ISSN 1995-0829, Inland Water Biology, 2018, Vol. 11, No. 3, pp. 310–316. © Pleiades Publishing, Ltd., 2018.
Original Russian Text © A.V. Krylov, E.G. Sakharova, R.Z. Sabitova, A.I. Tsvetkov, D.D. Pavlov, E.A. Movergos, S.A. Poddubny, 2018, published in Biologiya Vnutrennykh Vod, 2018, No. 3.

Phyto- and Zooplankton of Open Overgrown Shallows of the Rybinsk Reservoir Adjacent to a Mixed Grey Heron–Great Egret (*Ardea cinerea* L. and *A. alba* L.) Colony at a High Water Level

A. V. Krylov[a], *, E. G. Sakharova[a], R. Z. Sabitova[a], A. I. Tsvetkov[a], D. D. Pavlov[a], E. A. Movergos[a], and S. A. Poddubny[a]

[a] *Institute for Biology of Inland Waters, Russian Academy of Sciences,*
Borok, Nekouzskii raion, Yaroslavl oblast, 152742 Russia
**e-mail: krylov@ibiw.yaroslavl.ru*

Received June 14, 2017

Abstract—Phyto- and zooplankton communities developing in the open overgrown shallows of the Rybinsk Reservoir under the influence of a bird colony are shown to lose specific traits of quantitative characteristics and structure fluctuation in response to the elevated water level in contrast to previous findings. Possible reasons, such as the decomposition of sunken coastal vegetation playing the main role, accompanied by the development of semiaquatic macrophytes and trophic relations between algae and invertebrates, are discussed. It is found that increased atmospheric precipitation leads to an increased abundance of Copepoda in the zooplankton. Presumably, this effect correlates with more rapid and intensive inflow of avian vitality products rich in nitrogen into the water, resulting in a change in the stoichiometric ratio of nitrogen and phosphorus in zooplankton food objects to values favorable for copepods.

Keywords: littoral, colonial birds, *Ardea cinerea* L. and *A. alba* L., phyto- and zooplankton, water level, semiaquatic vegetation, amount of atmospheric precipitation

DOI: 10.1134/S1995082918020116

INTRODUCTION

Studies on the effects of aquatic and semiaquatic vertebrates on communities of hydrobionts in freshwater ecosystems allow for better understanding issues related to the sources of additional nutrient loads on the waterbodies. The inflow of vitality products of aquatic and semiaquatic colonial birds facilitates changes in the concentrations of nutrients and quantitative parameters of primary and secondary producers, evidencing the so-called guanotrophication of waterbodies [26, 27, 31]. It is clear that, similarly to anthropogenic eutrophication, the responses of various elements of aquatic biota may differ and depend not only on the quantity of inflowing matter, but on the specificity of the hydrological regime in a waterbody, meteorological conditions, etc. The fluctuations of water level play an important role in the formation of the structural–functional organization of littoral aquatic communities. This is especially true in regards to artificially controlled systems—reservoirs (man-made lakes). In addition, the density of the bird colony and amount of atmospheric precipitation facilitating the runoff of the feces to water play an important role in the changes in communities under avian impact.

The goal of the present paper is to study the phyto- and zooplankton of the area of an open overgrown littoral in the Rybinsk Reservoir affected by a mixed heron–egret (*Ardea cinerea* L. and *A. alba* L.) colony with a high water level in the reservoir.

MATERIALS AND METHODS

The materials for study were sampled in 2016 during the avian nesting period at the overgrown open littoral of the Volzhskii reach in the Rybinsk Reservoir (58°03.512′ N; 38°17.431′ E). The sampling was performed in the zone affected by the vitality products of mixed grey heron *Ardea cinerea* L. and great egret *A. alba* L. colony and at an area situated higher than the border of the colony (reference site). The water was sampled (six to eight samples on one date at each sampling site) at sites with depths of 0.3–0.8 m using a 1-L vessel and poured to a bucket, from which the water was taken for determining phytoplankton (PhP). The zooplankton (ZP) was sampled (six to eight samples on one date at each sampling site) using a bucket, the water from which (≥25 L) was filtered through a 64-μm mesh plankton net.

The phytoplankton was concentrated by direct filtration applying weak pressure; the samples were condensed and preserved with Lugol's solution with the addition of formalin and glacial acetic acid [17]. The biomass of PhP was determined using the counting-volumetric method [17]. Taxa with biomass comprising ≥10% in total were classified as dominants. The species composition and quantitative parameters of algae were determined under a Carl Zeiss Primo Star light microscope in the 0.01 mL Uchinskaya-2 counting chamber. The ZP samples were preserved with 4% formalin; cameral processing of the samples followed the standard routine [17]; upon determining the biomass, the sizes of animals were considered [1]; the quantitative parameters were calculated using the software given in [2].

