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Plankton Community in the Pelagic and Littoral Zones of the Overgrown Lake Beloe (Volzhsko-Kamskiy Biosphere Natural State Reserve, Republic of Tatarstan, Russian Federation)

Oksana V. Mukhortova[a]*,
Svetlana V. Bykova[a], Natalia G. Tarasova[a],
Elena N. Unkovskaya[b] and Sergey E. Bolotov[c]
[a] Institute of Ecology of the Volga River Basin RAS
10 Komzina, Togliatti, 445003, Russia
[b] Volzhsko-Kamskiy Biosphere Natural State Reserve
Sadovyi, Raifa, Zelenodolskiy District,
Republic of Tatarstan, 422537, Russia
[c] Institute for Biology of Inland Waters RAS
Borok, 152742, Russia

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Comparative analysis of different groups of the planktonic community (phytoplankton, protozoo- and zooplankton) was performed in the pelagic and littoral zones of overgrown Lake Beloe (Volzhsko-Kamskiy Biosphere Natural State Reserve, Republic of Tatarstan, Russain Federation). We detected a remarkable diversity of both pelagic and sublittoral plankton. The planktonic community of the macrophyte zone differs from the community of pelagic zone in a species composition and in larger species diversity.

Keywords: protozooplankton, zooplankton, phytoplankton, planktonic community, abundance, biomass, macrophytes.

* Corresponding author E-mail address: muhortova-o@mail.ru

Характеристика планктонного сообщества пелагической и литоральной зоны зарастающего мезотрофного озера Белое (Волжско-Камский биосферный природный государственный заповедник, Республика Татарстан)

О.В. Мухортова[а]*, С.В. Быкова[а], Н.Г. Тарасова[а], Е.Н. Унковская[б], С.Э. Болотов[в]
[а]*Институт экологии Волжского бассейна РАН*
Россия, 445003, Тольятти, ул. Комзина, 10
[б]*Волжско-Камский государственный природный биосферный заповедник,*
Россия, 422537, Республика Татарстан, Зеленодольский район, п. Садовый
[в]*Институт биологии внутренних вод им. И.Д. Папанина РАН*
Россия, 152742, п. Борок

Проведен сравнительный анализ развития планктонных организмов (фито-, зоо-, протозоопланктон) в пелагической и литоральной зоне зарастающего озера Белого (Волжско-Камский биосферный природный государственный заповедник, Республика Татарстан). Показано, что в макрофитах все компоненты планктонного сообщества отличаются большим, по сравнению с пелагиалью, видовым богатством и значительной видоспецифичностью. Отмечено значительное различие состава пелагического и зарослевого планктона. Планктонные сообщества водной толщи, обитающие в зарослях различных видов макрофитов, отличались меньше.

Ключевые слова: протозоопланктон, фитопланктон, зоопланктон, планктонное сообщество, численность, биомасса, макрофиты.

Introduction

The littoral zone of a lake is known to be an area with a specific complex of conditions that influences the entire lake ecosystem (Nurminen, 2003; Carpenter et al., 1992; Schindler et al., 1996). Macrophytes are an important component in regulating the biological structure of a lake (Timms, Moss, 1984; Schriver et al., 1995). Macrophytes influence organism distribution in a lake (Durte et al., 1986; Moddelboe, Markager, 1997), light transmission, temperature and pH (Dale, 1986; Duarte et al., 1986; Vant et al., 1986, 1995, 1996; Lodge, 1991).

Macrophyte occurrence in a lake and degree of its overgrowth show trophic conditions of a lake (Schulthorpe, 1967; Toivonen, Huttunen, 1995). Complex relations between planktonic organisms and between planktonic organisms and macrophytes are a subject matter and a basis for making hypothesis and theories for different scientists (Scheffer et al., 1993, 1992; Jeppesen et al., 1998).

Usually, sublittoral planktonic community in the macrophyte zone differs from that in the pelagic zone of a water body and consists of truly planktonic as well as of the periphytic and benthonic species (Barko, James 1999; Karabin, 1985; Lauridsen et al., 1996; Persson, 1991). Macrophytes form a community habitat and establish development peculiarities of all groups of planktonic community (particularly, protozoo-, zoo- and phytoplankton) in a littoral zone of a lake with macrovegetation (Nurminen et al., 2001). The problem of planktonic organisms development in macrovegetation is not limited to clearing up differences in biodiversity indicators in various biotopes for diverse planktonic components, but it also involves a study of interaction between macrovegetation and planktonic community as a whole. The interaction is reflected by a competition, by displacing a competitor in space, light interception (shading) or nutrient interception (intensive absorption), by allelopathic influence (Fairchild, 1981; Lauridsen et al., 1997; Nabivaiylo, Titlyanov, 2006; Nurminen, 2003), by interspecific competition of zooplankton in macrovegetation, by influence of invertebrate predators inter-connected with macrovegetation on zooplankton (Horppila, Nurminen, 2001, 2003; Semenchenko, 2006). Besides, this interaction affects structural and productional indicators of the whole planktonic community.

