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# Quantitative indicators and trophic structure of zooplankton in different types of shallow water zone in Meshinsky Bay (Kuibyshev Reservoir)

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**Abstract.** The trophic structure and quantitative characteristics of zooplankton in four shallow water areas of Meshinsky Bay of Kuibyshev Reservoir were studied in the summer and autumn seasons. The sites differed in their protection from wind and wave impacts, and in intensity of macrophyte overgrowth. The maximum species richness of zooplankters feeding in the water column was observed in open and vegetation-free shallow water and foraging from the surface of the substrate in closed areas, overgrown mainly with one type of submerged plant. The highest quantitative indicators of zooplankton in all areas were observed in summer. Regardless of the season, the maximum abundance and biomass of communities was observed in protected shallow water in thickets of *Potamogeton lucens* L. This is associated with the density of vegetation cover protecting invertebrates from predation by fish.

**Keywords:** Rotifera, Cladocera, Copepoda, Crustacea, macrophytes, littoral zone, overgrown, abundance, biomass, feeding strategy.

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## Introduction

The coastal (littoral) zone is an important biotope, which contributes significantly to basin hydrochemistry and biology. It shows pronounced variability of the qualitative and quantitative characteristics of communities of aquatic organisms, since it is the most affected by water level changes, interactions of air masses, land, water, and basin floor. It is influenced by coupled wave and wind mixing, and its macrophyte thickets. The coastal area differs from the deep-water

parts of the basin in warming up earlier in spring, high absolute water temperatures in summer, early cooling in autumn, freezing of grounds in winter (Butorin, 1984), as well as a higher supply of nutrients from the catchment area (Korneva, 1983; Lavrentieva, 1977). In the littoral zone, special conditions arise for the formation and further development of higher aquatic vegetation, which acts here as the main component of biocenoses and performs a number of important functions (the main producer of primary organic mat-

ter, a refuge and food object for different groups of animals, a substrate for spawning of phytophilous fish, a natural biofilter between the spillway and the reservoir, etc.) (Khaliullina and Yakovlev, 2015). As shallow zones occupy vast areas in some large reservoirs, play a significant role in their biological regime, and are the first to respond to changing environmental factors, their study remains relevant.

The area of overgrown shallow zones of the Kuibyshev Reservoir is 8.5 thousand hectares (Solovieva, 2008). The largest thickets are concentrated in Sviyazhsky, Meshinsky and Cheremshansky bays (Golubeva et al., 1990a, b). Meshinsky Bay, key for the reproduction and feeding of juvenile fish, is located in the northern part of the Volzhsko-Kamsky reach of the reservoir at the confluence of two large rivers, the Volga and Kama rivers (N 55°21'14", E 49°23'59"). It represents a flooded water extension of the Meshsha River and its floodplain estuaries, is characterized by a slightly indented coastline and experiences intense wave impact. The bay has a large number of shallow waters and islands, which serve not only as a favorite spawning ground for phytophilous fish species, but also as a feeding ground for their juveniles (Gvozdareva, 2018). On average, about 40% of the total fish population of the reservoir spawn in the coastal part of this section of the reservoir. According to the results of studies carried out in 2012–2017, the species composition of fish larvae is represented by mass species of plant-feeders, many of which are also the main objects of fishing (Severov et al., 2018).

It is known that zooplankton is one of the most important food elements for juvenile fish (Gutelmakher, 1986; Kiselev, 1969; Krylov, 2006; Popov and Mukhortova, 2016). Numerous studies of phyto- and zooplankton indicate that their abundance and diversity is higher in the coastal biotopes protected from wind and waves, which is most noticeable in the thickets of macrophytes (Mordukhai-Boltovskoy, 1974, 1976; Zarubina and Ermolaeva, 2014; Zimbalovskaya, 1981). Overgrown areas have distinct light, temperature, hydrochemical, hydrodynamic, and trophic conditions (Semenchenko et al., 2013), while the vegetation serves as an additional source of organics (Mordukhai-Boltovskoy, 1976).