Statistical analysis of the differences in the quantitative parameters of planktonic organisms included testing the normality of distribution using the Kolmogorov–Smirnov test, testing the significance of differences by the Mann—Whitney test, and calculating the Spearman nonparametric correlation coefficient ($p < 0.05$).

RESULTS

The colony occupied an area of 300 × 150 m; the first row of trees (pine, birch, and aspen) with nests was situated 40 m from the water line. The colony consisted of 60 nests of grey heron and 11 nests of great egret. The nests (three to five nests at one tree) were situated at a height of 6–12 m. The majority of grey herons left their nests by the end of July; most great egrets left by mid-August. During the last decade, the number of nests and birds remains in fact constant; the changes concern only the fact that, since 2015, the great egret started to nest in the colony [34].

In June, the total PhP biomass in the zone affected by the colony was lower, although the differences were insignificant (Table 1). The base of the biomass was built by diatoms (51.5% of the total biomass at the reference site and 28.3% in the site affected by the birds), cryptophyte (32.5 and 34.6%, respectively), and green (10.2 and 20.6%, respectively) algae. In addition, in the bird-affected zone, the share of dinophytic algae was higher: 12.3% versus 3.5%. At the reference site, the following species dominated: diatoms *Aulacoseira ambigua* (Grunow) Simonsen (12.2%) and *Diatoma tenuis* Agardh (29.4%) and cryptomonade *Cryptomonas curvata* Ehrenberg (19.2%). At the site affected by the colony, cryptomonade *Cryptomonas curvata* Ehrenberg (17%) and *C. marssonii* Skuja (17%), as well as dinoflagellates of g. *Peridiniopsis*, dominated by biomass (16%). Near the colony, diatoms were not among the dominants.

At the site affected by the colony, the number and biomass of Cladocera and total ZP biomass were significantly higher, but the density of Copepoda was significantly lower (Table 2). At the reference site, Copepoda (47.7%) and Rotifera (41.6%) dominated by number; near the colony, cladocerans (36.3%) and rotifers (35.1%) dominated. The following species dominated: *Keratella cochlearis* (Gosse, 1851); *Synchaeta pectinata* Ehrenberg, 1832; and juvenile Copepoda. At the reference site, the basis of the biomass was made up of Copepoda (69.5%) and dominated by *Eurytemora velox* (Lilljeborg, 1853), *Mesocyclops leuckarti* (Claus, 1857), and Cyclopoida copepodites; near the colony it was Cladocera (71.4%), dominated by *Polyphemus pediculus* (Linnaeus, 1761); *Alona costata* Sars, 1962; and *Chydorus sphaericus* (O.F. Müller, 1785).

By mid July, the PhP biomass at the reference site was significantly higher than at the zone affected by the birds (Table 1). The basis of the biomass was diatoms (42.6% of the total biomass at the reference site;

Table 1. Mean biomass (g/m^3) of phytoplankton and taxonomic groups at the reference site (I) and at the site affected by birds (II)

Taxonomic group	June 16			July 13			July 25			August 16		
	I	II	p	I	II	p	I	II	p	I	II	p
Cyanophyta	0.049	0.082	–	0.050	0.062	–	5.051	4.141	–	0.507	0.820	0.0209
Chrysophyta	0.019	0.018	–	0.018	0.008	–	0.081	0.024	–	0.028	0.024	–
Bacillariophyta	1.727	0.919	–	0.979	0.315	0.029	2.123	2.062	–	3.191	3.210	–
Xantophyta	0.014	0.002	–	0.087	0.002	–	0.006	0.000	–	0.000	0.000	–
Cryptophyta	1.054	1.183	–	0.868	0.261	0.029	0.220	0.299	–	0.208	0.503	0.0209
Dinophyta	0.114	0.406	0.004	0.033	0.017	–	1.613	0.389	–	0.157	0.132	–
Chlorophyta	0.338	0.700	0.006	0.318	0.204	–	0.685	1.108	–	0.131	0.366	0.0433
Euglenophyta	0.003	0.058	–	0.004	0.001	–	0.157	0.000	–	0.007	0.017	–
Mixotrophs	1.190	1.671	–	0.924	0.287	0.029	2.071	0.712	–	0.400	0.677	–
Total*	3.318	3.368	–	2.357	0.870	0.029	9.936	8.023	–	4.229	5.072	–

Here and in Table 2, – indicates a lack of significant differences, $p < 0.05$.

