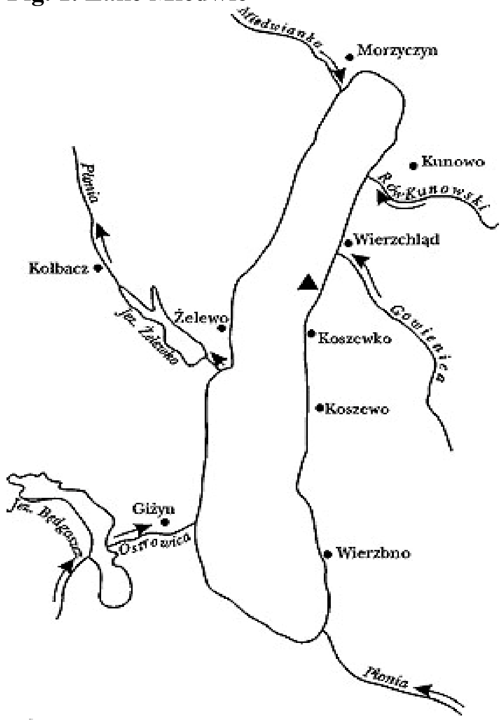
Lake Miedwie as a source of drinking water for the city of Szczecin remains the focus of attention. Discussions are centred predominantly around the Lake's purported eutrophication, much less time and resources being devoted to actual studies. The latter most often involve routine surveys carried out by institutions responsible for controlling and maintaining appropriate water conditions. So far, the most comprehensive studies of Lake Miedwie were carried out in the 1980s by the Institute of Spatial and Municipal Management in Poznan [30]. The studies involved, i.a., water chemistry, phyto– and zooplankton as well as zoobenthos. Mutko and Wierzchowska [12] summarised the abundant data yielded by physical and chemical assays necessary to evaluate the Lake water's utility for municipal purposes, agriculture, and fish culture. The database used covered the period 1975–1995. In other studies [7, 21], the Miedwie's potential for supplying the zooplankton, and its uses, from the potable water intake was explored. The results demonstrated a possibility of using that zooplankton in feeding fish larvae in cultures.

So far, no comprehensive studies on Lake Miedwie zooplankton – its composition, vertical distribution, and seasonal changes – had been performed. Such studies were the objective of the present work. In addition, an attempt was made to evaluate the Miedwie's wateron the basis of chemical and physical parameters, abundance and structure of the zooplankton, and the *Daphnia magna* test.

THE AREA AND METHODS OF STUDY

Lake Miedwie is located in the north–western part of Poland (53°17'N; 14°53'E) and, with its 35.5 km^2 area, 20 m mean depth, and 42 m maximum depth, belongs to the largest Western Pomeranian lakes [1]. This post–glacial lake has an elongated shape extending N–S. The lake's largest tributary is River Plonia, discharging from the south and leaving the lake on its western side to feed Lake Zelewskie. In addition, the Miedwie receives water from a number of smaller tributaries such as Gowienica, Miedwianka, Ostrowica, and Rów Kunowski (Fig. 1). The lake is surrounded mainly by meadows and cultivated fields [17].

Fig. 1. Lake Miedwie



▲Zooplankton sampling site

A regular trough, about 20 m deep, extends along the lake's long axis. The deepest spot (42 m depth) is situated close to the eastern shore, NW of Koszewko. This place was selected as the site at which to perform vertical (bottom to surface) zooplankton hauls. Due to the lake's bottom topography lacking individual pools and bars and the presence of wind–driven mixing, this single sampling site was regarded as sufficient.

The samples were collected once a season: during the winter stratification (15 March 1996), spring mixing (16 May 1996), summer stratification (19 August 1996), and autumn mixing (25 November 1996). The samples were collected with the "Ton" sampler, at 2 m intervals, from the depth of 40 m to the surface. From each depth, 5 dm^3 samples were taken. The water was passed through an 0.044 mesh netting. Simultaneously, water temperature and dissolved oxygen content were measured at the zooplankton sampling depths. Water transparency was determined with a Secchi disc.

Table 1. Rotifer species identified in the Lake Miedwie zooplankton within 15 Mar-25 Nov 1996

Species	1996			
	date			
	15 March	16 May	19 Aug.	25 Nov.
Argonotholca foliacea (Ehrb.)		+		
Asplanchna sp.	+	+	+	+
Brachionus angularis Gosse		+		+
Brachionus calyciflorus Pall.		+		
Brachionus leydigi leydigi Cohn		+		
Conochiloides natans (Seligo)		+		
Conochilus sp.		+		
Diurella sp.			+	
Filinia longiseta (Ehrb.)	+	+		
Filinia maior (Colditz)		+	+	+
Filinia terminalis (Plate)			+	+
Kellicottia longispina (Kellicott)	+	+	+	+
Keratella cochlearis cochlearis (Gosse)	+	+	+	+
Keratella cochlearis tecta (Gosse)		+	+	+
Keratella hiemalis Carlin	+	+		
Keratella irregularis (Lauterborn)	+		+	+
Keratella quadrata (Müller)		+	+	+
Keratella quadrata frenzeli (Eckstein)	+	+		
Lecane sp.		+	+	
Monostyla sp.			+	+

Notholca sp.		+		
Notholca acuminata (Ehrb.)		+		
Notholca intermedia Voronkov		+		
Notholca labis Gosse				+
Notholca squamula (Müller)	+	+		
Polyarthra sp.			+	+
Polyathra dolichoptera Idelson	+	+		
Polyarthra vulgaris Carlin	+		+	+
Pompholyx sulcata Hudson	+	+	+	+
Synchaeta sp.	+	+	+	+
Testudinella patina (Hermann)			+	
Trichocerca sp.			+	
Trichocerca capucina (Wierzejski et Zacharias)			+	
Trichotria truncata truncata (Whitelegge)			+	
Rotatoria indet.	+	+	+	+
No. of rotifer species	13	24	20	16

The zooplankton organisms were identified using keys provided by Floessner [2], Kiefer et al. [8], Kuticova [9], and Voigt et al. [31]. The list of rotifer, cladoceran, and copepod species identified is given in Table 1 and Table 2, while Tables 3–10 and Fig. 4 show the abundance, biomass, and per cent contribution of individual zooplankton taxa. Based on trophic status indices and zooplankton structure, the trophic status of the lake was assessed (Table 11). The trophic evaluation was assisted by the *Daphnia magna* test, described by Szlauer et al. [1994], the results of which are summarised in Table 12.

Table 2. Planktonic crustaceans and other taxa identified in the Lake Miedwie zooplankton within 15 Mar-25 Nov 1996

Species	1996			
	date			
	15 March	16 May	19 Aug.	25 Nov.
Bosmina coregoni kessleri Uljanin		+	+	
Bosmina longirostris (Müller)	+	+	+	+
Bythotrephes longimanus Leydig			+	
Chydorus gibbus Sars		+		+
Daphnia cucullata Sars	+		+	+
Daphnia cristata Sars			+	

Daphnia longispina (Müller)	+		+	+
Daphnia hyalina Leydig				+
Diaphanosoma brachyurum (Liév.)			+	
Leptodora kindtii (Focke)			+	+
No. of cladoceran species	3	3	8	6
Cyclops kolensis Lillj.	+	+	+	+
Cyclops vicinus Ulj.	+	+	+	+
Cyclops scutifer Sars			+	+
Cyclops sp.	+	+	+	+
Diacyclops languidus (Sars)			+	
Diacyclops nanus (Sars)				+
Eudiaptomus gracilis (Sars)	+	+	+	+
Eudiaptomus sp.	+	+		+
Eudiaptomus graciloides (Lillj.)	+	+	+	+
Mesocyclops leuckarti (Claus)		+	+	+
Thermocyclops oithonoides (Sars)		+	+	+
Kopepodit Cyclopoida	+	+	+	+
Harpacticoida				+
Nauplius Cyclopoida	+	+	+	+
Nauplius Calanoida	+	+	+	+
No. of copepod species	6	8	9	10
Chironomidae larvae			+	
Dreissena polymorpha larvae			+	
Nematoda			+	
Tardigrada	+			+
No. of other invertebrate taxa	1	0	3	1
Total no. of zooplankton taxa (*Rotatoria*, *Cladocera* and other invertebrates)	23	35	40	33