Observations of the development of zooplankton in the Kuibyshev Reservoir have been carried out since the moment of its filling. Many works have been published on comprehensive studies of the formation and dynamics of zooplankton communities in the conditions of the regulated runoff of the Volga River (Chernysheva and Sokolova, 1960, 1964; Kuibyshevskoe vodokhranilische, 1983; Lazareva et al., 2018; Romanova, 2010; etc.). Several publications consider the trophic structure and spatial distribution of zooplankton in shallow areas of the Volga-Kama Reach in the region of the Saralinsky section of the Volga-Kama Nature

Biosphere Reserve (Borisovich, 2005; Borisovich and Yakovlev, 2011). For the water area of Meshinsky Bay, species composition and indicators of the quantitative development of zooplankton were studied (Gvozdareva, 2014). However, studies of the trophic structure of zooplankton in shallow-water areas, which differ in the extent of overgrowth with macrophytes and protection from wind and wave impact, have not previously been conducted; hence, this topic is relevant.

The purpose of this paper is to describe the trophic structure and quantitative characteristics of zooplankton in different stages of the growing season in the different types of littoral zone of Meshinsky Bay of the Volga-Kama Reach of the Kuibyshev Reservoir.

## Materials and methods

The material was collected at six stations in 2017 in July (during the period of maximum growth of higher aquatic vegetation) and in October (at the beginning of processes of plant death and decomposition). The studied areas were divided into four categories according to the level of protection from wind and wave impact, as well as the degree of overgrowth with macrophytes: I – open areas devoid of vegetation (Stations 2 and 5); II – protected area, overgrown mainly with one type of aerial-aquatic plants (Station 1); III – a protected area, overgrown mainly with one kind of submerged plant with leaves floating on the surface of the water (Station 4); IV – protected areas overgrown with air-water and submerged higher plants (Stations 3 and 6) (Table 1).

Integral samples of zooplankton were collected from the border of vegetation with open water deep into the thickets every 0.5–0.8 m, filtering 50 liters of water through a plankton net (mesh size 96 µm). The fixation and office processing of the samples were carried out using conventional methods (Metodicheskie rekomendatsii..., 1982). Zooplankton was assessed by species richness, Shannon Species Diversity Index, abundance, biomass, and the ratio of taxonomic and trophic groups of planktonic invertebrates. The Shannon Species Diversity Index was calculated from the abundance, excluding Copepoda nauplii and copepodites (Shitikov et al., 2003). Trophic groups of aquatic invertebrates were identified according to the modes of movement and food capture (Chuikov, 1981a, b, 2018; Krylov, 2005).

## Results

The species composition of zooplankton in Meshinsky Bay, Kuibyshev Reservoir during the study period was represented by 66 species (Rotifera – 36, Cladocera – 20, Copepoda – 10), of which three are immigrants of the Ponto-Caspian assemblage (*Heterocope caspia* Sars, 1897, *Cornigerius maeoticus* (Pengo, 1879), *Eurytemora caspia* Sukhikh et Alekseev, 2013) and 1 – Boreal-Arctic (*E. lacustris* (Poppe, 1887)).

**Table 1.** Characteristics of the studied areas of the littoral zone of Meshinsky Bay of the Kuibyshev Reservoir.

Type	Station	Species of macrophytes
I	2	No thickets
	5	No thickets
II	1	Common reed – <i>Phragmites australis</i> (Cav.) Trin. ex Steud
III	4	Shining pondweed – <i>Potamogeton lucens</i> L., bordered by lesser bulrush – <i>Typha angustifolia</i> L.
IV	3	Common reed, lesser bulrush, flowering rush – <i>Butomus umbellatus</i> L., bladderwort – <i>Utricularia vulgaris</i> L., shining pondweed, sago pondweed – <i>Potamogeton pectinatus</i> L., various-leaved pondweed – <i>Potamogeton gramineus</i> L., clasping pond Weed – <i>Potamogeton perfoliatus</i> L., hornwort – <i>Ceratophyllum demersum</i> L., cladophoran – <i>Cladophora</i> sp.
	6	Variegated reed sweet-grass – <i>Glyceria maxima</i> (Hartm.) Holmb., flowering rush, spike rush – <i>Eleocharis palustris</i> (L.) R. Br., shining pondweed, sago pondweed, various-leaved pondweed, lesser bulrush

Among Rotifera, two ecological groups are most diverse in the studied shallow waters: verticators that forage from the substrate surface (12 species) and in the water column (10) – representatives of the families Brachionidae and Synchaetidae. Of Cladocera, the largest number of species was recorded among swimming primary filter feeders (nine species from the families Bosminidae and Daphniidae) and creeping-swimming secondary filter feeders (seven species from the family Chydoridae). Among Copepoda, swimming predators (three species of the subfamily Cyclopinae) showed the highest species richness. At all stations studied, immature Copepoda specimens with a mixed type of feeding and movement were found.

