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The vertical distribution of zooplankton in stratified mesotrophic Lake Arakhley (Eastern Transbaikalia)

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ABSTRACT. We have studied the vertical distribution of zooplankton of a stratified mesotrophic lake. Thus, in August 2011 and 2013, copepods dominated the composition of the zooplankton of the mesotrophic Lake Arakhley and had a density maximum either in the upper euphotic layer or in the area of the metalimnion, with a gradual decrease in the lower layers of water. By 2013, the zooplankton community changed and mainly consisted of cladocerans, and they both dominated in numbers.

Keywords: zooplankton, species composition, vertical distribution, temperature, Lake Arakhley, East Transbaikalia

1. Introduction

The zooplankton community is a complex and multicomponent system determined by many factors. The change in its species composition, quantitative and qualitative parameters with the depth of the water body as well as the factors that determine them are of great theoretical and practical interest. In recent decades, climate warming has been observed, which affects various processes occurring in aquatic ecosystems, including zooplankton communities. In Transbaikalia, air temperature increases by 1.0-1.5 °C in winter and by 0.5-1.0 °C in summer (Vezhnovets et al., 2012; Feniova et al., 2016). The increase in the surface water temperature by 1.21 °C was recorded in Lake Baikal (Moore et al., 2009). The 2011 and 2013 years of the study are from the arid climatic period.

The lake during these years, despite the large area of 59.0 km^2 and the water volume of 0.60 km^3, had an average depth of 10.2 m and a maximum depth of 17.0 m. The transition between the low-water and high-water years is 2017. Temperature, dissolved oxygen concentration, food resources, etc. have a significant effect on the distribution of zooplankton organisms. At the same time, temperature and oxygen are the most important factors in the regulation of zooplankton communities, as well as its spatial and temporal scale of lake ecosystems, since they affect the abundance and structure of zooplankton communities. In this regard, the impact of climate warming reflected in the increase in water temperature on the vertical structure of zooplankton and on subsequent changes in the ecosystem arises the question.

2. Materials and methods of research

Zooplankton studies were performed in the mesotrophic Lake Arakhley (52 ° 12’20 “N, lat. 112 ° 52’01” E) during the period of thermal stratification of the lake in August from 2011 and 2013. The sampling of zooplankton was carried out at the central station of the lake using a Patalas bathometer (volume 6 l) with triplicate from eight vertical layers every two meters of the water column. Samples were fixed with 4 % formalin. Quantitative processing of the collected material performed in the Kolkwitz and Bogorov chambers. Organisms were calculated and measured on LOMO Micmed-1, MBS-10 microscopes. Animals were determined on Nikon Eclipse E200 and AXIO SCOPE A1 microscopes. Quantification was performed based on generally accepted methods. The species composition of zooplankton was determined by the corresponding determinants. The temperature of the water was measured with a mercury thermometer embedded in the bathometer. At the same time, the temperature was considered together with the sampling of the zooplankton along the horizons of the water column – 0, 2, 4, 6, 8, 10, 12, and 14 m. The water transparency values for the Secchi disk for these years ranged from 4.5 to 6.4 m. Quantitative accounting of the number was carried out on the basis of generally accepted methods (Guidelines ..., 1983). The species composition of zooplankton was determined by the corresponding determinants (Manuylova, 1964; Kutikova, 1970; Borutsky et al., 1991).

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3. Results and discussion

Tables 1 and 2 show the species composition, number and relevance of each species to the selected horizons. In these tables, among all years studied we discuss 2011 and 2013 due to the fact that they have the most distinctive features in the distribution of zooplankton and the number of species. Thus, the dry 2013 showed rotifers of the genera *Brachionus* and *Synchaeta*, which were not previously observed. The number of individual species and the ratio of taxonomic groups in the vertical layers of water in August 2011 and 2013 significantly differed at the level of identical species composition.

The number of zooplankton in the surface layer of water in 2011 was small (2.6 thousand indiv./m^3) and consisted mainly of nauplial copepodite stages of diaptomus, cyclops and rotifers. The maximum number of zooplankton (76.2 thousand indiv./m^3) was observed in the epilimnion at a four-meter depth with 79 % dominance of the copepods, mainly *E. graciloides*. The number of zooplankton in the metalimnion (at a depth of 10 m) was 38.19 thousand indiv./m^3. Cladocerans *D. galeata* represented 60 % of the total number. In the hypolimnion, 52 % of the animals were rotifers – *K. longispina* and *A. priodonta*. Unlike crustaceans, rotifers in August were not the dominant zooplankton group in the epilimnion. Notably, there was a very significant increase in their share at the lower boundary of the metalimnion and in the hypolimnion. Thus, in 2011, different species dominated in number in different vertical layers of water (Table 1).