RESULTS

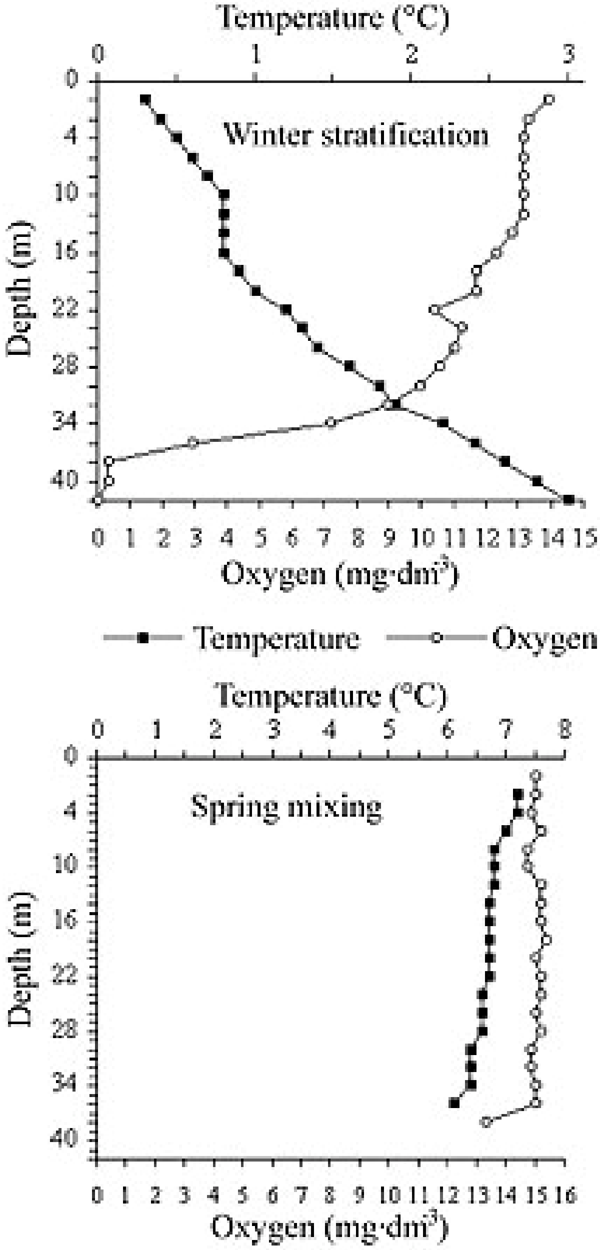
Thermal conditions and oxygen regime of the lake's water were typical of deep lakes at moderate latitudes.

The lake was frozen in winter (15 March 1996), the ice cover being 38–46 cm thick. Such thick an ice cover is not frequent in this lake. Water temperature was 0.3°C near the surface and 3.0°C near the bottom. The surface water oxygen content was 15.9 mg O_2 dm^{-3}, the

PRINT

content decreasing from 28 m downwards. Near the bottom, at the depth of 38–40 m, trace amounts of oxygen remained, no oxygen being detected at 41 m (Fig. 2).

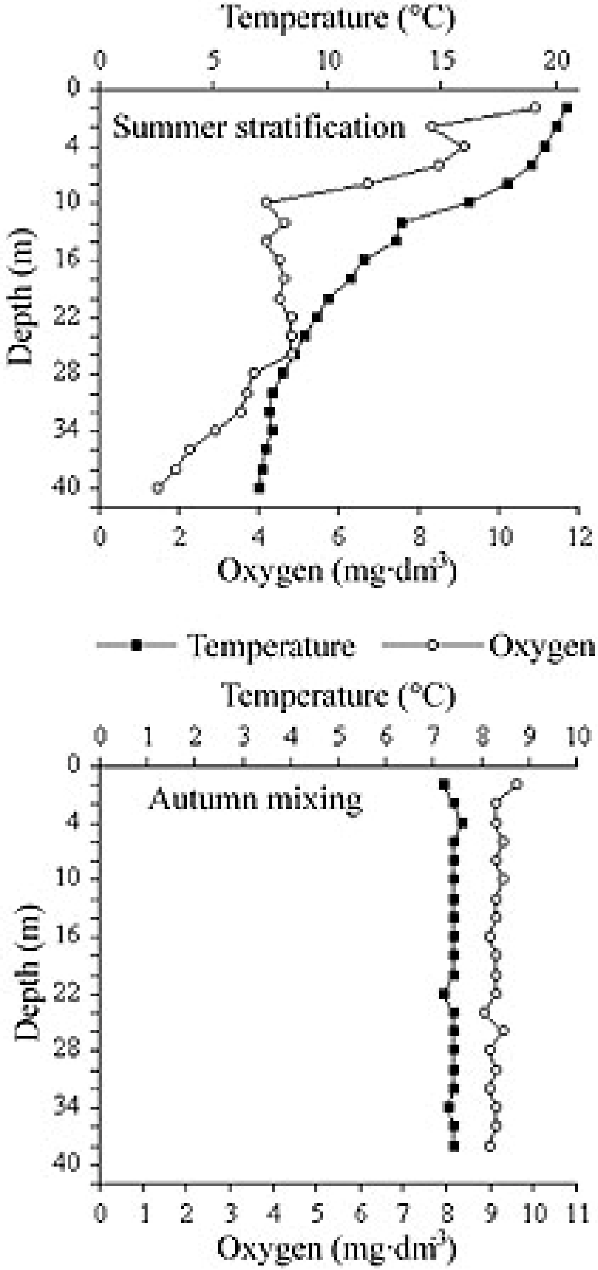
Fig. 2. Lake Miedwie water temperature (°C) and dissolved oxygen content (mg·dm^{-3}) in 1996



In spring (16 May 1996), the spring mixing resulted in uniform temperature and oxygen content throughout the water column. The temperature ranged from 6.1°C near the bottom to 7.2°C at the surface. The oxygen content was 15 mg O_2 dm^{-3} throughout most of the water column, decreasing to 13.3 mgO_2 dm^{-3} at 38 m (Fig. 2).

During the summer stratification (19 August 1996), the epilimnion temperature ranged from 20.5°C at the surface to 17.9°C at 8 m. Below that depth, within the 8–28 m layer, the temperature decreased from 18.0 to 8.0°C, and stayed at about 7.0°C in the hypolimnion (30–40 m). The oxygen content in the epi–, meta–, and hypolimnion ranged within 10.9–6.7; 4.16–4.8; and 3.8–1.4 mg O_2 dm^{-3}, respectively (Fig. 3).

Fig. 3. Lake Miedwie water temperature (°C) and dissolved oxygen content (mg·dm^{-3}) in 1996



The autumn mixing resulted in uniformisation of water column temperature and oxygen content, the respective average values being 7.4°C and 9.0 mg O_2 dm^{-3} (Fig. 3).

The Secchi disc visibility varied in time and amounted to 6.6, 4.5, 2.7, and 3.9 m in winter, spring, summer, and autumn, respectively.

The Lake Miedwie zooplankton was found to consist of at least 35 rotifer, 10 cladoceran, and 10 copepod species (Table 1, Table 2). Not all the higher taxa, listed in the tables, could be identified to species. The lowest and the highest numbers of taxa were found in winter and summer, respectively. The following species occurred throughout the year: *Kellicottia longispina*, *Keratella cochlearis cochlearis*, *Pompholyx sulcata*, *Asplanchna* spp., and *Filinia* spp. among the rotifers as well as *Bosmina longirostris*, *Cyclops kolensis*, *C.vicinus*, *Eudiaptomus gracilis*, and *E.graciloides* among the crustaceans.

In winter (15 March 1996), the most abundant among the rotifers was the cold–water species *Keratella irregularis* (4.1 ind. dm^{-3} mean abundance); its densest aggregations, 10.0 and 11.0 ind. dm^{-3}, were found at 4 and 36 m, respectively. Mean abundances of other species present were 2.8, 2.7, 1.6, and 1.1 ind. dm^{-3} for *Kellicottia longispina*, *Polyarthra vulgaris*, an unidentified tecate, *Keratella quadrata*, and *Synchaeta* sp., respectively. The densest aggregations of the species listed were observed near the surface and at 36 m.

