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Influence of Nitrate-Phosphate Overload on Macrozoobenthos Communities in Thickets of Aquatic Macrophytes

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Abstract: Eutrophication is one of the most important problems in the ecology of fresh waters. The aim of the present work was to investigate the effect of eutrophic overload (nitrates and phosphates) to the structure of zoobenthos in two types of experimental waters. Experimental mesocosms containing ground and water were used to investigate nitrate-phosphorus effect to hydrobionts. The negative effects of the pollutants were less evident in experimental mesocosms with aquatic macrophytes. The resistance of the bottom community to negative effects of nitrates and phosphates is probably connected with multifunctional role of aquatic macrophytes.

Key words: Eutrophication · Benthos · Aquatic macrophytes · Nitrates · Phosphates · Experimental reservoirs

INTRODUCTION

Eutrophication is one of the most important problems in the ecology of fresh waters [1, 2]. Evaluation of bottom organisms such as benthos is essential in assessing the environmental quality of a region, as they are exposed to potential toxicants [3-5]. Due to eutrophication, reducing of species diversity may occur in benthic hydrobionts. Eutrophication may result in dominance of detrital food chain at prominent development and activation of saprophytic microflora [6]. The proportion of predators is reducing while collectors-detritus and subsurface ground-slurpers are increasing. Also, proportion of shredders and filtrators are increasing [7]. The aim of the present work was to investigate the effect of nitrates and phosphates single-shot introduction to the zoobenthos community in two types of experimental waters.

MATERIALS AND METHODS

Experimental mesocosms containing ground (10 L) and water (30 L) were used to investigate nitrogen-phosphorus effect to hydrobionts. Natural water with complex of planktonic and benthic organisms was taken from mesotrophic Sredniy Kaban Lake (Kazan city, Russia). Two types of mesocosms were used-with aquatic macrophytes (*Typha angustifolia*) and without it. Hydrochemical analysis was performed to control water quality. Mineral nitrogen and phosphorus (5:1 and 20:1 ratios) were used. Biogenic elements ($NaNO_3$ and Na_3PO_4) were introduced at concentrations 100 mg(N)/L : 20 mg(P)/L, 400 mg(N)/: : 20 mg(P)/L, 600 mg(N)/L : 30 mg(P)/L. Observations were performed since June 22 to October 15, 2009 and from June 1 to September 20, 2010 with exposition time of 4.5 months. Zoobenthos analysis was performed taking ground samples using sampling tube (volume 60 mL, 10-20 repeats). 5 L of ground was sifted through metallic sieve with 1 mm aperture; water was filtered through sieve with 0.5 mm aperture.

RESULTS AND DISCUSSION

Characteristics of taxonomic content and basic quantitative parameters of zoobenthos. Considering data of 2009 and 2010, it is possible to state that we detected 47 species of zoobenthos belonging to 7 taxonomic groups of hydrobionts. Zoobenthos of overgrown mesocosms contained 34 species including oligochaetes (14 species), diptera (8 species), mollusks (7 species),

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leeches (2 species), crustaceans (1 species), beetles and ephemeras (1 species). In open mesocosms, we detected 25 species: oligochaetes (7 species), larvae of diptera (14 species), leeches (2 species), mollusks (1 species) and ephemeras (1 species). Zoobenthos was presented by species of limnological complex where representatives of the psammopelophilic and phytophilic fauna are predominant. Oligochaetes of *Tubificidae* family (*Limnodrillus hoffmeisteri, Limnodrillus udekemianus, Tubifex tubifex*) and *Naididae* (*Dero obtusa*) were dominant entering to experimental mesocosms along with the ground from the lake and allowing a high number due to the absence of large predators. Another dominant group of aquatic hydrobionts was presented by larvae of insects whose specific and number was season-dependent in experimental biotopes. In the beginning of the experiment insects were presented by *Chironomus tentans, Cryptochironomus gr defectus, Tanytarsus gr mendax, Cladotanytarsus gr mancus*; by the end of the experiment, there were a complex of phytophilic *Paratanytarsus gr lauterborni* and *Corynoneura gr scutellata* along with *Chironomus sp.* and some other species. Total number of macrozoobenthos in open mesocosms was 18-22x10^3 ind. per m^2 and biomass-15.8-30.3 g per m^2. High quantitavive parameters are mediated by development of *L.hoffmeisteri*, *T.tubifex* and *D.obtusa*. Specific number of these animals was 66.8-95.5% and biomass-42.5-73.1%. In overgrown mesocosms, total number of zoobenthos was 4050-14553 ind. per m^2, total biomass-7.71-33.55 g per m^2. Dominating role of number (67-83%) and biomass (44-71%), belonged to *L.hoffmeisteri* (2219-3183 ind. per m^2) and *L.udekemianus* (502-2513 ind. per m^2).