The first stage in research of any problem (particularly, revealing of interaction mechanism) consists of data accumulation. In this instance, phyto -, protozoo – and zooplankton are researched in various ecotopes diverse in mineralization, chemical structure, the extent of overgrowth and morphometry of various lakes. This work presents the results of the first planktonic community research in macrovegetation of Lake Beloe. The study is intended to identify peculiarities of planktonic community development (as a whole and its separate components), comparing a pelagic part of basin with a littoral one and associations formed by particular macrovegetation species.

Materials and methods

Study site

Lake Beloe (55º55′26.2″N, 48º45′49.9″E) is located in a protected zone of the Raifskiy area of Volzhsko-Kamskiy State Natural Biospheric reserve, Republic of Tatarstan, Russian Federation. It is located in a hydrosystem of the rivers Sumka and Ser-Bulak, located in a karst-suffosion valley (Fig. 1).

Lake Beloe is a water body of karst-suffosion origin, overgrown (30 % of its area is occupied by macrophytes located along the coastal zone). Water retention time in the lake is high, its maximum depth of 4 m, which is found in the south-eastern part of the lake (Fig. 2**.** The lake length is about 557 m and its width is about 170 m. At the sampling time, the lake was thermally stratified with a thermocline at the depth of 2-3 m. Water transparency was up to 1.4 m and water colour value was low (80°Pt).

Lake water has medium level of mineralization and belongs to calcium-hydrocarbonate type. In 2006, a surface layer was oxygen saturated (up to 168 %), while we revealed a saturation deficit (8.7 %) at the bottom. The following macrophytes are located in the 10 m width littoral zone: *Typha latifolia* L., *Zizania latifolia* Stapf. and *Sagittaria sagittifolia* L. A shallow part of the lake, with a depth of less than 1 m, is covered by *Ceratophyllum demersum* L., *Elodea canadensis* Michx., *Potamogeton angustifolius* J.Presl and *Nuphar lutea* L.

Sampling

Our study of the planktonic community (phyto-, zooplankton, ciliates) was conducted in July of 2006 in six different biotopes: a) a water column in the pelagic part, and b) in a macrovegetation, belonging to different

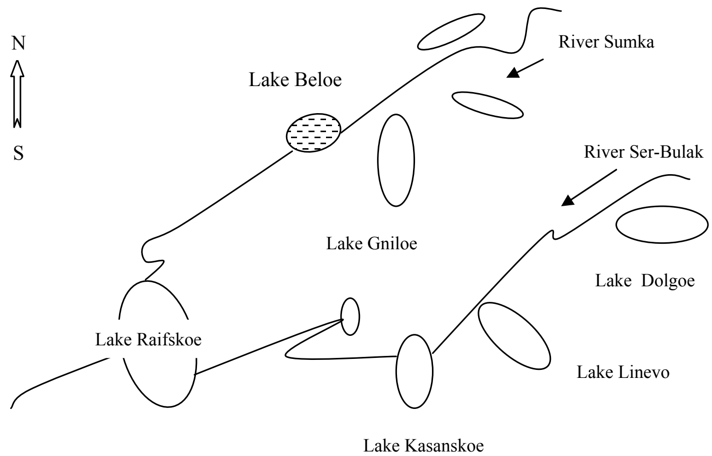

Fig. 1. System of lakes located in the protective zone of Raifskiy area of the Volzhsko-Kamskiy State Natural Biospheric reserve, Republic of Tatarstan, Russia

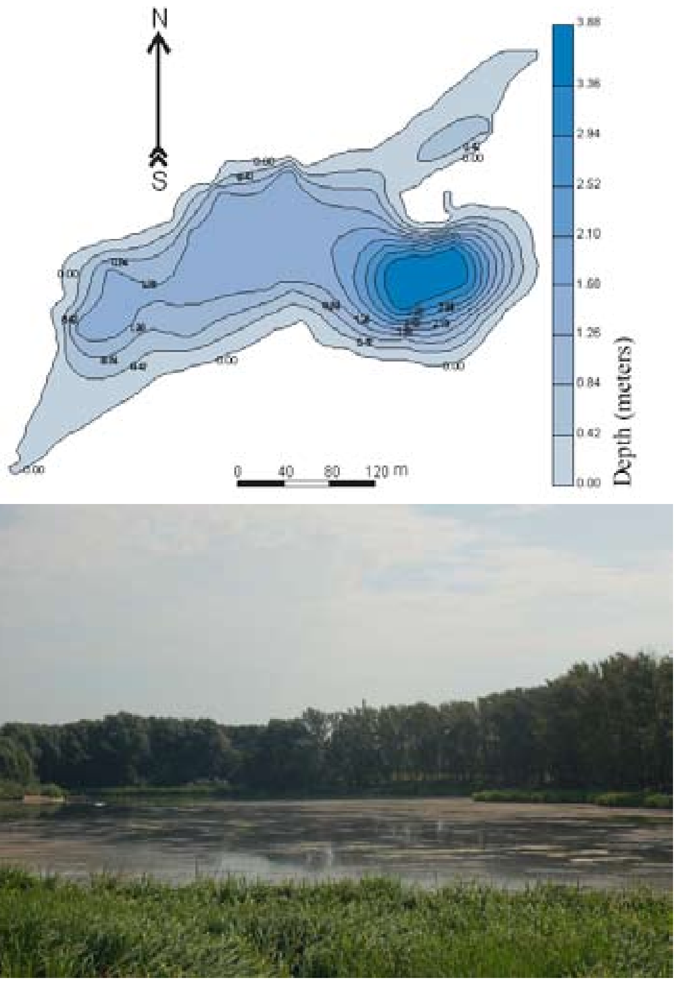

Fig. 2. Bathymetric map and photo of Lake Beloe

ecological types (Papchenkov, 2006): helophyte tall grass (*Z. latifolia*) and helophyte low-grass (*S. sagittifolia*), submerged rooted hydrophytes (*C. demersum* and *P. angustifolius*) and rooted hydrophytes with floating leaves (*N. lutea*).