In 2013, the temperature rise in the surface layers of water reached up to 22 °C. Under these conditions, zooplankton animals were distributed over the vertical layers of the water column more or less evenly. The maximum number was observed in the water layer from two to eight meters (up to 69.48 thousand indiv./m^3). Unlike 2011, in 2013, the crustacean *D. galeata* (thermophilic species presented in summer hypolimnion (Stolbunova, 2006; Rivier, 2012)) dominated all layers, and the situation differed fundamentally in Lake Arakhley: the largest proportion of Cladocera (81 %) was in the uppermost oxygenated epilimnion layer at a temperature of 20.0-21.9 °C, in metalimnion, with a decrease in temperature to 19.8 °C, *D. galeata* also dominated, but was 62 % of the total number of zooplankton. As the depth in the hypolimnion increased (at a temperature of 10.0 °C), the relative abundance of *D. galeata* continued to decrease, reaching 52 % in the bottom layer of water. This year, there was a change in the percentage of taxonomic groups due to an increase in the proportion of cladocerans and rotifers in the total number and a decrease in the share of copepods.

The dominant species of zooplankton in different years are presented in Table 3.

Thus, in 2011 *D. galeata* and *E. graciloides* were 22-24 %, and in 2013 *D. galeata* was 65 % of the total number of zooplankton.

Therefore, an increase in temperature can cause a change in the vertical structure of zooplankton and even in the dominant species. The vertical distribution of zooplankton communities in stratified lakes during summer is due to temperature, the abundance of food and the presence of oxygen. These factors affecting the state of the ecosystem regulate the structure and abundance of zooplankton communities. While in August 2011 the surface temperature of water ranged from 18 to 19 °C, in 2013 water temperature rose to 21.9 °C. We determined that with increasing water temperature there was a change in the percentage of taxonomic groups of zooplankton towards an increase in the proportion of cladocerans and a decrease in the share of copepods. Hence, an increase in the water temperature in low-water and high-water years affects the dominant zooplankton complex in different ways. Thus, with an increase in water temperature in the low-water period, cladocerans and rotifers dominate the zooplankton community, and in the high-water period – copepods (Table 2).

In the vertical distribution of zooplankton over the studied years, the identified features of the species composition, abundance of zooplankton show that in August 2011 copepods *E. graciloides* dominated at a water temperature of 18-19 °C, comprising 16-56 % in the upper layers (0-2 m), 73-75% at a depth of 4-6 m, and 49-37 % in metalimnion (8-10 m). In the hypolimnion (12-14 m), the number of organisms was 26-29 % of the number of zooplankton. Therefore, copepods *E. graciloides* were the most dominant at a depth of 4-6 m.

With a further increase in the water temperature to 21.9 °C in August 2013, cladocerans, mainly *D. galeata*, dominated the zooplankton community, accounting for 70-80 % in the upper water horizons (0-6 m) with a decrease to 50-67 % in the number of zooplankton in the corresponding layer of water in the horizons of 8-14 m. In 2013, the zooplankton community differed from the previous years. There were changes in the percentage of taxonomic groups towards an increase in the proportion of cladocerans in the total number of zooplankton and a decrease in the proportion of copepods.

We have obtained a vertical distribution of structural changes in zooplankton communities associated with the transformation of the temperature factor over the horizontal layers of the water column (species composition, abundance of zooplankton).

Conclusions

1. We studied the effect of water temperature on the vertical distribution of zooplankton in a stratified mesotrophic lake on the example of Lake Arakhley in the low-water period (when the water level of the lake was 0.35-0.43 m).
2. We revealed that the surface layer of water in August 2011 warmed up to a temperature of 18.1-19.3 ° C, and in the warmest 2013 the temperature reached 21.9 °C.
3. We found that copepods dominated the zooplankton community in 2011, whereas cladocerans dominated in warm 2013.

Table 1. Species composition and abundance (thousand indiv./m³) of zooplankton in the water column of Lake Arakhley in August 2011

Species	Depth, m							
	0	2	4	6	8	10	12	14
Cladocera, Crustacea								
Daphnia galeata Sars	0.06	1.56	14.76	11.34	13.08	19.56	3.54	2.76
Ceriodaphnia pulchella Sars	0	0	0.18	0	0.12	0	0	0
Bosmina longirostris (O.F.Muller)	0.06	0	0	0	0.33	0	2.28	2.28
Leptodora kindtii (Focke)	0	0.06	0.24	0.30	0.24	0	0.06	0
Bythotrephes longimanus Leydig	0	0	0.06	0	0.06	0	0.06	0
Alona rectangula Sars	0.06	0	0	0	0	0	0	0
Acroperus harpae Baird	0	0	0	0.06	0	0	0	0
Total Cladocera	0.18	1.62	15.24	11.76	13.83	19.56	5.88	5.04
Copepoda, Crustacea								
naplii	1.02	3.90	0.66	0.36	0.18	0	0.12	0
copepodit	0.42	2.64	1.44	0.45	2.04	2.34	1.80	1.86
Mesocyclops leuckarti *Thermocyclops crassus* (Fisher)	0	0.54	0.06	0.06	0.78	1.47	0.18	0.15
Eudiaptomus graciloides (Lilljeborg)								
naplii	0.36	4.44	1.02	0.72	0.36	0.06	0.78	0.12
copepodit	0.06	1.86	3.62	0.24	1.14	0.36	0.24	0.60
adults	0	9.00	53.10	30.84	17.60	13.26	8.46	8.76
Total Copepoda	1.98	22.38	60.24	32.67	22.08	17.49	11.76	11.64
Rotifera								
Asplanchna priodonta Gosse	0.06	0.12	0.12	0	0.24	0.18	7.92	3.18
Kellicottia longispina (Kellicott)	0	0	0.06	0.06	2.16	0.9	10.5	11.88
Keratella cochlearis (Gosse)	0	0.06	0	0	0	0	0	0
Euchlanis dilatata Ehrenberg	0.30	0.06	0.06	0	0	0	0	0
Conochilus unicornis Rousselet	0.06	0.66	0.33	0	0	0	0	0
Polyarthra vulgaris Carlin	0	1.65	0	0	0	0	0	0
Pompholyx sulcata Hudson	0	0.18	0.18	0	0.18	0	0.12	0.06
Trichocerca multicrinis (Kellicott)	0	0.30	0	0	0.36	0.06	0	0.06
Filinia longiseta (Ehrenberg)	0	0	0	0	0	0	0.24	0.66
Total Rotifera	0.42	3.03	0.75	0.06	2.94	1.14	18.78	15.96
Total	2.58	27.30	76.23	44.49	38.85	38.19	36.42	32.64