Characteristics of zoobenthos in open biotopes. We detected enormous rearrangements in the structure of the bottom community. In variant 400 mg(N)/L+20 mg (P)/L, we found inhibition of zoobenthos. A month later the introduction of pollutants, number of oligochaetes reduced 2.5-fold; 2 months later we saw 28-fold reduction. By the end of the experiment, the number of oligochaetes was 209 ind. per m^2 and 0.094 mg/m^2 (100-fold and 235-fold differences with control, respectively) (Fig. 1).

The negative action of 600 mg(N)/L+30 mg(P)/L was more evident. A month later, we detected a total death of all organisms (Fig. 2). All groups of zoobenthos as well as *Asellus aquaticus*, *Cloeon dipterum*, *Erpobdella octoculata* and *Helobdella stagnalis* were eliminated by the end of experiment. Despite inhibition and death of autochtonous fauna, we detected a partial recovery of zoobenthos in August and September: there were larvae of amphibiotic insects colonizing experimental waters by air way (*P.gr lauterborni, C.gr scutellata, Orthocladius gr saxicola, Chironomus annularis, Chironomus sp., Helophilus trivittatus* and others). Insects-colonizers made a new bottom community and a number of species increased till 7-9. Qualitative values of zoobenthos in variant 400 mg(N)/L+20 mg(P)/L recovered till control meanings and exceeded it by biomass (Fig. 3, 4). In variant 600 mg(N)/L+30 mg(P)/L by the end of 16^{th} week, fauna was poor-378 ind./m^2 and 2.3 g/m^2.

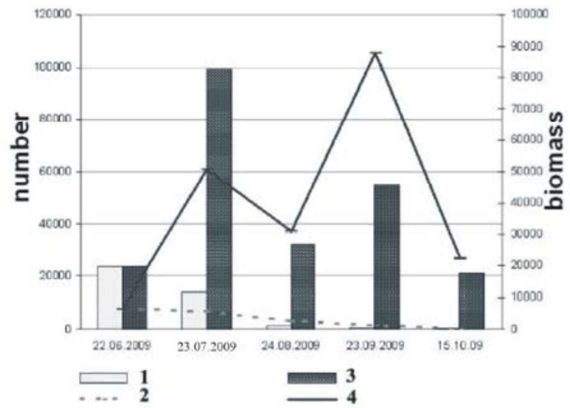

Fig. 1: Dynamics of oligochaete number and biomass (open biotopes, 2009). Notes: 1, 2 – N400+P20, 3, 4 – the corresponding controls.