Samples were collected with Ruttner bathometer (4 L). In macrophyte beds water was sampled from a surface layer (0.1-0.3 m). In the pelagic zone samples for phyto- and protozooplankton analyses and zooplankton analyses were taken from a surface layer (0.1-0.3 m) and from the whole water column (0-4 m), respectively.

Phytoplankton analysis

Phytoplankton was concentrated by filtering 0.5 L of sample through membrane filters of 1 µm pore diameter using Komovskiy pump and fixed in 4 % formalin. Cells calculation was made in Uchinskaya chamber (0.01 ml volume). Algae biomass was determined with geometric figures method (Kouzmin, 1984). Algae identification was made using standard guidebooks from the series "Susswasserflora von Mitteleuropa" (Ettl, 1983; Ettl, Gartner, 1983; Ettl et al., 1990; Hellawell, 1986; Husted, 1939; Krammer, Lange-Bertalot, 1986, 1988, 1991a, 1991b; Komarek, Anagnostidi, 2000; Popovsky, Pfiester, 1990; Starmach, 1985; Systematik und Biologie, 1983).

Protozooplankton analysis

Only ciliates from the group of protozoa were studied in this research. Ciliates were identified in alive state, or using samples fixed with mercury chloride ($HgCl_2$) and in vapors of osmium. We also used impregnation by silver nitrate ($AgNO_3$) (Chatton, Lwoff, 1936) and Feulgen nuclear staining. For species identification we used guide books as well as different papers (Corliss, 1979; Curds et al., 1982, 1983; Foissner et al., 1991, 1999; Kahl, 1931-1935). Counting of planktonic ciliates was performed after concentration 300 ml of a sample (Mamaeva, 1979) and its fixation with saturated solution of mercury chloride ($HgCl_2$). The results were generalized according to taxonomic system of E.B. Small and D.H. Lynn (1985, 2000), taking into consideration other literature sources (Yankovski, 2007). The trophic groups of ciliates were determined based on Pratt and Cairns (1985), Mamayeva (1979) and Zharikov (1996).

Zooplankton analysis

For zooplankton analysis we concentrated 5 L of water by filtering it through Apstein net of 64 µm mesh size. Zooplankton samples were fixed with 4 % formalin and counted in the Bogorov chamber. Abundance (ind./L) and biomass (mg/m^3) were calculated for each species in each sample. The tables of standart weights of organisms (Morduhay-Boltovskoy, 1954) and our measurements were used to calculate the biomass. The average length of the body was converted to weight by method of Vinberg (1971) and Balushkina & Vinberg (1979). The guide books of Kutikova (1970, 2005), Manuylova (1964), Smirnov (1976, 1996) and Orlova-Bienkowskaja (2001) were used for identification of the zooplankters.

Data analysis

In every group (phytoplankton, protozooplankton, zooplankton) we considered as dominant species those with abundance and biomass not less than 10 % of a total abundance and biomass (Belova, 1998).

Species diversity was evaluated using Shannon index (Odum, 1975):

$$H = \sum_{i}^{W} \left[\left(\frac{Ni}{N} \right) \log_2 \left(\frac{Ni}{N} \right) \right]$$

where: Ni – the abundance of species (i); N – the total abundance of all species (W).

Pielou index was used for confirmation of species community equitability on abundance:

$$E = H/\log N$$

where N – species community abundance in biocenosis (Odum, 1975).

Similarity of the planktonic communities in different ecotopes was calculated with Sørensen's similarity coefficient:

$$Ks = \frac{2c}{a+b}$$

where *a* – the number of species in the first ecotope, *b* – the number of species in the second ecotope, *c* – the number of species common to both ecotopes (Odum, 1975).

Stand Density Index (SDI) was calculated for each species in community. SDI is the criteria, connecting average biomass (*B*) and the abundance of individuals (*N*), characterizing species inside of biocoenosis (Dedyu, 1989):

$$SDI = \sqrt{NB}$$

To study the variations of plankton community, a principal component analysis (PCA) was conducted. A PCA was made for the total community on the basis of Stand Density Index.

Cluster analysis was made using Sørensen's similarity coefficient for planktonic communities in different ecotopes. Clustering of data was made by Ward method, euclidean distance was used as grouping parameter.

Statistical analysis (data clusterization and factor analysis) of the results was made using Statistica software, version 6.0 (StatSoft Inc., USA).

Plotting of a bathymetric map of the Lake Beloe was executed in the program Surfer 12 (Golden Software Inc., USA).