In summer, 53 species were found in the zooplankton of the studied shallow waters: Rotifera – 25, Cladocera – 19, Copepoda – 9. The largest number of species was recorded in shallow waters of type IV – 27; in the area of type II, 26 species were recorded, in shallow waters of types I and III – 24 species each. In areas of types I and II, the basis of the species composition was Rotifera (53 and 50%, respectively), and in the areas of III and IV types – Cladocera (46 and 44%).

The largest proportion of invertebrate species foraging in the water column (62%) is recorded in type I shallow water; the same ecological group accounted for more than half of the species composition in areas of types II and IV (58 and 54%, respectively). Among Rotifera, verticators predominated (representatives of the families Synchaetidae, Brachionidae, Filiniidae, Conochilidae, Dicranophoridae); their largest proportion was noted in the shallow waters of types I (30%) and II (25%). Swimming predators (family Asplanchnidae) were recorded in areas of types I, II, and IV (< 4%). In all studied

plots, of Cladocera, the leading position (21%) was occupied by floating primary filter feeders (representatives of the families Bosminidae, Daphniidae). Swimming active predators (family Polyphemidae) were found only in areas of types III and IV (4 and 2%, respectively). The proportion of Copepoda species foraging in the water column and from the substrate surface was, on average, the same everywhere ( $7 \pm 3\%$ ), however, the largest proportion of predators feeding in the water column (family Temoridae and subfamily Cyclopinae) was observed on the site Type IV (11%).

Zooplankters using food from the substrate surface prevailed in the protected area overgrown with shining pondweed (type III) (54%), their smallest proportion (38%) was observed in open shallow water (type I), and in areas II and IV – of these types, their proportion was no more than 46%. Rotifers-verticators associated with the substrate (representatives of the families Brachionidae, Euchlanidae, Testudinellidae) were represented in equal proportions (17% each) in protected areas (types II–IV), fewer in open shallow water (13%). A small (< 6%) number of zooplankter species foraging from the substrate surface from the families Notommatidae and Trichocercidae were found in areas of types I–III. Among cladocerans, secondary filter feeders from the family prevailed. Chydoridae, and their largest proportion (17%) was observed in a type IV closed area. The proportion of species from the number of primary filter feeders (representatives of the families Daphniidae and Sididae) is not high; it reached its maximum value (8%) in closed shallow waters in thickets of pondweed (type IV). Substrate-related copepods were maximally (12%) represented in shallow waters of

type III and included active predators (subfamily Cyclopinae) and scavengers (subfamily Eucyclopinae).

In summer, the average number of zooplankton in the studied areas was  $29.5 \pm 17.1$  thousand ind./m<sup>3</sup>, and the biomass was  $680.9 \pm 439.4$  mg/m<sup>3</sup>. The highest values were typical for the site of type III, the smallest for type IV (Fig. 1). In all types of shallow waters, the Cladocera contributed the most to abundance and biomass ( $55.0 \pm 8.0\%$  and  $71.0 \pm 12.0\%$ , respectively), the contribution of Rotifera and Copepoda was lower ( $22.0 \pm 4.0\%$  and  $8.0 \pm 5.0\%$  in abundance,  $23.0 \pm 6.0\%$  and  $21.0 \pm 9.0\%$  by biomass) (Fig. 1).

The maximum proportion of rotifers in terms of total abundance was noted in type I and II shallow waters, in the total biomass, only in type I of shallow waters. Cladocerans accounted for the largest proportion of the total abundance in closed shallow waters overgrown with one type of submerged plant, and in the total biomass – in an area overgrown with one type of aerial-aquatic plant. The proportion of copepods in the total abundance and biomass of zooplankton reached maximum values in closed shallow waters overgrown with air-aquatic and submerged plants.

The maximum values of the Shannon Index were recorded in the shallow water of type IV (4.06 bits/specimen), and the minimum values – of type III (1.82 bit/specimen), while in the areas of types I and II – 3.28 and 3.66 bit/specimen.

Apart from differences in species composition, differences in the trophic structure of zooplankton were also identified. Thus, non-growing open shallow waters (type I) were characterized by the maximum density of primary filter feeders due to the dominance of *Daphnia cucullata* (Sars, 1862), *Bosmina* (*Bosmina*) *longirostris* (O.F. Müller, 1785), and *B.* (*Eubosmina*) *coregoni* (Baird, 1857), as well as verticators (*Keratella quadrata* (Müller, 1786)), foraging in the water column (Table 2).