*The total sum was calculated without taking into account the mixotrophs, whose biomass is composed of part of the above groups.

Table 2. Mean number (top, thousands ind. /m^3) and biomass (bottom, g/m^3) of zooplankton and taxonomic groups of invertebrates at the reference site (I) and the site affected by birds (II)

Taxon	June 16			July 13			July 25			August 16		
	I	II	*p*	I	II	*p*	I	II	*p*	I	II	*p*
Rotifera	5.1 0.0065	4.7 0.0069	–	8.5 0.023	33.3 0.099	0.0157 0.0209	974.1 7.186	1019.9 8.323	–	22.5 0.035	21.2 0.040	–
Copepoda	5.8 0.0343	3.7 0.0235	0.0207 –	2.2 0.009	20.2 0.040	0.0033 0.0313	269.2 0.514	296.7 0.818	–	15.5 0.054	5.4 0.019	0.0082 0.0082
Cladocera	1.4 0.0085	5.3 0.1014	0.0019 0.0003	2.3 0.019	3.1 0.022	–	135.4 8.301	141.5 5.551	–	3.2 0.022	3.6 0.013	–
Total	12.3 0.0493	13.7 0.132	– 0.0011	13.0 0.051	56.6 0.161	0.0087 0.0107	1378.7 16.001	1458.1 14.692	–	41.1 0.111	30.2 0.072	– 0.0131

37.2%, near the colony), cryptophytic (36.8 and 29.7%, respectively), and green (12.8 and 22.5%, respectively) algae. At both sites the algal communities were dominated by cryptomonade *Cryptomonas curvata* (23 and 12%, respectively) and diatom *Cyclotella meneghiniana* Kützing (17 and 16%, respectively). In addition, at the reference site, diatoms *Stephanodiscus binderanus* (Kützing) Krieger (11.5%) and *Aulacoseira ambigua* (22%) dominated by biomass; at the bird-affected site, cryptophytic *Chroomonas acuta* Utermöhl (12%) and green algae *Cosmarium reniforme* (Ralfs) W. Archer (12%) and *Ulothrix subtilissima* Rabenhorst (11%) dominated.

At the reference site, the number of ZP was noticeably lower than near the colony, where the density of Rotifera and Copepoda were significantly higher (Table 2). No significant differences in the ZP biomass were noted, but the biomasses of rotifers and copepods at the reference site were significantly lower. At both sites, Rotifera (61.7% at the reference site; 57.9%, near the colony) were most numerous. Near the colony the share of Copepoda was higher (35.9% versus 16.7%); the share of Cladocera was lower (6.2% versus 21.6%). *Synchaeta pectinata*, *S. tremula* (O.F. Müller, 1786), and juvenile Copepoda dominated by number. At the reference site, cladocerans (41.4%) and rotifers (40.4%) dominated by biomass; at the site affected by the birds, the dominants were rotifers (60.1%) and copepods (24.1%), dominated by *Synchaeta tremula*, *Alona affinis* (Leydig, 1860), *Acroperus angustatus* (Sars, 1863), *Thermocyclops crassus* (Fischer, 1853), Cyclopoida copepodites, and Calanoida nauplii.

By the end of July, the biomasses of PhP at the compared sites did not differ significantly (Table 1). The most abundant were Cyanobacteria (52.5% at the reference site and 51.2% at the bird-affected site), diatoms (20.9 and 26.4%, respectively), dynophytic (13.9 and 5.5%, respectively), and green algae (7.6 and 13.1%, respectively). The community was dominated by *Anabaena scheremetievi* Elenkin (19 and 25%, respectively) and *Anabaena* sp.sp. (18 and 16%, respectively). In addition, near the colony *A. contorta* Bachmann (11.5%), *Aphanizomenon flos-aquae* (Linnaeus) Ralfs ex Bornet et Flahault (12%) and *Aulacoseira ambigua* (15%) prevailed; at the reference site, *Stephanodiscus binderanus* (19.5%) prevailed.