The winter cladoceran assemblage was dominated by *Bosmina longirostris* (2.5 ind. dm^{-3} mean abundance). The densest concentrations of the cladoceran, 19.2 and 23.4 ind. dm^{-3}, were recorded just beneath the surface (below the ice) and at 36 m, respectively. Single individuals of *Daphnia longispina* were found occurring just above the bottom. Among the copepods, those most abundant were copepodites, predominantly of *Cyclops kolensis* and *C. vicinus*; they occurred at 3.2 ind. dm^{-3} mean abundance and maximum abundances of 17.4 and 18.2 ind. dm^{-3} near the surface and at 36 m, respectively. The highest numbers of *Eudiaptomus* were caught at the same depth, too, the respective abundances being 4.0 and 16.2 ind. dm^{-3}. A sample collected from 41 m was found to contain some mud and resting stages (copepodite V) of *Mesocyclops leuckarti*.

Table 3. Abundance (ind. dm^{-3}) of major zooplankton taxa at different depths of Lake Miedwie during winter stratification (15 March 1996)

Depth (m)	*Rotatoria*	*Cladocera*	*Copepoda*	Nauplii	Other	Total
1	60.0	19.2	21.0	4.8	0	105.0
2	40.2	1.2	1.2	6.0	0	48.6
4	19.2	0.0	1.2	6.6	0	27.0
6	10.2	0.0	0	1.8	0	12.0
8	16.0	0.0	0.8	2.0	0	18.8
10	17.8	0.2	0.2	2.8	0	21.0
12	7.0	0.2	0.2	1.2	0	8.6
14	4.8	0.2	0.0	1.2	0	6.2
16	1.8	0.4	0.2	0.8	0	3.2
18	2.6	0.0	0.2	0.4	0	3.2
20	5.6	0.4	0.2	2.0	0	8.2
22	3.6	0.6	0.6	2.2	0	7.0
24	4.8	0.6	0.8	1.6	0	7.8
26	3.8	0.4	0.6	0.8	0	5.6
28	9.0	0.2	1.2	0.8	0	11.2
30	11.8	1.0	1.6	1.2	0	15.6
32	15.0	1.8	6.6	0.4	0	23.8
34	12.6	2.4	8.6	2.8	0.2	26.6
36	24.2	24.2	36.6	11.6	0	97.2

38	5.8	2.6	5.2	0.8	0	14.4
40	6.2	0.4	2.2	2.2	0	11.0
41	2.0	0.0	22.0	5.0	0	29.0
Mean	12.9	2.6	5.0	2.7	0.01	23.2

The abundance and biomass of major zooplankton taxa during the winter stratification are summarised in Table 3 and Table 4. Numerically, the rotifers with mean abundance of 12.9 ind. dm^{-3} were dominant. The highest abundances were recorded near the surface (60.0 – 40.3 ind. dm^{-3}) and at 36 m (24.2 ind. dm^{-3}). The rotifers were followed by copepod adults and copepodites (5.0 ind. dm^{-3} mean abundance) and by nauplii (2.7 ind. dm^{-3} mean abundance). The least abundant were the cladocerans, with a mean density of 2.6 ind. dm^{-3}. As in the rotifers, the highest densities of cladocerans and copepods were recorded just beneath the surface and at 36 m. Copepods proved quite abundant also at 41 m, mainly because of the presence of resting stages of *Mesocyclops leuckarti*. The total zooplankton mean abundance was 23.2 ind. dm^{-3}, the maximum densities at 1 and 36 m being 105.0 and 97.2 ind. dm^{-3}, respectively (Table 3).

Table 4. Biomass (mg dm^{-3}) of major zooplankton taxa at different depths of Lake Miedwie during winter stratification (15 March 1996)

Depth (m)	*Rotatoria*	*Cladocera*	*Copepoda*	Nauplii	Other	Total
1	0.0518	0.1386	0.4272	0.0216	0	0.6392
2	0.0622	0.0072	0.0204	0.0270	0	0.1168
4	0.0229	0	0.0204	0.0291	0	0.0724
6	0.0162	0	0	0.0078	0	0.0240
8	0.0308	0	0.0136	0.0089	0	0.0533
10	0.0168	0.0012	0.0034	0.0123	0	0.0337
12	0.0128	0.0012	0.0034	0.0052	0	0.0226
14	0.0042	0.0016	0	0.0045	0	0.0103
16	0.0007	0.0024	0.0034	0.0033	0	0.0098
18	0.0015	0	0.0054	0.0017	0	0.0086
20	0.0023	0.0024	0.0034	0.0088	0	0.0169
22	0.0024	0.0040	0.0102	0.0098	0	0.0264
24	0.0035	0.0036	0.0136	0.0070	0	0.0277
26	0.0016	0.0028	0.0102	0.0035	0	0.0181
28	0.0038	0.0012	0.0204	0.0035	0	0.0289
30	0.0083	0.0064	0.0272	0.0054	0	0.0473
32	0.0045	0.0130	0.1174	0.0017	0	0.1366
34	0.0055	0.0162	0.1640	0.0122	0.0003	0.1982
36	0.0070	0.2430	1.0934	0.0484	0	1.3918

38	0.0063	0.0209	0.1017	0.0035	0	0.1324
40	0.0031	0.0058	0.0374	0.0099	0	0.0562
41	0.0014	0	0.3180	0.0090	0	0.3284
Mean	0.0122	0.0214	0.1097	0.0111	+	0.1544

The copepods contributed most to the zooplankton biomass. The total copepod (including nauplii) mean biomass was 0.121 mg dm^{-3}. Mean biomasses of the cladocerans and rotifers were 0.0214 and 0.0122 ind. dm^{-3}, respectively. The mean biomass of the total zooplankton was 0.154 mg dm^{-3} (Table 4).

During the spring mixing (16 May 1996), the zooplankton was dominated by rotifers, the distribution of mean densities between individual rotifer species being as follows: 229.5; 42.7; 34.2; 24.9; 23.0; and 9.7 ind. dm^{-3} for *Conochiloides natans*, *Synchaeta* spp., unidentified tecates, *Keratella quadrata*, *Polyarthra dolichoptera*, and *K.cochlearis cochlearis*, respectively. *Pompholys sulcata*, *Keratella hiemalis*, *Kellicottia longispina*, and *Filinia longiseta* occurred at low densities. Most species formed the densest concentrations within 1–8 m layer; for instance, the density of *Conochiloides natans* in the layer was about 10 times that within 20–24 m.

Among the copepods, the following species contributed mean densities of 5.2; 4.9; and 1.3 ind. dm^{-3}: *Mesocyclops leuckarti*, cyclopoid copepodites, and *Cyclops kolensis*, respectively. It was at some depths only that single individuals of *Eudiaptomus gracilis*, *E.graciloides, Cyclops vicinus*, and *Thermocyclops oithonoides* were present. Copepod nauplii concentrated predominantly underneath the surface, down to 8 m, their mean abundance being 7 ind. dm^{-3}.

Among the cladocerans, single individuals of *Bosmina longirostris, B.coregoni kessleri*, and *Chydorus gibbus* were recorded.

Table 5 summarises densities of the major zooplankton taxa at different depth levels in spring. The table shows the rotifers to be most abundant, with mean densities of 384.7 ind. dm^{-3} out of the mean total zooplankton abundance of 404.5 ind. dm^{-3}. The rotifers were concentrated, with a mean density of 703.0 ind. dm^{-3}, within the 2–8 m layer. The copepods occurred most abundantly (28.5 ind. dm^{-3}) within 1–2 m, and the copepod nauplii showed the densest concentrations (13.2 ind. dm^{-3}) within 1–8 m. The cladocerans occurred as single individuals only, with a mean abundance of 0.6 ind. dm^{-3} (Table 5).