In a site of type II, the proportion of verticators associated with the substrate was higher due to *Brachionus calyciflorus* (Pallas, 1766). In the closed shallow water (type III) overgrown with pondweed, due to the dominance of *Sida crystallina* (O.F. Müller, 1776), the maximum number and proportion of planktonic invertebrates foraging from the substrate surface was recorded. At the same time, this type of coastal area was characterized by the largest number of verticators and predatory Cladocera feeding in the water column, as well as creeping-swimming verticators associated with the substrate. At the site of type IV, the maximum number and proportion of copepods foraging in the water column were found (due to the dominance of *E. lacustris*, *Acanthocyclops vernalis* (Fisher, 1853)) and on the substrate (due to the dominance of *Mesocyclops leuckarti* (Claus, 1857)). In the same type of shallow water, in contrast to others, the largest proportion of juvenile crustaceans was recorded. In general, in the site of

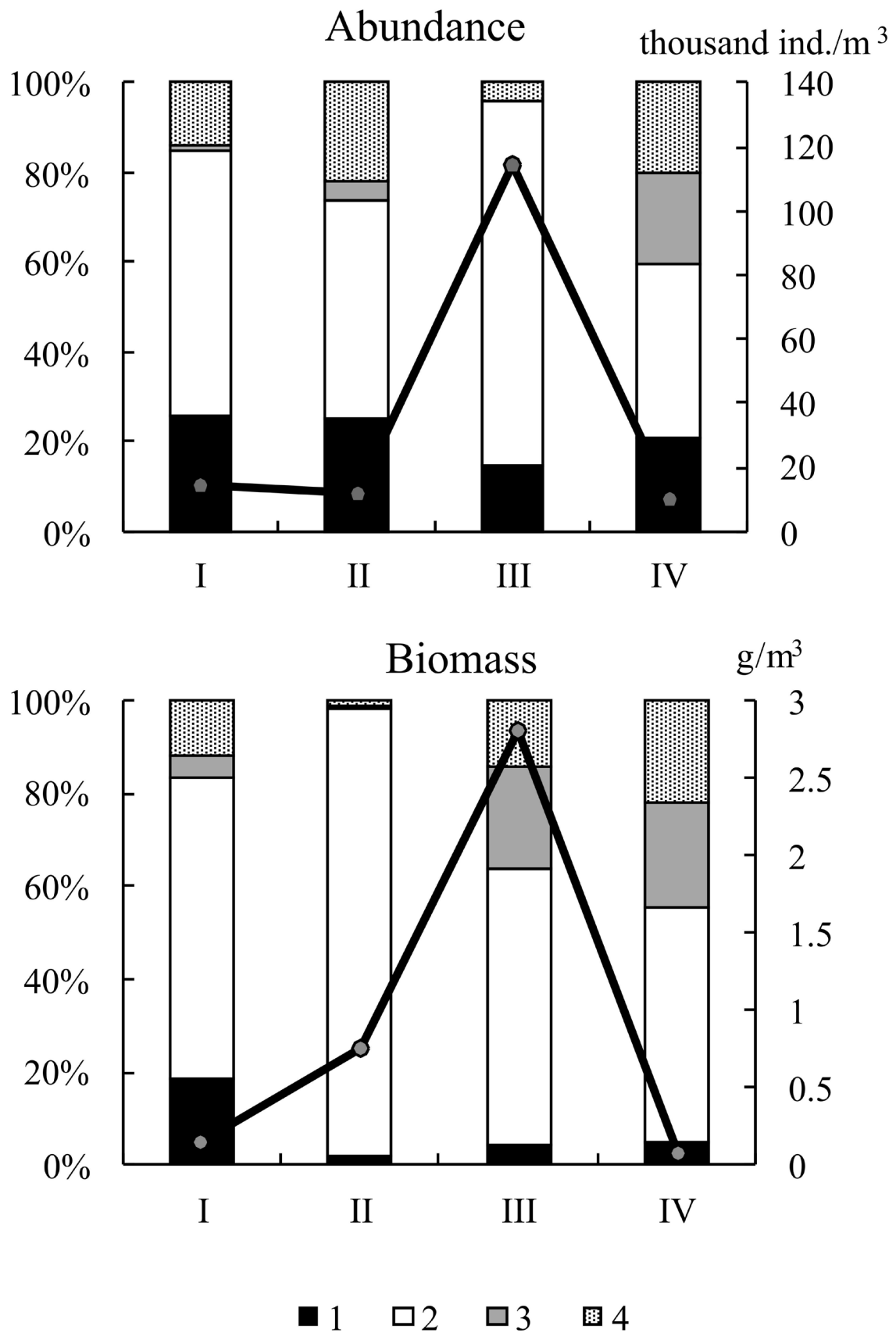
type I, floating non-predatory invertebrates prevailed, in areas of type II and III, filter feeders and verticators associated with the substrate, in the site of type IV, the proportion of all groups was approximately the same.