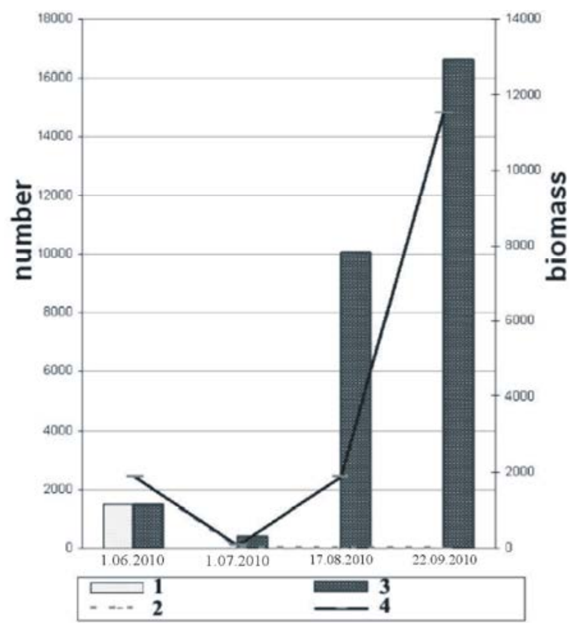

Fig. 2: Dynamics of oligochaete number and biomass (open biotopes, 2010). Notes: 1, 2 – N600+P30, 3, 4 – the corresponding controls.

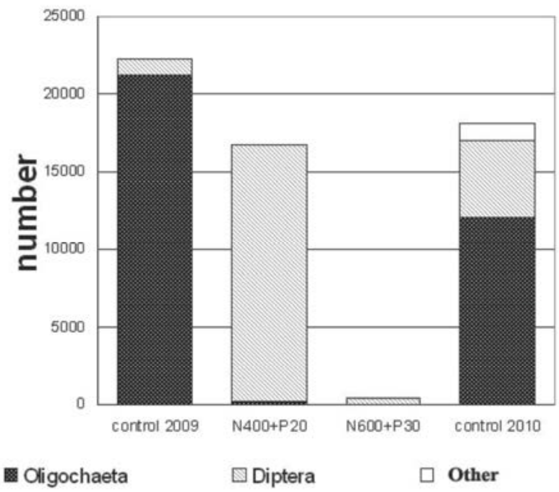

Fig. 3: Number of zoobenthos in open biotopes (2009-2010).

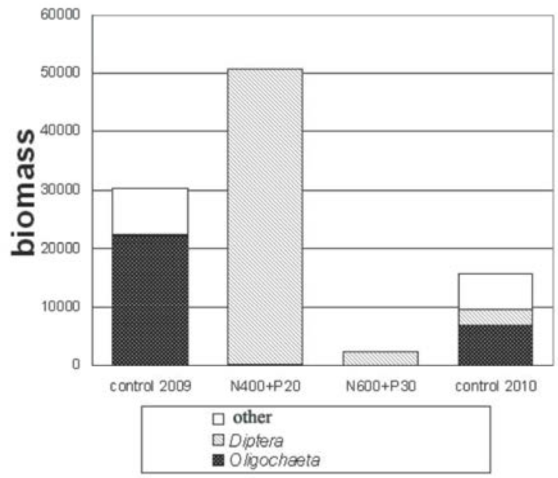

Fig. 4: Biomass of zoobenthos in open biotopes (2009-2010).

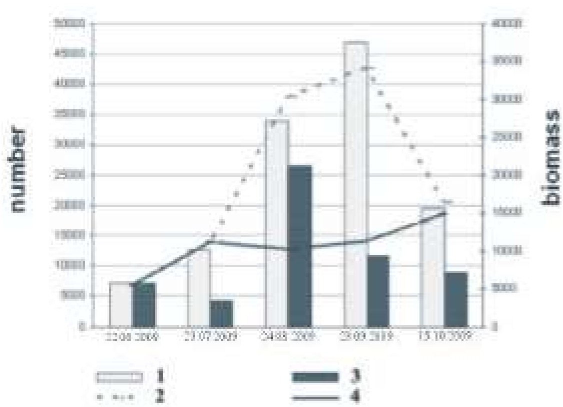

Fig. 5: Dynamics of oligochaete number and biomass (overgrown biotopes, 2009). Notes: 1, 2 – N400+P20, 3, 4 – the corresponding controls.