Results and discussion

Species diversity and species specificity of planktonic community in different biotopes

In 2006 in all biotopes we found 116 species of phytoplankton, 57 species of protozooplankton and 84 species of zooplankton (taking into account phyto- and protozooplankton inhabiting a surface layer of the pelagic zone and zooplankton inhabiting the whole water column of the pelagic zone). Among them, 17 % of phytoplankton species, 14 % of ciliate species and 18 % of zooplankton species were unique for pelagic zone and 47 % of phytoplankton species, 68 % of ciliate species and 60 % of zooplankton species were unique for the macrophyte zone. Similarities between pelagic and macrophyte zones were 55 % for phytoplankton community, 30 % for ciliates and 35 % for zooplankton community. Sørensen's coefficients indicated low similarity between plankton inhabiting pelagic zone and communities of different sublittoral ecotopes (34-45 % – for phytoplankton, 12-19 % – for ciliate, 45-57 % – for zooplankton). From the other side, similarity between plankton communities inhabiting different macrophyte species beds was high (43-66 % – for phytoplankton, 55-68 % – for ciliate, 44-50 % – for zooplankton). Cluster analysis indicated the peculiarity of pelagic plankton; and the community from *Nuphar* was the closest to the pelagic one among the sublitoral ecotopes (Fig. 3). Species diversity of zooplankton (Shannon index based on abundance Hn = 4.59; Pielou index E = 0.84) and phytoplankton (Hn = 4.76; E = 0.78) community was higher in the zone of submerged rooted macrophytes (*Ceratophyllum* and *Potamogeton*). Shannon index was high due to a high number of species and a relatively low number of dominant species (or even their absence) (Table 1).

Only two dominants were registered in the phytoplankton community of *P. angustifolius* –

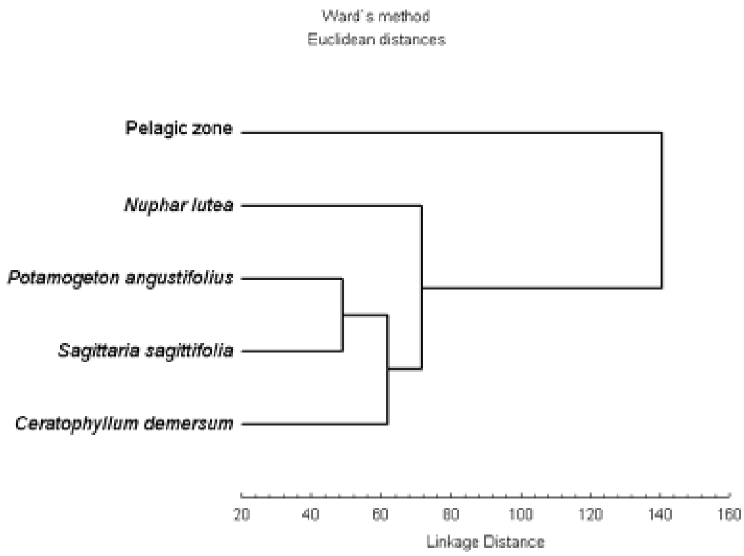

Fig. 3. Cluster analysis on similarity of the communities (phyto-, protozoo- and zooplankton) in Lake Beloe

Table 1: Comparison of plankton in different zones of Lake Beloe in July 2006

Parameter	Groups of plankton	Biotope					
		Pelagial, surface layer (0.3 m)	*Nuphar lutea*	*Potamogeton angustifolius*	*Ceratophyllum demersum*	*Sagittaria sagittifolia*	*Zizania latifolia*
Number of species	Phytoplankton	27	35	69	49	30	33
	Protozooplankton [c]	9	24	23	25	34	n.f.
	Zooplankton	n.d.	22	n.f.	44	24	37
Shannon index, Ha [a] /Hb [b]	Phytoplankton	3.9/2.2	3.79/2.74	4.76/3.38	4.28/2.56	1.63/3.17	2.64/2.40
	Protozooplankton	1.8/1.6	2.55/3.34	2.11/3.24	1.99/1.94	2.83/3.42	n.f.
	Zooplankton	n.d.	3.0/2.56	n.f.	4.59/3.86	4.17/3.26	4.18/3.01
Pielou index, E	Phytoplankton	0.82	0.74	0.78	0.76	0.33	0.52
	Protozooplankton	0.57	0.56	0.47	0.43	0.56	n.f.
	Zooplankton	n.d.	0.67	n.f.	0.84	0.91	0.80
Abundance, ind./L	Phytoplankton	1896000	1952000	6316000	3560000	4840000	4588000
	Protozooplankton	1006.5	1079.1	5349.3	30610.8	9810.9	n.f.
	Zooplankton	n.d.	266.8	n.f.	469.2	702	651.8
Biomass, mg/m^3	Phytoplankton	1642.2	1868.6	8006.6	7873.1	1037.5	5910.3
	Protozooplankton	35	19.9	55.9	457.8	116.2	n.f.
	Zooplankton	n.d.	1583.8	n.f.	3218.2	20745.4	11324.9

n.d. – not determined
n.f. – not found
[a] Shannon index calculated based on abundance
[b] Shannon index calculated based on biomass
[c] Protozooplankton = Ciliates

Pseudoanabaena limnetica (Lemmermann) Komárek (14 % of total abundance) and *Eudorina elegans* Ehrenberg (12 %). In zooplankton community from *C. demersum*, 94 % of total abundance was presented by subdominants, while dominants were absent. The maximum Shannon index for ciliates (Hn = 2.83; E = 0.56) was registered in *S. sagittifolia* zone (Table 1).