In autumn, the number of detected zooplankton species decreased to 40, among which Rotifera – 26, Cladocera – 8, and Copepoda – 6. Semi-isolated shallow waters of types II and III differed in the largest number of species – 20 each, 14 species were recorded in the area of type IV, and in the open shallow water without vegetation (type I), their minimum number was observed – 7. At all the studied stations, the basis of the species composition of zooplankton was formed by rotifers (71%), with the maximum proportion in the areas of I (79%) and IV (77%) types. The largest proportion of Cladocera and copepod species was found in shallow waters of types II (21 and 11%, respectively) and III (25 and 15%).

In the open shallow water (type I) devoid of thickets, the highest proportion of species foraging in the water column (57%) was noted at the expense of verticators (representatives of the families Synchaetidae and Brachionidae) (43%), as well as predators (families Synchaetidae and *Heterocope* spp.) (14%). Primary filter feeders among cladocerans (family Bosminidae) were only recorded in shallow waters of types III and IV (5 and 3%, respectively), where inactive predators (*Eurytemora* spp.) were also present (10 and 6%).

Zooplankton species that forage from the surface of the substrate are best represented in protected shallow waters of types II–IV (64, 65, and 68%), and their lowest proportion (43%) is in shallow waters of type I. At the same time, in areas of types III and IV, the largest proportion of species belonged to verticators (representatives of the families Brachionidae, Euchlanidae, Testudinellidae, and Trichotriidae) (25 and 37%, respectively). The composition of Cladocera in all types of shallow water was formed by secondary (family Chydoridae) and primary (families Daphniidae and Sididae) filter feeders, extracting food from the substrate surface. However, in closed shallow waters, overgrown mainly with one species of aquatic plants (types II and III), the proportion of these species was higher (21 and 20%) than in shallow waters of types I and IV (14 and 11%). Among the copepods in the shallow waters of the II and III types, the species of subfamily differed the subfamily Eucyclopinae – scavengers-omnivores associated with the substrate (11 and 5%), and in plots of type IV – active predators from subfamily Cyclopinae (3%).

The mean number of autumn zooplankton in the studied areas was  $7.2 \pm 2.6$  thousand ind./m<sup>3</sup>, and the biomass was  $22.7 \pm 10.9$  mg/m<sup>3</sup>. The highest values were typical for the site of type III, the lowest for types I and IV of shallow waters (Fig. 2). The bulk of the abundance was formed by Rotifera ( $43.9 \pm 8.5\%$ ) and Copepoda ( $41.6 \pm 9.9\%$ ); the proportion of Cla-



**Fig. 1.** Quantitative indicators and the proportion of taxonomic groups of zooplankton in Meshinsky Bay in different types of shallow water areas in July 2017: 1 – Rotifera, 2 – Cladocera, 3 – adult Copepoda, 4 – juvenile Copepoda. Roman numerals indicate the types of shallow waters (see text).

**Table 2.** Abundance of ecological groups of invertebrates and their share in the total abundance of zooplankton in the summer of 2017: 1a – swimming/vertical; 1b – swimming/primary filtration; 2a – swimming/gripping and suction; 2b – swimming/filtration and grasping; 3b – swimming/active grip; 4a – swimming and crawling/vertical; 5a – crawling and swimming/sucking; 5b – crawling and swimming/secondary filtration; 6b – swimming and crawling/picking up; 7 – crawling and swimming/active grip; 8 – swimming and attachment to the substrate/primary filtration; 10 – mixed by types of food and movement. Roman numerals indicate the types of shallow waters (see text).