At the compared sites, the quantitative parameters of ZP did not differ significantly (Table 2). At the reference site and near the colony, Rotifera (70.4 and 70.0%, respectively) made up the basis of the number; Rotifera (49.1 and 56.7%, respectively) and Cladocera (47.2 and 38.0%, respectively) made up the basis of biomass. At both sites *Ploesoma truncatum* (Levander), *Asplanchna henrietta* Lanthans, and Cyclopoida nauplii dominated by number; *Daphnia (Daphnia) galeata* Sars and *Asplanchna henrietta* dominated by biomass.

In August we noted no significant differences in PhP biomass, but at the site affected by birds the biomasses of cyanobacteria, cryptophytic, and green algae were significantly higher (Table 1). The basis of biomass was comprised of diatoms (75.1 and 63.3% at the reference site and near the colony, respectively) and cyanobacteria (12.5 and 16.6%, respectively). The communities were dominated by *Aulacoseira ambigua* (12 and 13.5%, respectively) and *A. granulata* (Ehrenberg) Simonsen (50 and 41%, respectively), along with green algae of g. *Chlamydomonadas* (11%) near the colony.

The ZP densities did not differ significantly at the compared sites, while the biomass was significantly higher at the reference site, where number and biomass of copepods were higher as well (Table 2). Rotifers were most numerous at both sites: 52.5% at the reference site and 70.4% near the colony. Copepods prevailed by biomass at the reference site (48.7%); near the colony, rotifers prevailed (56.4%). At the reference site, the community was dominated by *Polyarthra luminosa* Kutikova, 1962; *Mesocyclops leuckarti*; Cyclopoida copepodites; and Calanoida nauplii; at the site affected by birds, *Polyarthra major* Burckhardt, 1900 and *Synchaeta pectinata* dominated.

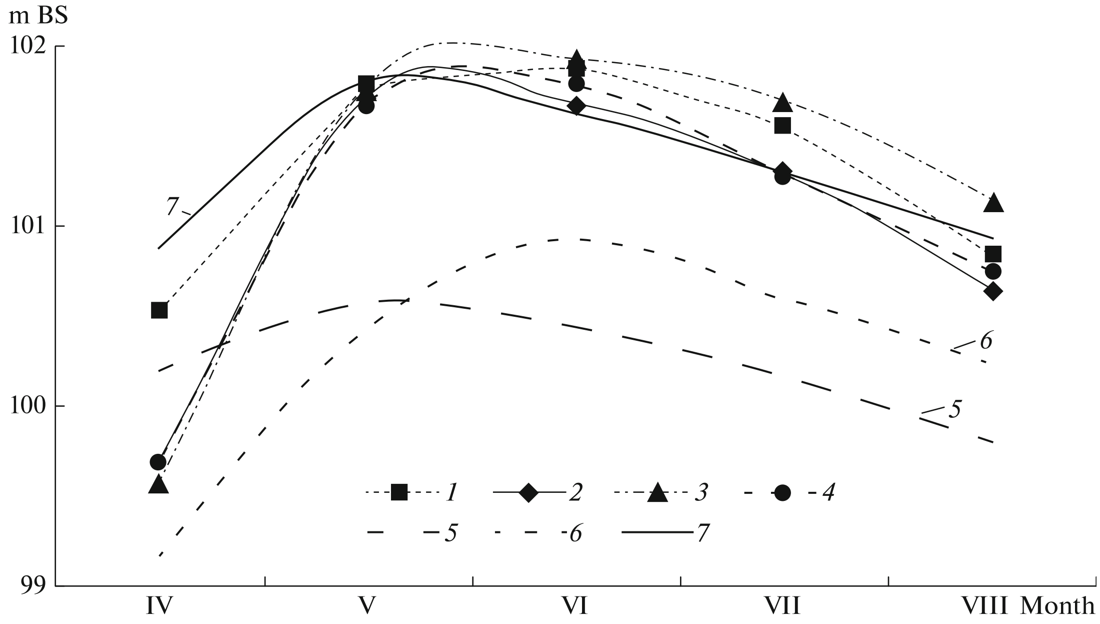

Fig. 1. Changes in the water level in the Rybinsk Reservoir (according to [6]): (*1*) 2010, (*2*) 2011, (*3*) 2012, (*4*) 2013, (*5*) 2014, (*6*) 2015, and (*7*) 2016.

DISCCUSSION

Unlike 2014 and 2015 observation years, when the fluctuations of the water level were characterized by a lack of sharp interannual changes, in 2016 the water level in the Rybinsk Reservoir was constantly high. The study on PhP and ZP of the open overgrown shallow affected by the vitality products of the mixed grey heron–great egret colony carried out in the latter year revealed no specificity in the quantitative and structural parameters of the communities. This concerns both certain observation dates and the whole span of the observation period, unlike the previous years, which lacked sharp fluctuations in water level.