Characteristics of general quantity parameters of planktonic community

Maximum total abundance (4.85 x 10^6 ind./L) and biomass (21.89 mg/L) for phyto-, protozoo- and zooplankton (from macrophyte association of three different ecotypes: *N. lutea*, *C. demersum* and *S. sagittifolia*) were registered for the zone of *S. sagittifolia*. Maximum total number of species (118 species) was registered for planktonic community in *C. demersum*. Maximum numbers of plankton species were registered in different biotopes: for phytoplankton and zooplankton – in submerged rooted hydrophytes zone; for ciliates – in low-grasses helophyte zone (Table 1). High abundance and biomass of plankton in submerged rooted plants communities was noticed previously (Bykova et al., 2009; Mukhortova, 2008; Tarasova, 2008; Unkovskaya et al., 2010). It is explained by (1) presence of a suspended organic matter and fine detritus, (2) better protection from waves and wind, (3) diversity of local niches etc. Maximum value of zooplankton abundance in *S. sagittifolia* was caused by a great number of nauplii there. Minimum number of species (81), total abundance (1.95 x 10^6 ind./L) and total biomass (3.47 mg/L) were registered in *N. lutea* zone. It's interesting that species inhabiting this zone were similar to those in pelagic zone, because the *N. lutea* forms the most "pelagic" zone of macrophytes. As it is also known, this plant extracts the alkaloid nupharin, depressing the development of cyanophyta (Lauridsen et al., 1997; Zimbalevskaya, 1981). Furthermore, broad leaves of *N. lutea* reduce the light penetration to the water column and due to this unfavorable for the phytoplankton. Lack of available food decreases number of protozoan (ciliates) and metazoan plankton species.

Structure of plankton in different zones

Chlorophyta was the only group dominating in phytoplankton of all zones in 2006 (Table 2). The abundance of Chlorophyta was maximum in the pelagic zone and in the *Z. latifolia* zone that was correlated with the complete absence of cyanobacteria there. However the dominants inside the group were different in different zones: *Eutetramorus planctonicus* (Korsch.) Bourrelly (19.4 % of total abundance) and *Eudorina elegans* Her. (18.1 %) in pelagic zone; *E. planctonicus* was absent in *Z. latifolia*, while abundance of *E. elegans* was 54 % of total.

Phytoplankton in 2006 was characterized by a lack of cyanoprokaryota in pelagic zone and its maximum ability (76 % of total abundance) in *S. sagittifolia* community due to a single species, *Microcystis pulverea* (Wood) Forti emend. Elenk. In Kuibyshev reservoir, a large water body located near Lake Beloe, *M. pulverea* causes water blooms. We assume that in Lake Beloe bloom of *M. pulverea* probably started to develop just in a warm, shallow zone of *Sagittaria* community. However due to the fact that small-celled *Microcystis* (cell diameter – 1 µm; colony diameter – less than 20 µm) was probably consumed by nauplii (Jeppesen et al., 1992; Kerfoot et al., 1988; Kryuchkova, 1989), this bloom did not spread. In other macrophyte communities, blue-green algae were presented by attached forms *Oscillatoria*, *Lyngbia, Phormidium* etc., which could be a food for secondary filterers, cladocerans. The number of attached algae was especially high in the plankton inhabiting macrophytes having broad leaves (*S. sagittifolia*, *N. lutea*).

Table 2: The dominant species of phytoplankton, protozoo- and zooplankton in different biotopes of Lake Beloe in July 2006