Motion method	Ecological group	Taxon	Abundance, ind./m <sup>3</sup>				Proportion of total population, %			
			I	II	III	IV	I	II	III	IV
Swimming	1a	Rotifera	2050	575	6100	425	15.8	5.0	5.3	4.1
	1b	Cladocera	5775	2625	27300	2270	38.2	22.7	23.7	21.7
	2a	Rotifera	187.5	225	0	12.5	1.5	1.9	0.0	0.1
	2b	Copepoda	37.5	50	75	256.5	0.3	0.4	0.1	2.5
	3a	Cladocera	0	50	425	25	0.0	0.4	0.4	0.2
	3b	Copepoda	12.5	50	150	187.5	0.1	0.4	0.1	1.8
	<b>Total</b>		<b>8063</b>	<b>3575</b>	<b>34050</b>	<b>3177</b>	<b>55.9</b>	<b>30.9</b>	<b>29.6</b>	<b>30.4</b>
Sessile	4a	Rotifera	850	1850	10600	1056.5	6.8	16.0	9.2	10.2
	5a	Rotifera	175	25	125	0	1.3	0.2	0.1	0.0
	5b	Cladocera	750	550	325	657	5.1	4.8	0.3	6.4
	6b	Copepoda	37.5	375	50	25	0.3	3.2	0.0	0.2
	7	Copepoda	0	0	125	300.5	0.0	0.0	0.1	2.9
	8	Cladocera	2775	2100	64575	607	15.3	18.1	56.2	5.9
	<b>Total</b>		<b>4588</b>	<b>4900</b>	<b>75800</b>	<b>2646</b>	<b>28.8</b>	<b>42.3</b>	<b>65.9</b>	<b>25.5</b>
Mixed	10	Copepoda	2038	2525	3725	3482	14.2	2.1.8	3.2	33.4

docera was minimal ( $14.6 \pm 3.9\%$ ). The largest contribution to the total biomass was made by Copepoda ( $54.0 \pm 6.0\%$ ), the proportion of Rotifera was  $23.3 \pm 8.1\%$ , Cladocera –  $18.7 \pm 5.5\%$ . The maximum proportion of rotifers in the total abundance and biomass of zooplankton was recorded in closed shallow water overgrown with reeds (type II), cladocerans – in a closed area overgrown with pondweed (type III), copepods – in an open, not overgrown area and in closed shallow water with a complex of air – aquatic and submerged higher plants (types I and IV).

The highest index of species diversity was recorded in the site of type IV (2.92 bits/specimen), the lowest – in the area of type III (2.03 bit/specimen), and in the areas of types I and II, it was almost the same (2.38 and 2.40 bit/ specimen respectively).

The zooplankton of the coastal areas of types I (with the dominance of *Keratella quadrata* and *Kellicottia longispina* (Kellicott, 1879)) and II (with the dominance of *Polyarthra vulgaris* (Carlin, 1943) and *P. major* Skorikov, 1896) types was characterized by the maximum proportion of floating invertebrates due to verticators, the largest number of which was recorded in shallow waters of type II (Table 3).

In shallow waters of types II–IV, the proportion of invertebrates associated with the substrate was more than 50% of the total number of zooplankton. In plots of types II and III, due to the dominance of *Euchlanis dilatata* (Ehrenberg, 1832), the largest number and proportion of the total number of verticators associated with the substrate was noted. At the same time, in areas of types III and IV, due to the dominance of *Chydorus sphaericus* (Müller, 1776) and *Disparalona rostrata* (Koch, 1841), secondary filter feeders, extracting food from the substrate surface, made a significant contribution to the total number. Type III shallow water was characterized by the maximum abundance and proportion of primary filter feeders associated with the substrate (*Sida crystallina*), as well as the highest abundance of juvenile Copepoda. The zooplankton of the type IV site differed from other shallow waters in the highest abundance and highest proportion of the total abundance of rotifers associated with the substrate, due to the dominance of *Trichocerca pusilla* (Lauterborn, 1898) (absorption feeding type) and the rotifer *Lecane* spp. (vertical and suction feeding).