Note: 0 – the species is absent.

Table 2. Species composition and abundance (thousand indiv./m^3) of zooplankton in the water column of Lake Arakhley in August 2013

Species	Depth, m							
	0	2	4	6	8	10	12	14
Cladocera, Crustacea								
Daphnia galeata Sars	32.52	55.74	33.46	24.96	34.02	34.98	37.38	19.92
Ceriodaphnia pulchella Sars	0	0	0	0	1.32	0.18	0	0
Bosmina longirostris (O.F.Muller)	3.12	1.92	1.62	1.44	4.56	4.32	1.74	1.98
Leptodora kindtii (Focke)	0	0	0.06	0	0.36	0.12	0.06	0
Bythotrephes longimanus Leydig	0	0	0.06	0	0	0	0	0
Chydorus sphaericus (O.F. Muller)	1.08	0.12	0	0	0	0	0	0
Total Cladocera	36.72	57.78	35.20	26.40	40.26	39.66	39.18	21.90
Copepoda, Crustacea								
naplii	1.74	2.04	1.98	1.74	11.76	4.02	1.80	1.80
copepodit	1.50	2.46	1.20	1.32	6.12	5.06	5.64	8.40
Mesocyclops arachlensis Alekseev	0.12	1.86	1.38	2.04	1.56	0.42	1.44	0.84
Thermocyclops crassus (Fisher)	0.42	0	0	0.06	0.12	0.36	5.82	2.70
Macrocyclops albidus (Jurine)	0.06	0	0	0	0	0.12	0.12	0
Eudiaptomus graciloides (Lilljeborg)								
naplii	0.96	0.90	0.90	0.36	5.10	2.16	0.12	0.54
copepodit	0	0	0	0	0	0	0	0.06
adults	0	0	0	0	0	0	0	0.06
Total Copepoda	4.80	7.38	6.18	5.85	24.72	12.14	14.94	14.4
Rotifera								
Asplanchna priodonta Gosse	0.18	0.12	0.18	0.06	0.24	0.48	0.54	0.06
Kellicottia longispina (Kellicott)	0.60	0.66	0.60	0	0.54	0.84	0.24	0.48
Keratella cochlearis (Gosse)	0.90	0.36	0.30	0.24	0.78	0	0.18	0.18
K.quadrata (Muller)	0.06	0	0.18	0	0.12	0.18	0	0.12
Euchlanis dilatata Ehrenberg	0	0	0	0	0	0.54	0	0
Conochilus unicornis Rousselet	0.06	0.06	0.12	0	0	0	0	0
Polyarthra vulgaris Carlin	0.24	0.18	0	0.33	0.24	0.12	0.12	0.54
Pompholyx sulcata Hudson	0	0	0	0	0.06	0.30	0	0.18
Trichocerca multicrinis (Kellicott)	2.10	2.94	1.92	2.16	1.14	1.50	0.18	0.12
Filinia longiseta (Ehrenberg)	0.06	0	0	0.06	0	0.06	0.18	0.9
Synchaeta sp.	0	0	0	0	0.18	0	0	0
Brachionus sp.	0.12	0.06	0	0	0	0	0	0.06
Total Rotifera	4.32	4.32	3.24	2.97	3.30	4.02	1.44	2.70
Total	45.84	69.48	44.62	35.22	68.28	55.82	55.56	39.10

Table 3. The dominant zooplankton complex of Lake Arakhley in 2011 and 2013

2011	% of the total abundance	2013	% of the total abundance
Eudiaptomus graciloides	22	*Daphnia galeata*	65
Daphnia galeata	24	*Eudiaptomus graciloides*	22
Kellicottia longispina	9	*Trichocerca multicrinis*	3

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