Biotope	Dominant on abundance	Dominant on biomass
1	2	3
	Phytoplankton	
Surface layer (0.3 m)	*Eutetramorus planctonicus* (19) *; *Eudorina elegans* (18); *Syncripta volvox* Ehr. (17); *Stephanodiscus hantzschii* Grun. (11); *Dinobrion divergens* Imgh. (11)	*Stephanodiscus hantzschii* (54); *Dinobrion divergens* (11); *Eudorina elegans* (10)
Nuphar lutea	*Planctolyngbya limnetica* (Lemm.) Kom.-Leg. et Cron. (18); *Eudorina elegans* (16); *Dinobrion divergens* (14); *Stephanodiscus hantzschii* (12)	*Stephanodiscus hantzschii* (56); *Eudorina elegans* (14); *Dinobrion divergens* (13)
Potamogeton angustifolius	*Pseudoanabaena limnetica* (Lemm.) Kom. (14); *Eudorina elegans* (12)	*Cosmarium cyclum* Lund. var. *articum* Nordst. (35); *Stephanodiscus hantzschii* (22)
Ceratophyllum demersum	*Cyclotella meneghengiana* Kutz. (20); *Leptolyngbya fragilis* (Gom.) Angnostidis et Komárek (19)	*Cosmarium cyclum* var. *articum* (50); *Cyclotella meneghengiana* (22)
Sagittaria sagittifolia	*Microcystis pulverea* (76)	*Dinobrion divergens* (33); *Eudorina elegans* (19); *Stephanodiscus hantzschii* (14); *Gyrosigma kuetzingii* (Grun.) Cl. (10)
Zizania latifolia	*Eudorina elegans* (54)	*Eudorina elegans* (37); *Stephanodiscus hantzschii* (33); *Melosira varians* Agardh 1827 (11)
Protozooplankton		
Surface layer (0.3 m)	*Litonotus* sp. (50)*; *Peritricha* spp. in *Bosmina* (39)	*Paradileptus conicus* Wenrich, 1929 (81); *Litonotus* sp. (11)
Nuphar lutea	*Halteria grandinella* (O.F. Muller, 1773) (47); *Ctedoctema acanthocrypta* Stokes, 1884 (27)	*Halteria grandinella* (25); *Ophryoglena* sp. (16); *Amphileptus pleurosigma* (Stokes, 1884) (19)
Potamogeton angustifolius	*Ctedoctema acanthocrypta* (63); *Halteria grandinella* (12)	*Ctedoctema acanthocrypta* (24); *Lembadion lucens* Maskell, 1877 (15); *Strobilidium caudatum* (Fromentel, 1876) (12); *Halteria grandinella* (11)
Ceratophyllum demersum	*Coleps hirtus* (Muller, 1786) Nitzsch, 1827 (57)	*Coleps hirtus* (57); *Furgasonia trichocystis* (Stokes, 1894) (13)
Sagittaria sagittifolia	*Ctedoctema acanthocrypta* (37); *Coleps hirtus* (17); *Halteria grandinella* (14)	*Coleps hirtus* (22); *Lembadion lucens* (22); *Ctedoctema acanthocrypta* (13); *Halteria grandinella* (12)

Continuation Table. 2

1	2	3
	Zooplankton	
Surface layer (0.3 m)	n.d.	n.d.
Nuphar lutea	*Chydorus sphaericus* (O.F. Müller, 1776) (13); *Ceriodaphnia reticulata* (Jurine, 1820) (12); nauplius Cyclopoida (22)	Cyclopoida copepodites III-IV (41); Cyclopoida copepodites I-II (21); *Simocephalus vetulus* (O.F. Muller,1776) (10); *Ceriodaphnia reticulata* (12)
Potamogeton angustifolius	n.f.	n.f.
Ceratophyllum demersum	-	Cyclopoida copepodites III-IV (21); *Mesocyclops leuckarti* (Claus, 1857) (13);
Sagittaria sagittifolia	nauplius Cyclopoida (11)	Cyclopoida copepodites III-IV (33)
Zizania latifolia	nauplius Cyclopoida (11); *Ceriodaphnia reticulata* (12)	*Mesocyclops leuckarti* (35); *Acanthocyclops vernalis* (Fischer, 1853) (10); *Eucyclops macruroides* (Lilljeborg, 1901) (20)

* In parentheses we indicated the abundance of species (in percent of the total abundance or biomass);
«-» – absence of dominant species (> 10 % of total abundance or biomass);
n.d. – not determined
n.f. – not found

Another peculiarity of the plankton of Lake Beloe in 2006 was a relatively high number of Rotifera in pelagic zooplankton (44 %) comparing with littoral community (11-24 %). Our results are in a good agreement with those by O.Yu. Derevenskaya (2002), who also found high abundance of Rotifera in the pelagic zone of Lake Beloe. As Rotiferia prefer more eutrophic conditions, we can propose that in the littoral zone macrophytes adsorb the organic particles from the water, but there is a lot of fine detritus on the leaves surface. It could be regarded as explanation of high number of the sessile rotifers *Rotaria neptunia* (Ehrenberg, 1832), *R. rotatoria rotatoria* (Pallas, 1766), *Dissotrocha aculeata aculeata* (Ehrenberg, 1832) and scrapping crustaceans (*Pleuroxus truncatus* (O.F. Müller, 1785), *P. aduncus* (Jurine, 1820), *Chydorus sphaericus* (O.F. Müller, 1785), *C. ovalis* Kurz, 1875*, Alona intermedia* Sars, 1862, *Alona rectangula* Sars, 1861) occasionally present in plankton samples. These species generally are filterers. They were washed out from the floating leaves of *Nuphar lutea* and gave about 94 % of "plankton" abundance. In zooplankton inhabiting other macrophytes (*Typha latifolia*, *Zizania latifolia, Sagittaria sagittifolia*, *Ceratophyllum demersum*, *Elodea Canadensis* and *Potamogeton angustifolius*) and in the pelagic zooplankton the percentage of filterers was lower (68-80 % of total abundance) and the role of predators (*Mesocyclops leuckarti* (Claus, 1857), *Thermocyclops oithonoides* (Sars G.O., 1862), *Eucyclops macruroides* (Lilljeborg, 1901), *Microcyclops varicans* (Sars G.O., 1863)) was more considerable. Some authors (Lauridsen et al., 1997; Zimbalevskaya, 1981) observed similar distribution of filterers and predators in zooplankton community.