It was revealed [19] that, at the site affected by the bird colony, the total PhP biomass and biomass and share of mixotrophic phytoflagellates were higher than at the reference site. In 2016 (June, end of July, and August) the biomass of PhP near the colony did not differ significantly from the biomass at the reference site; in fact, at the peak of nesting activity (mid-July), it was significantly lower. Only in June and August the biomasses of some mixotrophic phytoflagellates were significantly higher near the colony; in July it was either significantly lower or did not differ (Table 1). In addition, it was noted earlier that, during the nesting period on the open overgrown shallow, the number and biomass of copepods were higher and the abundance of rotifers was lower, but there were no significant differences in total number and biomass between the compared sites [12]. In 2016 we revealed the opposite phenomenon: at the site affected by birds, the total number and biomass of ZP (significantly in June and by the end of July), Cladocera and Rotifera, were higher than at the reference site, while in June the values of quantitative parameters of Copepoda at the former site were significantly lower than at the latter (Table 2).

In our opinion the main reason for the specific response of planktonic organisms revealed in 2016 is as follows. During 2014–2015, the water level was low (Fig. 1) and the cover of amphibian and terrestrial plants was formed on the dried coast. Upon a rise in water level in 2016, these plants were subject to decomposition, resulting in an increase in the inner nutrient load. As was revealed earlier [18], the highest PhP biomass in the coastal shallows is observed in the year next to the year with low water level, i.e., when dried areas are overgrown by macrophytes dying out in fall and decomposing during next spring, being flooded with water. Such conditions are also favorable for the development of ZP with number and biomass increased owing to the mass development of Rotifera and Cladocera [20].

Consequently, upon an increase in the inner nutrient load, the effect of vitality products of the bird colony on the Ph and ZP that was observed earlier changed. During some periods the effects of decomposition and additional inflow of matter from the catchment area were synergistic, which results in the domination of cladocerans and rotifers in the ZP near the colony, while copepods prevailed at the unaffected reference site. During other periods, the effect of inflow of avian vitality products was leveled by the processes of decomposition of the sunken vegetation, resulting in the prevalence of nonpredatory filter-feeding zooplankters. In turn, the latter determined the decline of the algal biomass, as is indicated by values of correlation coefficients of Cladocerans versus PhP biomass ($r = -0.50$) and ZP versus PhP biomass ($r = -0.74$). In addition, with an increase in the ZP biomass, the biomass of mixotrophic phytoflagellates ($r = -0.34$) and green algae ($r = -0.48$) decreased significantly.

The lack of differences in the PhP biomasses may be determined by several other factors as well. The inflow of avian vitality products to the nutrient-rich zone of sunken shallow stimulated the development of macrophyte stands. It is well known that macrophytes strongly affect PhP [4, 10, 14], either stimulating or retarding its development [13, 14, 23]. At the site affected by the colony, the width of the plant stands averaged 30 m; at the reference site, it was 15 m. At both sites common reed *Phragmites australis* (Cav.) Trin. ex Steud prevailed. At the bird-affected site, reed forms a monodominant community with a leaf-area density reaching 80%. This plant is a helophyte with anisotropic elongated shoots and partially submersed and aerial leafs branching from the hypogeogenic rhizome [15]. At the reference site, terrestrial wet phytomass in the common reed communities during the seasonal peak of biomass was 0.425 kg/m^2 at an air-dry phytomass of 0.250 kg/m^2; near the colony it was 0.665 kg/m^2 and 0.410 kg/m^2, respectively. These values indicate a higher nutrient load on the area of the shallow affected by the birds. It is known that in the dense vegetation stands the accumulation of wastes from the previous year takes place, along with the hyperaccumulation of organic matter accompanied with the subsequent deterioration of the oxygen regime and the accumulation of ammonium nitrogen, hydrogen sulfide, and swamp gas [5]. These factors may also result in a decrease in PhP abundance at the site affected by the colony. However, we did not conduct a relevant study, and this is why the exact role of these factors in the reed stands is still unclear. Most likely opacity played the most important role. For instance, it was shown [11, 22] that sometimes, in the dense stands of reed and cattail, only <1% of photosynthetically active radiation reaches the water surface, which determines the low abundance of phytoplankton. In addition, the development of macrophytes stands leads to a decrease in concentrations of nitrogen and other nutrients. Common reed possesses two types of roots: thick, tubular stretching down vertically, and thin horizontally oriented [5]. At the site affected by birds, owing to their vitality products, reed forms heavy horizontal runners of thick tubular roots. This is why both underground and terrestrial wet phytomass increased considerably (on average by a factor of 1.3), which may have enhanced the outflow of nutrients. In addition, PhP may compete for nutrients not only with macrophytes, but also with the epyphytic algae most actively developing on the helophytes [8].