Table 5. Abundance (ind. dm^{-3}) of major zooplankton taxa at different depths of Lake Miedwie during spring mixing (16 May 1996)

Depth (m)	*Rotatoria*	*Cladocera*	*Copepoda*	Nauplii	Total
1	462	0	27	17	506.0
2	804	1	30	15	850.0
4	637	0.2	12	11	660.2
6	766	0	14	13	793.0
8	605	0	12	10	627.0

PRINT

10	339	0	11	5	355.0
12	497	0	8	3	508.0
14	372	1	7	2	382.0
16	224	1	12	4	241.0
18	173	1	8	2	184.0
20	92.5	1	4	0.5	98.0
22	93	0	7.8	2.4	103.2
24	93	0	4	6	103.0
26	409	0.4	8.6	8	426.0
28	403	1	8	9	421.0
30	320	1	12	9	342.0
32	314	2	12	5	333.0
34	300	1	17	3	321.0
36	406	1	17	8	432.0
38	-	-	-	-	-
Mean	384.7	0.6	12.2	7.0	404.5

The zooplankton biomass was dominated by that of rotifers which supplied 1.2 mg dm^{-3}. Within 2–8 m, the rotifer biomass exceeded 2.0 mg dm^{-3}. The second highest mean biomass (0.201 mg dm^{-3}) was contributed by the copepods (nauplii, copepodites, and adults), followed by the cladocerans (mean biomass of 0.003 mg dm^{-3}). The mean total zooplankton biomass was 1.402 mg dm^{-3}; the biomass maximum (3.015 mg dm^{-3}) was recorded at 2 m (Table 6).

Table 6. Biomass (mg dm^{-3}) of major zooplankton taxa at different depths of Lake Miedwie during spring mixing (16 May 1996)

Depth (m)	*Rotatoria*	*Cladocera*	*Copepoda*	Nauplii	Total
1	1.4319	0	0.3100	0.0680	1.8099
2	2.5677	0.0075	0.3800	0.0600	3.0152
4	2.1449	0.0060	0.1200	0.0440	2.3149
6	2.5382	0.0015	0.1800	0.0520	2.7717
8	2.1018	0	0.1670	0.0400	2.3088
10	1.0119	0.0015	0.1300	0.0200	1.1634
12	1.5555	0	0.0800	0.0120	1.6475
14	1.2004	0.0015	0.0700	0.0080	1.2799
16	0.6778	0.0060	0.2350	0.0160	0.9348
18	0.4924	0.0015	0.1400	0.0080	0.6419
20	0.2797	0.0041	0.0685	0.0020	0.3543

22	0.2537	0	0.1540	0.0096	0.4173
24	0.2319	0	0.1058	0.0240	0.3617
26	1.1267	0.0018	0.1062	0.0320	1.2667
28	1.2116	0.0015	0.1000	0.0360	1.3491
30	1.0526	0.0060	0.2312	0.0360	1.3258
32	0.9632	0.0099	0.1600	0.0200	1.1531
34	0.8477	0.0015	0.2300	0.0120	1.0912
36	1.0677	0.0060	0.3271	0.0320	1.4328
Mean	1.1977	0.0030	0.1734	0.0280	1.4021

During the summer stratification (19 Aug. 1996), similarly to the spring mixing, the zooplankton was dominated by rotifers, the dominant species being, however, different from those in the spring. The following mean water column densities: 86.0; 44.0; 19.0; 9.0; 8.0; 7.0; 4.0, and 2.0 ind. dm^{-3} were supplied by *Keratella cochlearis cochlearis*, *Pompholyx sulcata*, *Polyarthra vulgaris*, *Filinia terminalis*, unidentified tecates, *Keratella quadrata*, *K.cochlearis tecta*, and *Kellicottia longispina*, respectively. Most rotifer species showed peak abundances within the upper part of the water column, from 1 down to 10 m, that is in the epilimnion. For instance, *Keratella cochlearis cochlearis* occurred in the epilimnion at densities of 104–401 ind. dm^{-3}, its mean densities in the meta– and hypolimnion being 40 and 13 ind. dm^{-3}, respectively. Another rotifer species, *Pompholyx sulcata*, showed the highest density (103–173 ind. dm^{-3}) in the epilimnion as well, its mean density in the hypolimnion being as low as 4 ind. dm^{-3}. It was *Filinia terminalis* only that showed a reverse pattern of density distribution: the highest mean density (23 ind. dm^{-3}) was recorded in the hypolimnion within 20–40 m, the mean density of the species in the epilimnion being as low as 2 ind. dm^{-3}.

The summer cladoceran taxocoene was dominated by *Bosmina longirostris* supplying a mean density of 9 ind. dm^{-3}. The vertical distribution of the species was very interesting: single individuals were recorded down to 34 m depth, while densities of 13 and 28 ind. dm^{-3} occurred at 36 and 38 m, respectively; the highest density of as many as 102 ind. dm^{-3} were recorded deepest in the water column (40 m). Other cladocerans present included *Daphnia hyalina*, *D.cucullata*, *Leptodora kindti, Bythotrephes longimanus, Bosmina coregoni*, *Diaphanosoma brachyurum*, and *Daphnia cristata*. *Daphnia hyalina* and *D.cucullata* occurred deeper in the water column, predominantly within 14–36 m. On the other hand, the predatory *Leptodora kindti* and *Bythotrephes longimanus* kept to the 1–8 m depth layer. Among the copepods, those most abundant included *Mesocyclops leuckarti* with 1.7 ind. dm^{-3}), *Thermocyclops oithonoides* (0.8 ind. dm^{-3}), cyclopoid copepodites (1.1 ind. dm^{-3}), and *Cyclops scutifer* (0.7 ind. dm^{-3}). The first two species, as thermophiles, were predominant in the upper part of the water column, within 4–16 m where the mean temperature was 16.7°C. *Cyclops scutifer*, a mesotrophic lake indicator, occurred mostly within 24–40 m layer at a mean temperature of 7.9°C. Other copepods recorded in the summer, i.e., *Cyclops kolensis*, *C.vicinus, Eudiaptomus gracilis*, and *E.graciloides*, were not abundant and concentrated at mid–depths.

The entire zooplankton was dominated by the rotifers which supplied a mean density of 180 ind. dm^{-3}, and by the cladocerans, occurring at a mean density of 12.5 ind. dm^{-3}. The copepods (without nauplii) supplied 5.3 ind. dm^{-3}. Nauplii (24.5 ind. dm^{-3} mean density) were more abundant than in the winter and spring (Table 7).

Table 7. Abundance (ind. dm^{-3}) of major zooplankton taxa at different depths of Lake Miedwie during summer stratification (19 August 1996)

Depth (m)	*Rotatoria*	*Cladocera*	*Copepoda*	Nauplii	Other	Total
1	659.0	10.0	1.0	43.0	1	714.0
2	480.0	5.0	1.0	17.0	1	504.0
4	660.0	6.0	5.0	43.0	1	715.0
6	461.0	5.0	8.0	38.0	0	512.0
8	392.0	3.0	11.0	40.0	0	446.0
10	221.0	0	11.0	63.0	1	296.0
12	127.0	3.0	10.0	36.0	0	176.0
14	109.0	7.0	16.0	27.0	1	160.0
16	72.0	12.0	15.0	22.0	0	121.0
18	94.0	4.0	2.0	28.0	0	128.0
20	80.0	6.0	3.0	18.0	0	107.0
22	72.0	8.0	3.0	24.0	1	108.0
24	52.6	3.0	2.2	12.4	0	70.2
26	51.0	3.8	1.2	16.6	0	72.6
28	42.6	8.6	2.8	10.0	0.2	64.2
30	22.2	7.8	1.8	9.6	0.4	41.8
32	38.2	15.2	2.2	12.2	0	67.8
34	25.6	8.0	1.8	10.4	0.2	46.0
36	60.2	16.0	2.0	15.0	0	93.2
38	50.4	28.2	3.6	16.6	0.2	99.0
40	24.8	102.4	7.6	13.8	0	148.6
Mean	180.7	12.5	5.3	24.5	0.3	223.3

The rotifers concentrated within 1–14 m, with densities ranging from 659.0 to 109.0 ind. dm^{-3}. Below that layer, rotifer abundances gradually decreased down to 24.8 ind. dm^{-3} at 40 m. The cladocerans occurred at densities of a few to several ind. dm^{-3} down to 40 m where they formed a dense concentration of as many as 102.4 ind. dm^{-3}. The highest densities of copepod copepodites and adults (several ind. dm^{-3}) were recorded within 8–16 m, the remaining parts of the water column housing a few individuals per dm^{3} each. Nauplii were most abundant (few tens of larvae per dm^{3}) from the surface down to 22 m, much lower densities being recorded beneath that depth (Table 7).