Ciliate community was characterized by the dominance of predators in pelagic plankton (54 % of total number and 92 % of total biomass). In macrophyte zone, besides bacteriodetritophages, the dominants in the plankton were hystophages of genera *Coleps* and *Ophryoglena* (76 % of the total abundance of ciliates in *C. demersum*), which consume decomposing plant tissues and even being predators. Probably, the degradation processes are more intensive in the *C. demersum* zone. In contrast, in Lake Raifskoe, located close to Lake Beloe, the predators are found only in plankton from macrophyte zone (Bykova, Zharikov, 2009). The reason of such differences is not obvious.

As a result of PCA analysis based on stand density index for all three groups of plankton from macrophyte association of three various zones (*N. lutea*, *C. demersum* and *S. sagittifolia*), we selected 2 groups which included species from phytoplankton, protozooplankton and zooplankton, corresponding to the first two principal components (Tabl 3). The selected two principal components describe more than 80 % of variability of structure of community. Probable, grouping factors for PCA axis were trophical preferences of protozooplankton and zooplankton depending on size.

The first principal component (61.57 % of variance explained of structure of community) contained colonial species of phytoplankton: *Dinobrion divergens* Imgh., *Aulacoseira subarcticaca* (O. Müller) Hawoath, *Fragilaria virescens* Ralfs, *Eudorina cylindrica* Korsch., *Pediastrum duplex* Meyen.; small copepods: *Metacyclops gracilis gracilis* (Lilljeborg, 1853) and cladocerans: *Ceriodaphnia reticulate* (Jurine, 1820), *C. pulchella* Sars, 1862, *Alona rectangula* Sars, 1862 (Fig. 4). This combination is explained by the fact that the large-sized colonial algae are more protected from the grazing by small zooplankton, which prefers protozoans from the same group: *C. hirtus*, *C. hirtus viridis* Ehrenberg, 1831, *Furgasonia trichocystis* (Stokes, 1894), *Lembadion bullinum* Perty, 1852, *Strobilidium caudatum* (Fromentel, 1876).

Table 3: Result of the Principal Components Analysis (PCA) for planktonic species, their interset correlation coefficients (*r*) with PCA axes, eigenvalue and the percentage of variance explained by the first two components for planktonic community in the Lake Beloe in July 2006. Only species with |*r*| > 0.9 are presented.

Species	Abbreviation	PCA Axis 1	PCA Axis 2
Phytoplankton			
Microcystis pulverea (Wood) Forti emend. Elenk.	aMp	-0.178	**0.984**
Aulacoseira subarctica (Müller) Haworth	aAsu	**0.971**	-0.239
Crucigenia tetrapedia (Kirchner) W. et G. S. West	aCte	-0.178	**0.984**
Dinobryon divergens Imhof	aDd	**-0.995**	-0.096
Eudorina cylindrica Korshikov	aEcy	**0.941**	-0.338
Fragilaria crotonensis Kitton	aFcr	-0.084	**-0.996**
Fragilaria virescens Ralfs	aFvi	**0.941**	-0.338
Gomphonema parvulum Kützing	aGpa	0.303	**-0.953**
Kephyroin moniliferum (Schmid) Bourrelly	aKm	-0.178	**0.984**
Pandorina morum (Müller) Bory	aPmo	**0.999**	-0.019
Pediastrum duplex Meyen	aPdu	**0.999**	0.027
Scenedesmus denticulatus Lagerheim	aSde	-0.178	**0.984**
Scenedesmus armatus Chodat	aSar	-0.134	**-0.991**
Trachelomonas volvocina Ehrenberg	aTvo	-0.283	**-0.959**
Protozooplankton			
Coleps hirtus (Muller) Nitzsch	cChi	**0.988**	-0.153
Coleps hirtus viridis Ehrenberg	cChv	**0.957**	-0.289
Furgasonia trichocystis (Stokes)	cFtr	**0.956**	-0.292
Lembadion bullinum Perty	cLbu	**0.941**	-0.338
Limnostrombidium viride (Stein)	cLvi	-0.178	**0.984**
Oxytricha sp.	cOse	-0.178	**0.984**
Pelagostrombidium fallax (Zach.)	cPel	-0.178	**0.984**
Stentor roesili Ehrenberg	cSroe	-0.178	**0.984**
Strobilidium caudatum (Fromentel)	cScau	**-0.982**	-0.188
Zooplankton			
Asplanchna priodonta Gosse	zApr	-0.178	**0.984**
Alona rectangula Sars	zAre	**0.941**	-0.338
Alona intermedia Sars	zAin	-0.263	**-0.965**
Ceriodaphnia pulchella Sars	zCpu	**0.991**	-0.131
Ceriodaphnia reticulata (Jurine)	zCre	**-0.999**	-0.044
Daphnia cucullata Sars	zDcu	-0.178	**0.984**
Eucyclops macruroides (Lilljeborg)	zEma	-0.178	**0.984**
Mesocyclops leuckarti (Claus)	zMle	0.284	**0.959**
Microcyclops gracilis (Lilljeborg)	zMgr	**0.941**	-0.338
Sida crystallina (Müller)	zScr	0.117	**0.993**
Eigenvalue		3.16	1.27
Variance explained, %		61.57	24.75