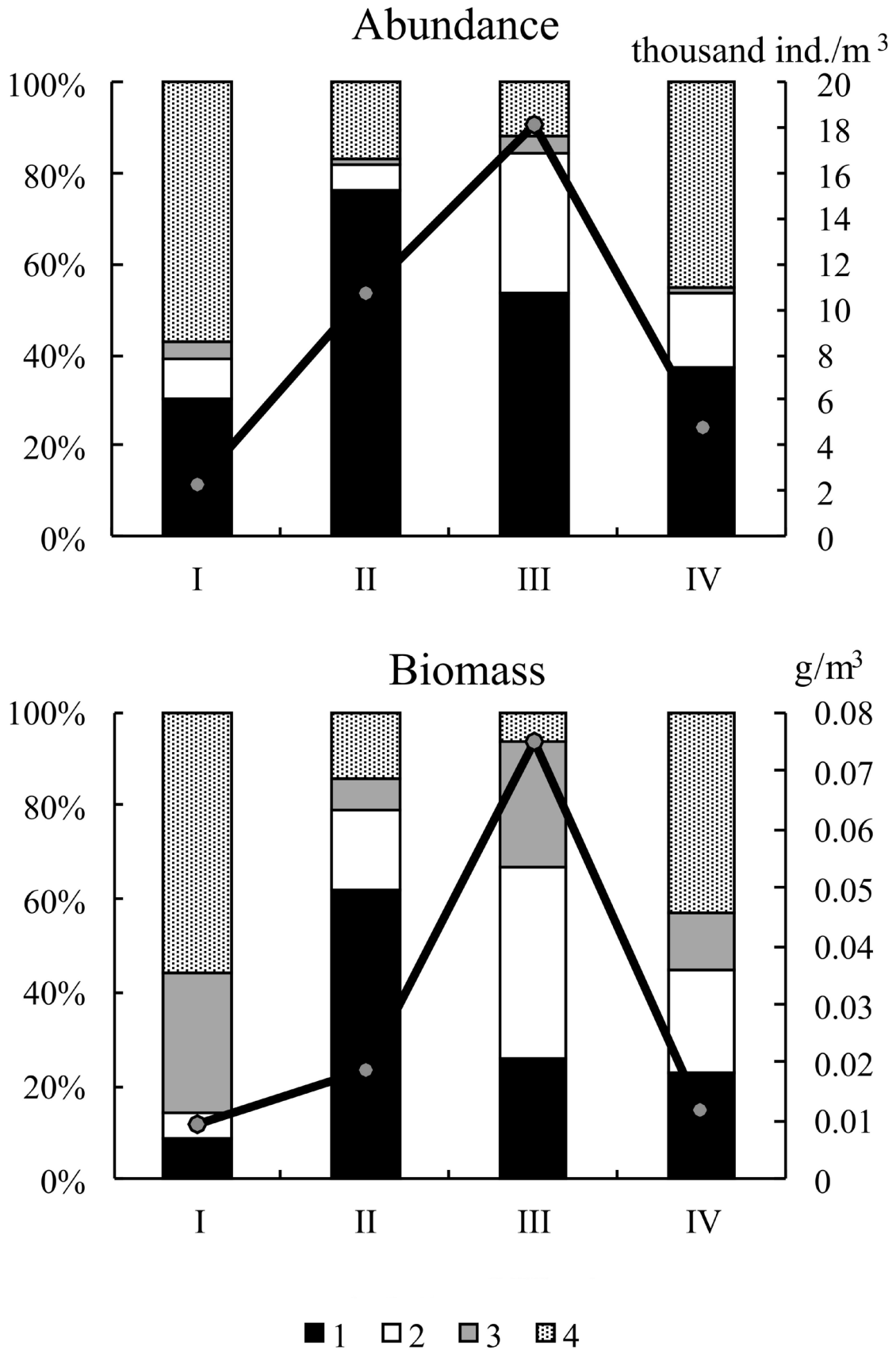
## Discussion

Most studies indicate that the species richness, abundance and biomass of planktonic invertebrates is higher in overgrown and protected shallow waters of water bodies and streams than in open areas lacking macrophytes (Ermolaeva et al., 2016; Mordukhai-Boltovskoy, 1976; Stolbunova, 1976; Stolbunova and Stolbunov, 2010). Thickets of macrophytes contribute to the development of zooplankton, creating shelters and protecting them from planktivorous fish and large

invertebrate predators. At the same time, dense thickets change the dynamics of waters, reducing the flow velocity and hindering the development of wind waves (Brekhovskikh et al., 2008; Dembowska and Napiórkowski, 2015; Janse et al., 1998; Lucena-Moya and Duggan, 2011). In addition, favorable conditions for the development of phytoplankton are formed in shallow waters sheltered from the wind and warmed up (Chernysheva and Sokolova, 1960; Khaliullina and Yakovlev, 2015), which forms the basis of invertebrate nutrition.