The mean total zooplankton biomass in the summer was 0.558 mg dm^{-3}. The major part of that biomass (0.340 mg dm^{-3}) was supplied by the cladocerans, while the copepods (with

PRINT

nauplii) and the rotifers contributed 0.138 and 0.080 mg dm^{-3}, respectively. The maximum zooplankton biomass (3.017 mg dm^{-3}) was recorded at 6 m (Table 8).

Table 8. Biomass (mg dm^{-3}) of major zooplankton taxa at different depths of Lake Miedwie during summer stratification (19 August 1996)

Depth (m)	*Rotatoria*	*Cladocera*	*Copepoda*	Nauplii	Other	Total
1	0.1699	0.2496	0.0306	0.0215	0.0002	0.4718
2	0.1362	0.5600	0.0100	0.0085	0.0002	0.7149
4	0.1995	0.6972	0.0830	0.0215	0.0002	1.0014
6	0.1731	2.5900	0.2346	0.0190	0	3.0167
8	0.1240	0.2398	0.1766	0.0200	0	0.5604
10	0.1425	0.0360	0.1370	0.0315	0.0002	0.3472
12	0.1809	0.0800	0.1420	0.0180	0	0.4209
14	0.0710	0.2534	0.4854	0.0135	0.0002	0.8235
16	0.0595	0.3035	0.5110	0.0110	0	0.8850
18	0.0678	0.1090	0.0820	0.0140	0	0.2728
20	0.0589	0.1540	0.2570	0.0090	0	0.4789
22	0.0960	0.1340	0.1470	0.0120	0.0020	0.3910
24	0.0259	0.0652	0.0737	0.0062	0	0.1710
26	0.0383	0.0592	0.0312	0.0083	0	0.1370
28	0.0283	0.1381	0.0444	0.0050	+	0.2158
30	0.0213	0.2172	0.0198	0.0048	0.0001	0.2632
32	0.0130	0.3200	0.0252	0.0061	0	0.3643
34	0.0086	0.1494	0.0180	0.0052	+	0.1812
36	0.0351	0.1577	0.0200	0.0075	0	0.2203
38	0.0246	0.1856	0.0360	0.0083	0.0010	0.2555
40	0.0079	0.4347	0.0802	0.0069	0	0.5297
Mean	0.0801	0.3397	0.1259	0.0123	0.0002	0.5582

During the autumn mixing (25 Nov. 1996), the zooplankton was dominated numerically by the rotifers, with mean densities of 55; 34; 15; 14; 5; 5 and 3 ind. dm^{-3} being supplied by *Keratella cochlearis cochlearis, Polyarthra vulgaris, Keratella irregularis*, *Kellicottia longispina*, unidentified rotifers, *Synchaeta* sp., and *Asplanchna* sp., respectively. Single individuals of *Keratella cochlearis tecta, K.quadrata*, and *Filinia maior* were present as well.

All the species showed similar patterns of vertical distribution, the highest concentrations being formed within 1–6 m. The only exception was *Keratella cochlearis cochlearis* the highest mean concentrations of which (163 ind. dm^{-3}, i.e., three times that at other depths) being recorded just above the bottom (38 m).

The most abundant cladoceran in autumn was *Daphnia hyalina* producing a mean abundance of 10 ind. dm^{-3} and a peak mean density (27 ind. dm^{-3}) within 4–8 m. The remaining species, *Daphnia cucullata* and *Bosmina longirostris*, occurred at densities of a few or single individuals per dm^3.

The copepods present during the autumn mixing included *Mesocyclops leuckarti, Thermocyclops oithonoides, Cyclops vicinus, C.kolensis, Eudiaptomus gracilis*, and *E.graciloides*, each represented by few individuals per dm^3 of water. Most abundant (several ind. dm^{-3} at different depths) were unidentified cyclopoid copepodites. The densest copepod concentrations occurred just above the bottom, at 38 m, where *Mesocyclops leuckarti* (copepodites IV and V), *Cyclops kolensis*, and unidentified cyclopoid copepodites were dominant.

Table 9 shows the abundance of major zooplankton taxa. As shown by the table, most abundant were the rotifers, with the mean and maximum densities of 135.8 and 228.6 ind. dm^{-3}, respectively. Much less abundant were the copepods (excluding nauplii), which formed concentrations of the mean and maximum abundances of 19.9 and 54.8 ind. dm^{-3}, respectively, the maximum concentrations occurring in the near–bottom water layer. The least abundant were the nauplii (13.8 ind. dm^{-3} mean abundance), distributed more or less evenly throughout the water column, and the cladocerans (13.2 ind. dm^{-3} mean abundance), the densest concentrations of which (31.0 ind. dm^{-3}) being found within the 4–8 m depth layer.

Table 9. Abundance (ind. dm^{-3}) of major zooplankton taxa at different depths of Lake Miedwie during autumn mixing (25 Nov. 1996)

Depth (m)	*Rotatoria*	*Cladocera*	*Copepoda*	Nauplii	Other	Total
1	142.2	6.6	16.8	22.2	0	187.8
2	114.0	7.8	16.2	13.8	0	151.8
4	192.0	37.2	28.2	15.0	0	272.4
6	183.6	26.4	19.2	19.2	0	248.4
8	127.8	29.4	12.0	9.0	0	178.2
10	86.4	9.0	15.6	5.4	0	116.4
12	121.8	10.8	19.2	13.2	0	165.0
14	112.2	11.4	25.2	13.8	0	162.6
16	139.8	15.0	24.0	11.4	0	190.2
18	136.8	10.8	16.2	14.4	0	178.2
20	133.2	15.4	21.2	12.4	0	182.2
22	112.0	14.4	20.4	12.0	0	159.0
24	111.6	15.0	12.0	12.6	0	151.2
26	113.4	16.8	15.6	19.2	0	165.0
28	133.8	9.0	16.8	13.8	0	173.4
30	135.0	7.8	21.6	19.2	0	183.6
32	146.4	8.4	12.6	12.6	0	180.0

PRINT

34	104.4	4.2	17.4	17.4	0	143.4
36	141.6	0.6	13.8	14.4	0.6	171.0
38	228.6	7.8	54.8	5.4	0	296.6
Mean	135.8	13.2	19.9	13.8	0.03	182.8

During the autumn mixing, the mean total zooplankton biomass was 0.92 mg dm^{-3}, the highest biomass (2.2 mg dm^{-3}) being recorded at 4 m. The cladocerans contributed most (0.437 mg dm^{-3}) to the total biomass, followed by the copepods (0.362 mg dm^{-3}, including nauplii), and rotifers (0.121 mg dm^{-3}) (Table 10).