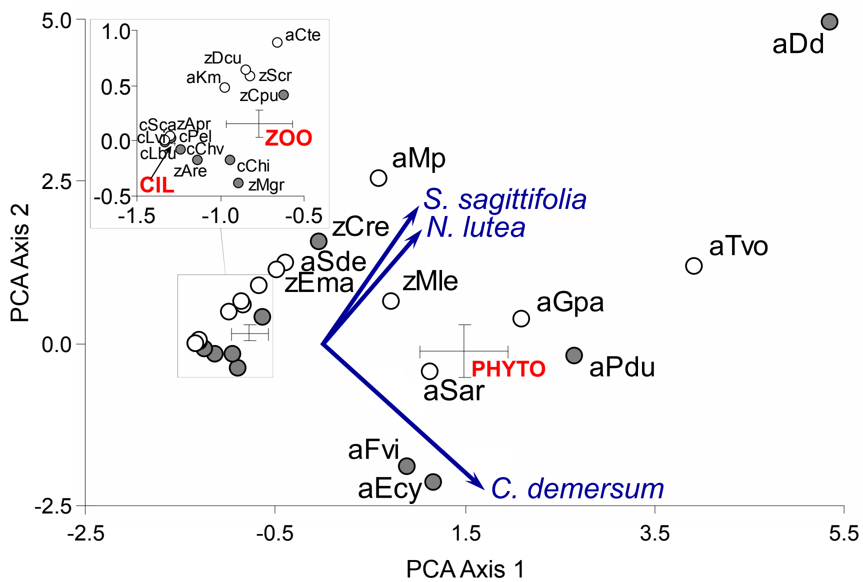

Fig. 4. Principal component analysis biplot of ordination between planktonic community and different biotopes of Lake Beloe in July 2006. Plot of centroids (mean) of clouds distributions of the plankton community and some plankton species (species abbreviations are given in Table 3) in the space of the first and second PCA axis; ± 95 % confidence interval. Grey circles – species most correlated (|*r*| > 0.9) with the first principal component, open circles – with the second principal component. PHYTO – phytoplankton, CIL – protozooplankton, ZOO – zooplankton

The second principal component (24.75 % of variance explained of structure of community) included small-sized solitary algae or small-sized colonial algae: *M. pulverea*, *Kephyrion moniliferum* (Schmid) Bourrelly, *Gomphonema parvulum* Kütz. var. *parvulum*, *Trachelomonas volvocina* Ehr., *Crucigenia tetrapedia* (Kirchn.) W. et G.S. West, *Scenedesmus armatus* Chrod. var. *armatus, S. denticulatus* Lagerh. var. *linearis* Hansg (Fig. 4). The listed above forms are bad food for the large forms of zooplankton also included to the same group: *Asplanchna priodonta* Gosse, 1850, *Sida crystallina crystallina* (O.F. Müller, 1776), *Daphnia cucullata* Sars, 1862, *Eucyclops macrurus* (Sars G.O., 1963), *Mesocyclops leuckarti* (Claus, 1857). Algophages and non-selective omnivorous ciliates were also in the same group: *St. roeseli* Ehrb., 1835, *Oxytricha* sp., *Limnostrombidium viride* (Stein, 1867), *Pelagostrombidium fallax* (Zach., 1895). They were associated mainly with a community of *S. sagittifolia* and able to consume fine phytoplankton. Obviously, zooplankton in both cases prefers to consume medium-sized algae and ciliates (Nurminen, Horppila, 2002; Gulati, DeMott, 1997 et al.)

Our study has demonstrated that plankton of macophyte zone is characterized by a high species diversity and peculiarity of all groups as compared with pelagic zone of Lake Beloe.

Maximum total abundance and biomass of plankton (phyto-, protozoo-, and zooplankton) were registered in the zone of *S. sagittifolia*, maximum number of species was registered in the zone of *C. demersum*. However maximums of different plankton groups were registered in different zones: phytoplankton and ciliates – in submerged rooted hydrophytes (*C. demersum*, *P. angustifolius*); zooplankton – in zone of low-grasses helophytes (*S. sagittifolia*). Minimum abundance, biomass and Shannon index is registered in the zone of plants with floating leaves (*N. lutea*) because of inhibition by nupharin, shadowing and closeness to pelagic zone.

We have not found any strong differences in the species composition of zoo- and phytoplankton between littoral zones covered by different macrophytes. However there were differences between the pelagic and littoral plankton: the absence of Cyanophyta in pelagic plankton; higher percentage of rotifers in pelagic zone as compared with littoral zooplankton; the presence of predaceous ciliates as a part of pelagic community, and the presence of hystohpages as a part of the littoral plankton community.

The peculiarity of our study is finding specific character of planktonic community organisms (protozoo-, zoo- and phytoplankton) in phytal zone of Lake Beloe, its comparing with pelagic complex of organisms and determining of its contributing factors.

Conclusion

Phytophilous flora and fauna play a significant role in species diversity development in planktonic community of the lake, and communities of planktonic organisms forming in various ecotopes are characterized by high species diversity. Differences in components of planktonic community developing in the pelagic part of the lake and in individual macrophyte species are more significant than differences between macrovegetation plankton communities. Reaction of different planktonic community groups (phyto-, zoo-, ciliaplankton) to conditions in different ecotopes is similar in spite of peculiar properties of their biology and organization.

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