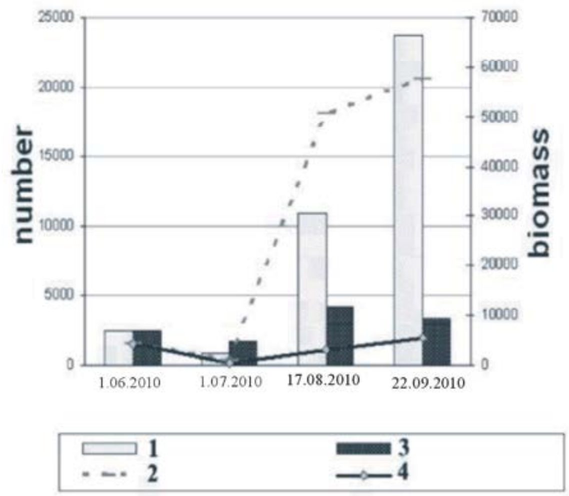

Fig. 6: Dynamics of oligochaete number and biomass (overgrown biotopes, 2010). Notes: 1, 2 – N600+P30, 3, 4 – the corresponding controls.

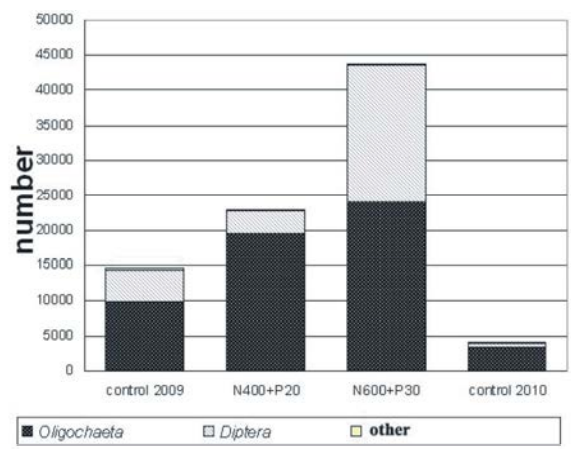

Fig. 7: Number of zoobenthos (overgrown biotopes, 2009-2010).

Characteristics of zoobenthos in overgrown biotopes. In two variants with pollutant concentrations, we detected increase in growth of a number and biomass of oligochaetes (Fig. 5, 6). Dominating role of oligochaetes was rised and reached 85% of total number. In variant 400 mg(N)/L+20 mg(P)/L, we detected 1.6-fold increase in zoobenthos number due to development of oligochaetes (Fig. 7). In variant 600 mg(N)/L+30 mg(P)/L, we detected increase in number and biomass (43800 ind. per m^2 and 78.5 g per m^2 (that is 7-fold and 10-fold much than in control) (Fig. 7, 8). The high values are due to development of oligochaetes (primarily, *L.hoffmeisteri*) as well larvae of bloodsucking mosquitos (*Culex pipiens*) and chironomids (*P.gr lauterborni, C.gr scutellata*

Table 1: Dynamics of nitrates, nitrites and phosphates (mg per dm^3) in mesocosms with (AM) and without aquatic macrophytes