Table 10. Biomass (mg dm^{-3}) of major zooplankton taxa at different depths of Lake Miedwie during autumn mixing (25 Nov. 1996)

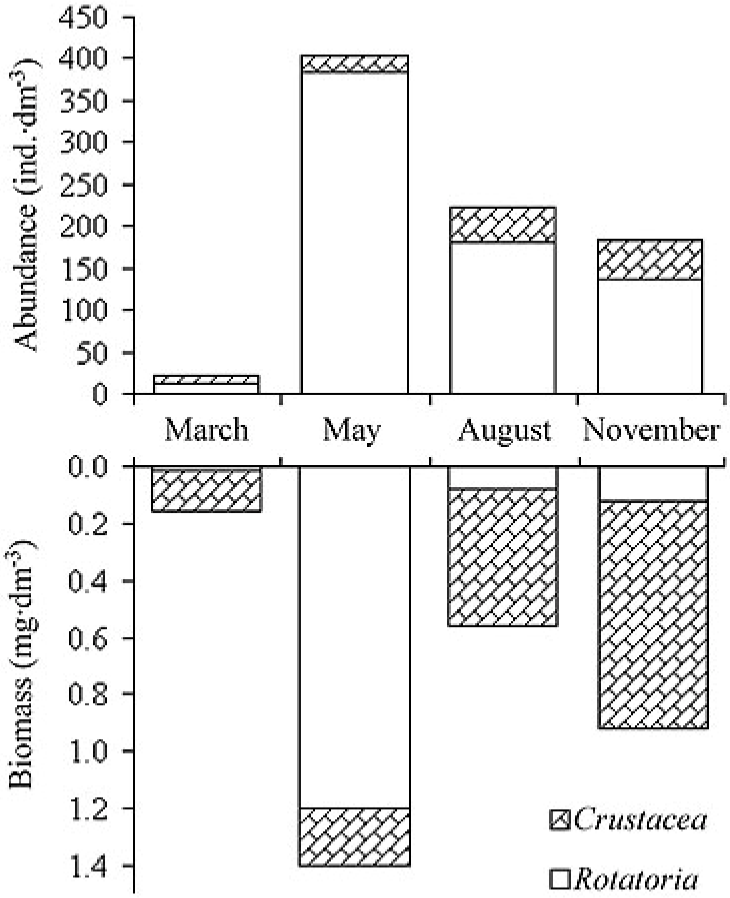
Depth (m)	*Rotatoria*	*Cladocera*	*Copepoda*	Nauplii	Other	Total
1	0.1197	0.0504	0.1080	0.0237	0	0.3018
2	0.1061	0.1272	0.3510	0.0195	0	0.6038
4	0.2124	1.3623	0.6023	0.0222	0	2.1991
6	0.1457	1.1631	0.3346	0.0159	0	1.6593
8	0.1344	1.0801	0.1200	0.0129	0	1.3474
10	0.0656	0.3396	0.3780	0.0069	0	0.7901
12	0.1037	0.2496	0.3006	0.0171	0	0.6710
14	0.0832	0.3477	0.5460	0.0153	0	0.9922
16	0.1331	0.5223	0.7590	0.0120	0	1.4264
18	0.1146	0.2031	0.2730	0.0135	0	0.6042
20	0.1564	0.5116	0.4997	0.0139	0	1.1816
22	0.0779	1.3902	0.3420	0.0144	0	1.8245
24	0.0870	0.4488	0.2346	0.0189	0	0.7893
26	0.1723	0.2733	0.1770	0.0201	0	0.6427
28	0.1747	0.2379	0.3450	0.0090	0	0.7666
30	0.1179	0.2061	0.2610	0.0159	0	0.6009
32	0.1877	0.1098	0.2616	0.0063	0	0.5654
34	0.0951	0.0447	0.1290	0.0108	0	0.2796
36	0.0554	0.0015	0.1290	0.0072	0.0007	0.1938
38	0.0692	0.0669	0.8172	0.0048	0	0.9581
Mean	0.1206	0.4368	0.3484	0.0140	+	0.9198

The present study showed the numerical domination of the rotifers over crustaceans in all the seasons. In terms of biomass, the rotifers dominated only during the spring mixing,

PRINT

crustaceans contributing most to the zooplankton biomass during the winter and summer stratification as well as during the autumn mixing (Fig. 4).

Fig. 4. Changes in the Lake Miedwie zooplankton abundance and biomass (water column means) in different seasons of 1996



The basic indices and indicators of the Lake Miedwie trophic status, based on the quantitative and qualitative aspects of the zooplankton structure during the summer stratification are presented in Table 11. The Carlson trophic status index (TSI_{SD}) (determined following Karabin 1985), based on the Secchi disc visibility, was 45.7. Other indices, such as the contribution of community II to the total rotifer biomass and the contribution of *forma tecta* to the *Keratella cochlearis* assemblage were 23.3 and 4.8%, respectively. The total rotifer density during the summer stagnation was 181 ind. dm^{-3}. Still other indices, including the contribution of community II to the total crustacean biomass and the percentage of cyclopoids in the total crustacean biomass were 16.5 and 16.8%, respectively. The cyclopoid to cladoceran biomass ratio was 0.24 (Table 11).

Table 11. Lake Miedwie trophic status indices (bold numbers) during summer stratification (19 Aug. 1996), compared with corresponding values reported by Karabin (1985)

Trophic status index	Trophic status indices in various lake types			
	mesotrophic	meso-eutrophic	eutrophic	polytrophic
TSI_{SD} [= 10(6-$\log_2$ SD*)]	< 45	45–55 **45.7**	55–65	>65

Percentage of community II** in total rotifer biomass	< 10	10–90 **23.3**	> 90	
Percentage of forma tecta in *Keratella cochlearis* assemblage abundance	0–5 **4.8**	5–20	20–60	> 60
Rotifer abundance (ind. dm^{-3})	< 400 **181.0**	400–2000		> 2000
Percentage of community II** in the total crustacean biomass	< 25 **16.5**	25–60	> 60	-
Cyclopoid contribution to the total crustacean biomass	< 15	15–30 **16.8**	> 30	-
Cyclopoid to cladoceran biomass ratio ($B_{Cyclopoida}:B_{Cladocera}$)	< 0.2	0.2–0.8 **0.24**	> 0.8	

* SD, Secchi disc visibility

** Community II;

rotifers: *Keratella cochlearis* f.*tecta*, *K.quadrata, Pompholyx sulcata, Filinia longiseta, Anuraeopsis fissa, Trichocerca pusilla, Brachionus* sp., *Proales micropus*

crustaceans: *Mesocyclops leuckarti, M.oithonoides, Diaphanosoma brachyurum*, *Chydorus sphaericus, Bosmina coregoni thersites, B.longirostris*

Results of the *Daphnia magna* tests applied to the Lake Miedwie water (Table 12) showed the mean production (increase in the *D.magna* stock biomass after 5 days) to be 6.58 mg dm^{-3}, the production range being 3.50–8.04 mg dm^{-3}. The mean length and mean individual weight of *D.magna* after 5 days were 1.57 and 0.29 mg, respectively.

Table 12. Results of *Daphnia magna* test on the Lake Miedwie water in 1996

Water sampling season	Winter	Spring	Summer	Autumn	Mean
Mean temperature of water tested	22.0°C				
Mean initial length of *Daphnia* individuals (mm)	0.848	0.904	0.883	0.867	0.875
Mean initial individual weight of *Daphnia* (mg)	0.02	0.04	0.02	0.02	0.025
Mean length of *Daphnia* individuals after 5 days	1.302	1.685	1.605	1.671	1.566
Mean individual weight of *Daphnia* after 5 days (mg)	0.150	0.361	0.298	0.334	0.286
Increase in *Daphnia* stock biomass after 5 days ($mg \cdot dm^{-3}$)	3.50	8.04	6.94	7.85	6.58

Phytoplankton blooms were observed in the lake during different seasons. In winter and spring, the phytoplankton was dominated by diatoms, mainly by representatives of the genus *Cyclotella*, accompanied by some *Asterionella* and *Fragillaria*. The most intense bloom occurred in summer, with domination of the dinoflagellate *Ceratium hirundinella*; the bloom resulted in the water column transparency dropping to 2.7 m. The autumn phytoplankton assemblage was dominated by *Cyclotella* and filamentous cyanobacteria.

DISCUSSION

A certain improvement in the oxygen regime is observable when the Lake Miedwie dissolved oxygen contents recorded in this study are compared with earlier data [11, 12, 30]. Although a decrease in the oxygen content was recorded in the hypolimnion during the 1996 summer stratification, the decrease was much weaker than that observed previously, and occurred deeper in the water column. Moreover, no extensive hypoxia event in the hypolimnion was recorded. It was only in the winter that the dissolved oxygen content dropped below 1.0 mg dm^{-3} at depths greater than 38 m (Fig. 2). It should be, however, remembered that the decrease happened at the end of a very severe winter, when the lake was covered by thick ice, which is infrequent on the Miedwie.

The relatively high Secchi visibility recorded in the lake (2.7–6.6 m) attested, too, to an improvement in the environmental conditions in the Miedwie, compared to the situation in the 1980s when intensive phytoplankton blooms, and hence low visibility (1.0–2.4 m) were the norm [30].