Thus, despite the seemingly favorable conditions for PhP, its quantitative parameters at the site affected by the bird colony were at the same level as at the reference site and, during the peak of nesting activity, the values of these parameters were even significantly lower.

The macrophyte stands consuming nutrients may have also determined the biomass of mixotrophic phytoflagellates. As was shown earlier using the example of cultivated euglenales, nitrogen plays a crucial role for growth, the accumulation of protein, and the formation of valuable metabolites in mixotrophyc phytoflagellates [7]. The feces of birds contain nitrogen in high concentrations [28–30], which presumably serves as the mechanism responsible for the rise in biomass of mixotrophes at the site affected by bird colonies [19]. It is known that aquatic plants are one of the main agents of reserving and cycling of nutrients [16, 35]. At the same time, it was revealed that these plants accumulate predominantly nitrogen, and the amount of this chemical element in plant tissues directly depends on the external nutrient load, while the amount of phosphorus in the plant tissues is much lower and depends on the allogenic inflow to a lesser extent [9]. The abovementioned facts suggest that the mechanism of decrease in the nitrogen load along with the grazing of cladocerans and increase in the phosphorus load due to the decomposition of sunken vegetation may have determined the relatively low biomass of mixotrophic phytoflagellates at the site affected by the vitality products of the bird colony, where the intensity of overgrowth in 2016 was higher. For the same reason, the number and biomass of cladocerans in ZP increased: the rise in phosphorus load owing to the decomposition of sunken coastal vegetation and consumption of nitrogen by macrophytes changed the stoichiometric proportion of nitrogen and phosphorus in the food items of zooplankters to values favorable for the development of nonpredatory Cladocera [21, 24, 33].

The intensity of bird droppings that enter the water after initially falling on land depends on the amount of atmospheric precipitation. The duration that bird feces stay on land determines the contents of some chemical elements and compounds. Under the effects of microorganisms, solar radiation, air, and some other factors, the compounds in the feces are subject to various chemical reactions. As a result, some compounds turn into others, parts of them either volatilize into the atmosphere and disappear, or terrestrial plants consume them (which is especially true in regards to nitrogen) [25, 32]. It was shown earlier that the level of development of Copepoda depends directly on the concentrations of nitrogen and amount of atmospheric precipitation [12]. The results of our 2016 study also indicate the important role of atmospheric precipitation in various periods. For instance, the periods from June 16 to July 12 and from July 25 to August 16 where characterized by largest amount of atmospheric precipitation (Table 3). During the for-

Table 3. Amount of atmospheric precipitation during the study period (according to [3])

Period	15.V–15.VI	16.VI–12.VII	13.VII–24.VII	25.VII–16.VIII
Amount of precipitation, mm				
total	35.7	87.6	8.3	125.8
mean	1.08	3.24	0.69	5.72
Number of days with precipitation	13	15	5	8
Number of days with precipitation/number of days of the period	0.4	0.6	0.4	0.3
Mean per day, mm	1.1	3.5	0.6	5.5

mer period, the intensity of precipitation was maximal, as is evidenced by the value of the ratio of number of days with precipitation to the total number of days of the analyzed period (Table 3). During these periods, particularly in the shallows affected by the bird colony, more nitrogen may have washed out to water with the surface runoff. This may have changed the stoichiometric proportion of nitrogen and phosphorus in the food items of zooplankters to the values favorable for copepods [21, 22, 33]. This is why the number and biomass of these crustaceans were significantly higher than at the reference site (Table 2).

CONCLUSIONS

Under the conditions of a high-water year, the phyto- and zooplankton communities developing in the open overgrown shallow of the Rybinsk Reservoir affected by the vitality products of the bird colony lack specific features of changes in the quantitative parameters and structure. The decomposition of sunken coastal vegetation, the development of semiaquatic macrophytes, and trophic relations determine this phenomenon. A rise in the amount of atmospheric precipitation facilitates faster and more intensive inflow of avian vitality products rich in nitrogen to the water. This results in a change in the stoichiometric proportion of nitrogen and phosphorus in the food items of zooplankters to values favorable for Copepoda.