	Year of observation								
	2009				2010				
	Control		N400+P20		N600+P30		Control		
Duration of exposition (weeks)	Without AM	With AM	Without AM	With AM	Without AM	With AM	Without AM	With AM	Duration of exposition (days and weeks)
Nitrates delta 2.0 (p=0.95 n=2)									
1	0.61	<0.5	1345.4	810.0	2178.00	2370.00	1.00	1.00	2 days
2	<0.5	<0.5	975.7	297.0	2937.00	2099.00	1.48	1.48	1
4	<0.5	<0.5	1144	160.5	1972.00	1044.00	1.00	1.12	3
9	<0.5	<0.5	230	0.52	1110.00	266.00	1.00	1.00	4
13	<0.5	<0.5	49.1	<0.5	1.00	1.00	1.00	1.00	12
16	0.66	<0.5	3.0	<0.5	3.37	1.73	1.00	1.00	16
Phosphates delta 0.05 (p=0.95 n=2)									
1	0.080		0.680	0.310	13.30	17.10	0.05	0.07	2 days
2	<0.05		0.259	0.105	0.52	0.86	0.05	0.05	1
4	0.301		0.624	<0.05	0.86	0.14	0.05	0.05	3
9	0.57	<0.05	0.82	<0.05	0.51	0.05	0.09	0.10	4
13	0.36	<0.05	0.34	<0.05	0.06	0.89	0.05	0.05	12
16	1.86	<0.05	0.89	<0.05	0.05	0.05	0.06	0.05	16
Nitrites delta 0.02 (p=0.95 n=2)									
1	<0.02	0.027	10.70	11.21	1.35	10.00	0.02	0.02	2 days
2	<0.02	<0.02	12.15	5.55	23.30	36.50	0.03	0.04	1
4	<0.02	0.054	34.60	10.30	49.40	30.70	0.02	0.02	3
9	<0.02	<0.02	77.5	0.025	83.60	30.50	0.04	0.03	4
13	0.076	<0.02	41.8	<0.02	0.04	0.06	0.02	0.02	12
16	<0.02	<0.02	8.7	<0.02	0.10	0.23	0.02	0.02	16

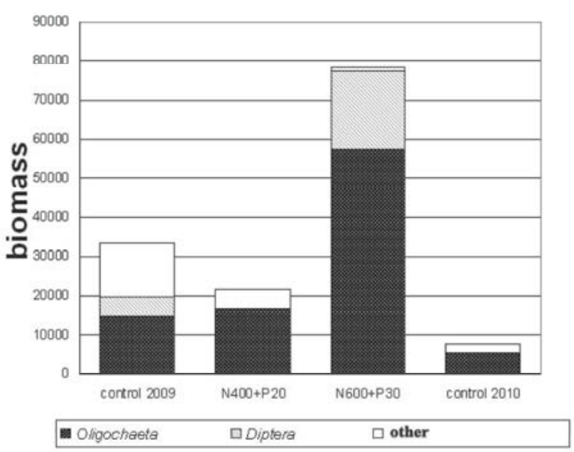

Fig. 8: Biomass of zoobenthos (overgrown biotopes, 2009-2010).

and *Chironomus sp.*). In 2009, we detected dominance of oligochaetes while in 2010-insects-colonizers.

The single-shot introduction of high doses of pollutants (400 mg(N)/L+20 mg(P)/L and 600 mg(N)/L+30 mg(P)/L) resulted in evident negative effects to ecosystem of open type. Probably, death of the bottom community occurred due to changes in basic hydrochemical parameters. 2 days after the introduction of pollutants, we detected high concentrations of biogenic elements, alkalization (till 10.3), increasing chemical consumption of oxygen (till 207 mgO^2/dm^3) and electrical conduction (Table 1). Apart from increase of nitrates, we detected elevation of nitrites that did not reducing till the end of the experiment (16th week). The partial recovery of zoobenthos was due to amphibiotic insects colonizing experimental substrates. Aborigenic aquatic fauna did not recover due to disconnectedness with natural waters.

In experimental waters with aquatic macrophytes, the negative effects of the pollutants were less evident. There was a massive development of oligochaetes of *Tubificidae* family. In trophic structure leading role was related with families of *Tubificidae*, *Lumbriculidae*, *Enchytraeidae*-73-74% of relative biomass.

The resistance of the bottom community to negative effects of nitrates and phosphates is connected with multifunctional role of aquatic macrophytes. These plants may detoxify the environment [8]. Data from Table 1 suggests on the role of *Typha angustifolia* plants in decreasing nitrate-phosphate overload. Plants actively included the pollutants ton their metabolism and reduced their content in the aquatic environment. Previous studies revealed incorporation of nitrates into leaves of *T. angustifolia* and stimulation of protein, lipid and polysaccharide fractions [9]. The detoxifying effect of aquatic macrophytes also may be connected with induction of hydrobionts that are active consumers of biogenic elements [10, 11].

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