The zooplankton composition reflects changes that have been occurring in the lake since the 1980s [7, 21, 30]. A higher number of species was recorded in 1996, including some species not recorded so far and characteristic of mesotrophic lakes: *Bythotrephes longimanus*, *Daphnia cristata* (Cladocera), and *Cyclops scutifer* (Copepoda) (Table 2). The species composition recorded can be taken as an evidence of the improvement. The environmental conditions can be assessed by the presence of indicator species. Each record of such a species equals in weight to many a chemical assay. In the case of Lake Miedwie, the indicator species mentioned above attest to the prevailing conditions being much better than those in eutrophic lakes. This is particularly true with respect to the near–bottom water layer oxygen regime. The present findings lend more weight to the conclusions reached by [27] who, in a 1995 study, recorded the presence of *Pallasea quasdrispinosa*, another mesotrophic lake indicator. They are right in maintaining that the routine surveys in the Miedwie should be broadened by recording the presence of indicator, and at the same time endangered, species.

This study showed seasonal changes in abundance and biomass of most zooplankters. The changes were brought about by an array of factors, including the water temperature and trophic relationships. After the winter minimum, the zooplankton reached its peak abundance and biomass in May, following which the abundance gradually decreased again (August, November). Such changes in the abundance and biomass of zooplankton are typical of lakes at moderate latitudes, although not always does the pattern of peaks and troughs coincides in time with that recorded in this study [6, 20, 21].

Trophic relationships can be invoked to explain changes in the abundance of rotifers, the dominant zooplankton taxon in the Miedwie. The lowest abundance (the water column mean of 13 ind. dm^{-3}) was recorded in the winter, as a result of the minimum phytoplankton density (Secchi disc visibility of 6.6 m). Once the ice cover disappeared (which happened as late as at the end of April), during the spring mixing, the rotifers attained their peak abundance due to the presence of a quality food in the form of diatoms. In May, the water column mean rotifer abundance was 384.7 ind dm^{-3}, the most abundant species including

Conochiloides natans, Synchaeta spp., small unidentified rotifers, *Polyarthra dolichoptera*, and *Keratella quadrata*.

The vertical distribution of the major zooplankton taxa or species was not always uniform throughout the water column. Denser concentrations were recorded at different depths (Tables 3–10). The non–uniform vertical distribution of zooplankton has been attracting attention or researchers for a long time [6, 10, 24, 28]. The vertical distribution of zooplankters is affected by numerous factors, the most important role being widely attributed to depth–dependent changes in light intensity, temperature, pH, dissolved oxygen content, available food, changes in patterns and intensity of predator pressure. The vertical distribution of zooplankton can be also related to water currents and biology of a species in question. Ultimately, the spatial distribution is a net result of all those factors acting in concert [16, 26, 28]. In Lake Miedwie, dense concentrations of *Mesocyclops leuckarti*, a warm–water species, were observed near the bottom in winter, which is related to the species' biology. The resting stages of the species (copepodites IV and V) spend this unfavourable season by staying deep in the water column. They are resistant to anoxia and hydrogen sulphide [25]. On the other hand, the cladoceran *Bosmina longirostris* attained its peak densities near the bottom (about 40 m), too, but in the summer. Similar densities of the species were recorded in the summer in the hypolimnion of Lake Chelmzynskie [23]. The species is not adapted to floating in the water column for a prolonged period of time. Therefore, as the water temperature increases and water density and viscosity decrease, the individuals of the species sink to the hypolimnion [23]. The Lake Miedwie oxygen regime was sufficient for the species to remain even as deep as at 40 m. A similar behavioural pattern was observed in *Daphnia hyalina* in the Miedwie, the species forming dense summer concentrations in the hypolimnion. The tendency of the species to occur beneath the epilimnion in the summer had been earlier recorded by other workers [13, 28]. On the other hand, during autumn, when the temperature was uniform throughout the water column (7.4°C), the densest concentrations of *D. hyalina* were recorded just beneath the surface (at 4–8 m). The vertical distribution pattern observed in the species was most likely a result of the feeding pressure exerted by the fish [3, 4]. Predatory cladocerans, *Leptodora kindti* and *Bythotrephes longimanus*, encountered at dense concentrations in the lake in August, kept to the epilimnion with its dense concentrations of rotifers, the prey, and light conditions appropriate for catching the prey.

The Lake Miedwie zooplankton abundance data collected in 1984/1985 [30] and in 1996 (this study) show the abundance to have been reduced by half. This is also the case with rotifers, the abundance of which in the eighties was indicative of eutrophication, while the rotifer abundance at present points to the mesotrophic status of the Miedwie.

When assessing the trophic status of the Miedwie in 1996, indices developed by Karabin [5] were used (Table 11). Some of them, e.g., the *forma tecta* contribution to the *Keratella cochlearis* assemblage, rotifer abundance, and percentage of community II in the total crustacean biomass, point to the mesotrophic status of the lake. On the other hand, the water transparency–based TSI_{SD}, contribution of community II to the total rotifer biomass, contribution of cyclopoids to the total crustacean biomass, and the cyclopoid to cladoceran biomass ratio attest to the meso–eutrophic status of Lake Miedwie.

The trophic status of lakes can be diagnosed also from the zooplankton biomass. According to Petrovic [14], mesotrophic, eutrophic, and intermediate lakes support, during ice–free season, zooplankton biomasses of 1.35, 4.75, and 3.74 mg dm^{-3}, respectively. During the so–called

PRINT

growth season in Lake Miedwie, the zooplankton biomass was as low as 0.96 mg dm^{-3}, which classifies the lake as mesotrophic.

The Miedwie's trophic status was evaluated also with the *Daphnia magna* test [22, 29]. The advantage of the test lies, i.a., in the fact that it simultaneously produces a number of indices, related mainly to the weight increase of the test species. Generally, the higher the biomass increase of *Daphnia* kept in the water tested, the more fertile the water. The range of possible values covers 0–150 mg dm^{-3}. The *Dapnia* test was run four times on the Lake Miedwie water. The mean *Daphnia* biomass increase (6.6 mg dm^{-3}) was very low, indicating low fertility of the lake. For comparison, the *Daphnia* production recorded in a test for the River Ina water, polluted with municipal waste, reached 148 mg dm^{-3} [19]; the value obtained in the River Odra water (collected near Szczecin) was 70.0 mg dm^{-3} [29], while the production values for lakes Nowowarpienskie and Glebokie in Szczecin (in the summer) reached 16.5–70.6 [15] and 14.5 mg dm^{-3} [20], respectively.

The results obtained in 1996 allow to regard the Miedwie as a (still) mesotrophic lake. It should be emphasised that the lake's trophic status improved, compared to that in the 1980s when clear symptoms of eutrophication were visible. It is not frequently that the trophic status of a Polish lake changes from higher to lower. Studies in the Leczynsko–Wlodawskie Lake District [18] brought similar data. The improvement in the Lake Miedwie status resulted from a number of factors. As a consequence of sewage treatment plants installed in Pyrzyce, the River Plonia water entering the Miedwie is substantially cleaned. A non–conventional treatment plant was set up on the Gowienica Miedwianska. In addition, the use of fertilisers on the fields surrounding the lake diminished.

The improvement in the Lake Miedwie status should be maintained and supported, if only because of the fact that the lake serves as the major source of drinking water for the city of Szczecin.

As demonstrated by the studies described here, trophic status of a lake can be evaluated from data on the zooplankton community structure and from biological tests. Such methods should be incorporated into the Lake Miedwie monitoring.

SUMMING UP

The Lake Miedwie zooplankton was studied during the winter and summer stratification periods and during the spring and autumn mixing of 1996. Changes in the zooplankton abundance, species composition, and vertical distribution were followed in relation to physical and chemical conditions of the environment. The results obtained as well as the data produced by the *Daphnia magna* tests served to evaluate the lake's trophic status.

The Lake Miedwie zooplankton was found to consists of not less than 35 species of rotifers, 10 cladoceran, and 10 copepod species.

Both the abundance and biomass of the zooplankton were low, classifying the lake as mesotrophic.