ACKNOWLEDGMENTS

This study was supported by the Russian Foundation for Basic Research, grant no 16-04-00028_a.

REFERENCES

1. Balushkina, E.B. and Vinberg, G.G., The relationship between weight and body length in planktonic animals, in *Obshchie osnovy izucheniya vodnykh ekosistem* (General Principles of the Study of Aquatic Ecosystems), Leningrad: Nauka, 1979, pp. 169–172.
2. Bolotov, S.E., FW-Zooplankton environmental analysis module for freshwater zooplankton communities, RF Patent no. 2012617486, 2012.
3. Bulygina, O.N., Razuvaev, V.N., Korshunova, N.N., and Shvets, N.V., Description of the data array of total monthly precipitation at Russian stations, Database State Registration Certificate no. 2015620394. http://meteo.ru/data/158-total-precipitation#описание-массива-данных.
4. Guseva, K.A. and Goncharova, S.P., The effect of higher aquatic vegetation on the development of planktonic cyanobacteria, in *Ekologiya i fiziologiya sinezelenykh vodoroslei* (Ecology and Physiology of Cyanobacteria), Moscow: Nauka, 1965, pp. 230–234.
5. D'yachenko, T.N., Biological and ecological characteristics of the common reed (*Phragmites australis*) in the aspect of optimum use of its resources, *Gidrobiol. Zh.*, 2011, vol. 47, no. 4, pp. 23–33.
6. An information system on water resources and water management of basins of Russian rivers (Information-Analytical Center of Registers and Cadastre). http://gis.vodinfo.ru.
7. Ismailkhodzhaev, B.Sh., Physiological and biochemical characteristics of green microalgae and euglenophytes and their application prospects, *Extended Abstract of Doctoral (Biol.) Dissertation*, Tashkent, 1994.
8. Kasperovichene, Yu. and Karosene, Yu., Structural and functional characteristics of epiphyton and phytoplankton of the littoral zone of Lake Spera (Lithuania), *Vestn. Tyumen. Gos. Univ.*, 2005, no. 5, pp. 70–77.
9. Klochenko, P.D., Gorbunova, Z.N., Pasichnaya, E.A., and Kharchenko, G.V., Some features of the content of biogenic elements in aquatic macrophytes in urban areas, in Gidrobotanika-2005: Mater. VI Vseros. shk.-konf. po vodnym makrofitam (Hydrobotany-2005: Proc. VI All-Russia School-Conf. on Aquatic Macrophytes), Rybinsk, 2006, pp. 280–282
10. Kogan, Sh.I., Algae and higher aquatic plants under conditions of anthropogenic eutrophication of water bodies, *Bot. Zh.*, 1980, vol. 65, pp. 1569–1578.
11. Komarkova, I.Ya., Marvan, P., and Rychkova, M.A., Primary production and the role of algae in the littoral zone of water bodies of different types, in *Gidrobiologicheskie protsessy v vodoemakh (Hydrobiological Processes in Water Bodies)*, Leningrad: Nauka, 1983.
12. Krylov, A.V., Kulakov, D.V., Chalova, I.V., and Papchenkov, V.G., *Zooplankton presnykh vodoemov v usloviyakh vliyaniya gidrofil'nykh ptits* (Freshwater Zooplankton Under the Influence of Hydrophilic Birds), Izhevsk: Izdatel' Permyakov S.A., 2012.

13. Kutova, T.N., The relationship between the development of higher aquatic plants and phytoplankton in Lake Pestovo, *Izv. GosNII Ozer. Rech. Ryb. Khoz.*, 1968, vol. 67, pp. 167–183.
14. Kutova, T.N The relationship between the development of higher aquatic plants and phytoplankton in Lake Edrovo, *Izv. GosNII Ozer. Rech. Ryb. Khoz.*, 1973, vol. 84, pp. 78–89.
15. Lelekova, E.V., Biomorphology of aquatic and coastal-aquatic seed plants of the northeast of European Russia, *Extended Abstract of Cand. Sci. (Biol.) Dissertation*, Kirov, 2006.
16. Lukina, L.F. and Smirnova, N.N., *Fiziologiya vysshikh vodnykh rastenii* (Physiology of Higher Aquatic Plants), Kiev: Nauk. Dumka, 1988.
17. *Metodika izucheniya biogeotsenozov vnutrennikh vodoemov* (Method of Study of Biogeocenoses of Inland Water Bodies), Moscow: Nauka, 1975.
18. *Rybinskoe vodokhranilishche i ego zhizn' (Rybinsk Reservoir and Its Life)*, Leningrad: Nauka, 1972.
19. Sakharova, E.G., Phytoplankton of ecotone zones of the Rybinsk Reservoir, *Extended Abstract of Cand. Sci. (Biol.) Dissertation*, Borok, 2017.
20. Stolbunova, V.N., Zooplankton of the coastal zone of the Rybinsk and Ivankovo reservoirs in 1971–1974, in *Gidrobiologicheskii rezhim pribrezhnykh melkovodii volzhskikh vodokhranilishch* (Hydrobiological Regime of Coastal Shallow Water Areas of the Volga Reservoirs), Yaroslavl: Inst. Biol. Vnutr. Vod AN SSSR, 1976, pp. 170–213.
21. Tolomeev, A.P., The concept of "ecological stoichiometry" in aquatic ecosystems: a review, *Sib. Ekol. Zh.*, 2006, no. 1, pp. 13–19.
22. Khaliullina, L.Yu. and Yakovlev, V.A., *Fitoplankton melkovodii v verkhov'yakh Kuibyshevskogo vodokhranilishcha* (Phytoplankton of Shallow Water Areas in the Upper Reaches of the Kuibyshev Reservoir), Kazan: Izd. Akad. Nauk RT, 2015.
23. Ekzertsev, V.A. and Lisitsyna, L.I., Synopsis of the flora of the Gorky Reservoir, in *Flora, fauna i mikroorganizmy Volgi* (Flora, Fauna, and Microorganisms of the Volga River, Rybinsk: Inst. Biol. Vnutr. Vod AN SSSR, 1974, pp. 100–116.
24. Andersen, T. and Hessen, D.O., Carbon, nitrogen, and phosphorus content of freshwater zooplankton, *Limnol., Oceanogr.*, 1991, vol. 36, pp. 807–814.
25. Bazely, D.R. and Jefferies, R.L., Goose faeces: a source of nitrogen for plant growth in a grazed salt marsh, *J. Appl. Ecol.*, 1985, vol. 22, pp. 693–703.
26. Brandvold, D.K., Popp, C.J., and Brierley, J.A., Waterfowl refuge effect on water quality: chemical and physical parameters, *J. Water Pollut. Contr. Fed.*, 1976, vol. 48, pp. 685–687.
27. Chaichana, R., Leah, R., and Moss, B., Birds as eutrophicating agents: a nutrient budget for a small lake in a protected area, *Hydrobiologia*, 2010, vol. 646, pp. 111–121.
28. Gould, D.J. and Fletcher, M.R., Gull droppings and their effects on water quality, *Water Res.*, 1978, vol. 12, pp. 665–672.
29. Hahn, S., Bauer, S., and Klaassen, M., Estimating the contribution of carnivorous water birds to nutrient loading in freshwater habitats, *Freshwater Biol.*, 2007, vol. 52, pp. 2421–2433.
30. Hahn, S., Bauer, S., and Klaassen, M., Quantification of allochthonous nutrient input into freshwater bodies by herbivorous waterbirds, *Freshwater Biol.*, 2008, vol. 53, pp. 181–193.
31. Madsen, J., Kuijken, E., Meire, P., et al., Pink-footed goose *Anser brachyrhynchus*: Svalbard, in *Goose Populations of the Western Palearctic. A Review of Status and Distribution*, Wetlands International Publication, 1999, vol. 48, pp. 82–93.
32. Skrzypek, G., Wojtuń, B., Richter, D., et al., Diversification of nitrogen sources in various tundra vegetation types in the high Arctic, *PLoS One*, 2015, vol. 10, no. 9, pp. 3–21.
33. Sterner, R.W. and Schulz, K.L., Zooplankton nutrition: recent progress and a reality check, *Aquat. Ecol.*, 1998, vol. 32, pp. 261–279.
34. Stolbunov, I.A., Kutuzova, O.R., Krylov, A.V., and Pavlov, D.D., Northward range expansion by great egret *Casmerodius albus* and the impact of a mixed heron-egret colony on fish species in the adjacent waters, *Vogelwelt*, 2017, vol. 137, pp. 124–128.
35. Wiece, G., Mayer, H.-G., Jorda, W., and Bahr, I., Phosphoraufnahme durch *Potamogeton natans* und submerse Makrophyten einem Fliessgewässer Laboratoriums model, *Acta Hydrochim. Hydrobiol.*, 1985, vol. 13, no. 3, pp. 307–317.

Translated by D. Pavlov