The zooplankton abundance and biomass were found to change seasonally.

PRINT

In all the seasons, rotifers were a dominant component in terms of abundance, while the rotifer biomass was dominant only during the spring mixing; crustaceans dominated in terms of biomass during the winter and summer stratification as well as during the autumn mixing.

The zooplankton taxa differed clearly in their vertical distribution; some species displayed also season–dependent changes in their vertical distribution patterns.

The Lake Miedwie zooplankton was found to contain species regarded as mesotrophic indicators, i.e., *Bythotrephes longimanus, Daphnia cristata*, and *Cyclops scutifer*.

Such trophic status indices as the contribution of *forma tecta* to the *Keratella cochlearis* assemblage, rotifer abundance, and percentage of community II in the total rotifer biomass point to the Lake Miedwie being still mesotrophic. On the other hand, indices such as TSI_{SD}, percentage of community II in the total crustacean biomass, and the cylopoid to cladoceran biomass ratio demonstrate the meso–eutrophic status of the lake (Table 11).

The above evaluation was supported by results of the *Daphnia magna* test for water fertility.

The Lake Miedwie oxygen regime, too, evidenced an improvement in the environmental condition of the lake, compared to the 1980s.

The shift from eu– to mesotrophic status described here is rare in Polish lakes and is most likely a result of treating the water discharging into the lake.

REFERENCES

1. Filipiak J., Sadowski J.: Szczecin Lakes, AR, Szczecin, 1994, 285 pp.
2. Floessner D.: Krebstiere, Crustacea. Kiemen-und Blattfüsser, Branchiopoda Fischläuse, Branchiura, VEB Gustav Fischer Verlag, Jena, 1972, 501 pp.
3. Jacobs J. Coexistence in similar zooplankton species by differential adaptation to reproduction and escape in an environment with fluctuating food and enemy desities. I. A model, Ocelogia, 29, 1977a, 233-247.
4. Jacobs J.: Coexistence in similar zooplankton species by differential adaptation to reproduction and escape in an environment with fluctuating food and enemy densities. II. Field data analysis of *Daphnia,* Oecologia, 30, 1977b, 313-329.
5. Karabin A.: Pelagic zooplankton (Rotatoria + Cladocera) variation in the process of lake eutrophication, I. Structural and quantitative features, Ekol. Pol., 33, 4, 1985, 567-616.
6. Karabin A., Ejsmont-Karabin J.: Structure, dynamics and distribution of zooplankton, and its many-years' changes in the Wigry Lake, Ekol. Pol., 39, 3, 1991, 357-375.
7. Kazmierczuk J., Szlauer B.: Zooplankton in Lake Miedwie water treatment plant installations, Zesz. Nauk. AR Szczec. Ser. Ryb. Mor. i Techn.Żywn. 108, 1984, 45-57.
8. Kiefer F., Fryer G.: Das Zooplankton der Binnengewaesser. 2 Teil. In: Die Binnengewässer, Band 26, E. Schweizerbartsche Verlagsbuchhandlung, Stuttgart, 1978, 380 pp.
9. Kuticova L. A.: Kolovratki fauny SSSR (Rotatoria), "Nauka", Leningrad, 1970, 744 pp.
10. Mikulski J. St.: Biology of inland waters, PWN, Warszawa, 1982, 491 pp.
11. Mutko T.: Information on the status of the Szczecin District environment, PIOS, WIOS, Szczecin, 1992, 57 pp.
12. Mutko T., Wierzchowska E.: Assessment of long–term data on changes in Lake Miedwie water quality and protection measures, II Konferencja Nauk.- Techn. "Ochrona i rekultywacja jezior i zbiorników wodnych", Międzyzdroje, 1996, 73-86.
13. Patalas K.: Seasonal changes in pelagic crustacean assemblage of Lake Zamkowe in relation to thermal conditions and oxygen regime, Pol. Arch. Hydrobiol., 3 (16), 1956, 203-251.
14. Petrovic P. G. Biomasa i produkcja zooplanktona raznotipnych ozer Naroč, Mjastro i Batorino po mnogoletnim nabludenijam. Metody opredelenija produkcji vodnych životnych, Minsk. Vyssaja Skola, Minsk, 1968, 173-183.

PRINT

15. Piasecki W. An attempt to evaluate the status of Lake Nowowarpienskie and the southern part of the Szczecin Lagoon, based on zooplankton studies and biological tests. In: Stan i perspektywy badań hydrobiologicznych i rybackich w estuarium Odry. Mater. symp., Stud. Mater. MIR, Ser. S, 1993, 65-71.
16. Pijanowska J.: Mechanisms of protection against predators in planktonic animals. Wiad. Ekol., PWN, Warszawa 31, 2, 1985, 123-170.
17. Prawdzic K.: Lakes of the Western Pomerania, Wydaw. Wiad. Zach.- Szczecin, 1966.
18. Radwan S., Kornijow R., Kowalik W., Kowalczyk C., Popiolek B., Stepien B., Wojciechowska In: Hydrobiological processes in a lake–peatbog complex within a renaturalisation area. In: Renaturalizacja ekosystemów wodno-torfowiskowych na Pojezierzu Leczynsko-Wlodawskim. Wydaw. UMCS Lublin, 1996, 61-80.
19. Szarapanowska J.: The use of the cladoceran *Daphnia magna* Straus to evaluate effects of pollution from Stargard Szczecinski on River Ina, USzczec., Szczecin, 1992, (manuscript).
20. Szlauer B.: Zooplankton of Lake Glebokie in Szczecin as an indicator of the lake's trophic status, Zesz. Nauk. AR Szczec., Ser. Ryb. Mor. i Techn. Zywn. 22, 171, 1996, 19-34.
21. Szlauer B., Szlauer L.: Zooplankton in the drinking water intake in Lake Miedwie and perspectives of its utilisation in fish fry feeding, Zesz. Nauk. AR Szczec. Ser. Ryb. Mor. i Techn. Zywn., 103, 1983, 123-138.
22. Szlauer B., Szlauer L.: An attempt to determine effects of the Police Chemical Works on the Szczecin Lagoon trophic status, Zesz. Nauk. AR Szczec., 133, 1988, 23-37.
23. Szlauer L.: The Lake Chelmzynskie plankton, Nauki mat.-przyrodn., Torun, 3, 1956, 33-61.
24. Szlauer L.: Vertical migrations of zooplankton as elucidated by trap sampling, Pol. Arch. Hydrob., 8 (21), 1960, 63-86.
25. Szlauer L.: The resting stages of Cyclopidae in Stary Dwor Lake, Pol. Arch. Hydrob., 11 (24), 3, 1963, 385-394.
26. Szlauer L.: Horizontal movement of the waters in the Insko Lake and its effect on biological phenomena in the lake, Pol. Arch. Hydrob., 23, 2, 1976, 175-188.
27. Szlauer L., Swierczynski M.: A glacial relict lives in Lake Miedwie, Aura, 2, 1996, 26.
28. Szlauer L., Widuto J.: The Lake Sukiel crustacean plankton within 1955–1957, Zesz. Nauk. WSR Olszt., 21, 512, 1966, 733-755.
29. Szlauer L., Wolska-Neja B., Szlauer B.: An attempt to use the crustacean *Daphnia magna* to assess effects of Szczecin sewage on River Odra, Zesz. Nauk. AR Szczec., 164, 1994, 51-60.
30. Szyper H., Goldyn R., Mastynski J., Szelag-Wasielewska E., Stempniak M., Ground–truthing of sanitary protection zones of Lake Miedwie from the standpoint of maintaining the quality of water supplied to Szczecin, Stage III, Part II, Effects of changes in water table on the Lake Miedwie water purity. Inst. Gosp. Przest. i Komun., Oddz. w Poznaniu, 1987, (manuscript).
31. Voigt M., Koste W.: Rotatoria. Die Raedertiere Mitteleuropas. I. Textband, II Tafelband, Gebrueder Borntraeger, Berlin, Stuttgart, 1978, 673 pp.

Submited:

Barbara Szlauer
Department of Hydrobiology
Agricultural University of Szczecin
Poland

PRINT