However, under certain conditions, aquatic vegetation can develop excessively. F.D. Mordukhai-Boltovskoy (1976) noted a decrease in the abundance of zooplankton and juvenile fish in thickets of air-aquatic vegetation, and in dense thickets, juvenile fish may be absent altogether. As the thickets develop (increase in density, height above the bottom, etc.), the feeding conditions for planktivorous fish deteriorate due to a decrease in the availability of food. In dense thickets of macrophytes, invertebrates are more successful in seeking refuge in case of danger, while it is more difficult for fish to find them due to reduced visibility and more difficult to catch due to the constraint of maneuvering in a confined space among thickets (Gerasimov, 2007). Obviously, for this reason, the highest quantitative indicators of zooplankton both in July and October were recorded in a protected area, densely overgrown mainly with one species of submerged higher aquatic plant with leaves floating on the surface (type III).

At the same time, the zooplankton of the most similar shallow-water area, overgrown with a complex of air-aquatic and submerged plants (type IV), in summer was characterized by the minimum abundance and biomass. It is known that in sparse thickets of macrophytes, zooplankton is more accessible to fry than in dense thickets (Cherevichko, 2007). One-time fishing with a gas drag (6 m), which was carried out in July, showed that the average number of specimens per drag sample, recalculated to 30 m, in the type IV site was 2900, type II was 304. It is known that grazing by fish leads to a decrease in the number and biomass of zooplankton, primarily due to Cladocera (Brooks and Dodson, 1965; Gilyarov, 1987; Hrbaček, 1962; Sadchikov, 2007; Stenson et al., 1978). Obviously, therefore, in shallow waters of type IV, where a high density of juvenile fish was found, the minimum abundance and biomass of summer zooplankton, in particular Cladocera, were noted. At the same time, the highest abundance and biomass of Copepoda were observed here, which are characterized by greater mobility and the ability to avoid predators. In addition, the grazing of zooplankters is evidenced by the minimum average individual weight of organisms in the type IV site, where it was 0.011 mg, while in the type II site, it was 0.065 mg. The maximum value of the



**Fig. 2.** Quantitative indicators and contribution of the proportion of the main zooplankton groups of Meshinsky Bay in different types of shallow water areas in October 2017: 1 – Rotifera, 2 – Cladocera, 3 – adult Copepoda, 4 – juvenile Copepoda. Roman numerals indicate the types of shallow waters (see text).

**Table 3.** Abundance of ecological groups of invertebrates and their share in the total abundance of zooplankton in autumn 2017. a – swimming/vertical; 1b – swimming/primary filtration; 2a – swimming/gripping and suction; 2b – swimming/filtration and grasping; 2c – swimming/filtration and active grip; 3b – swimming/active grip; 4a – swimming and crawling/vertical; 5a – crawling and swimming/sucking; 5b – crawling and swimming/secondary filtration; 6b – swimming and crawling/picking up; 7 – crawling and swimming/active grip; 8 – swimming and attachment to the substrate/primary filtration; 10 – mixed by types of food and movement. Roman numerals indicate the types of shallow waters (see text).

Motion method	Ecological group	Taxon	Abundance, ind./m <sup>3</sup>				Proportion of total population, %			
			I	II	III	IV	I	II	III	IV
Swimming	1a	Rotifera	545	2925	725	322.5	25.9	27.1	3.9	6.5
	1b	Cladocera	0	0	25	37.5	0	0	0.1	0.6
	2a	Rotifera	0	0	50	0	0	0	0.28	0
	2b	Copepoda	0	0	575	75	0	0	3.2	1.2
	2c	Copepoda	112.5	0	0	0	4.2	0	0	0
	3a	Rotifera	10	0	0	0	0.7	0	0	0
	<b>Total</b>		<b>667.5</b>	<b>2925.0</b>	<b>1375.0</b>	<b>435.0</b>	<b>30.6</b>	<b>22.2</b>	<b>7.6</b>	<b>8.4</b>
Sessile	4a	Rotifera	57.5	5100	8700	1195	2.8	47.3	47.9	23.1
	4b	Rotifera	0	75	50	147.5	0	0.7	0.3	2.6
	5a	Rotifera	0	50	200	240	0	0.5	1.1	4.8
	5b	Cladocera	202.5	525	5000	757.5	8.8	4.9	27.6	15.8
	5b	Copepoda	0	50	150	0	0	0.5	0.8	0
	6b	Copepoda	0	25	0	0	0	0.2	0	0
	7	Copepoda	0	0	0	12.5	0	0	0	0.2
	8	Cladocera	0	125	500	0	0	1.2	2.8	0
	<b>Total</b>	<b>260</b>	<b>5950.0</b>	<b>14600.0</b>	<b>2352.5</b>	<b>11.6</b>	<b>55.2</b>	<b>80.4</b>	<b>46.5</b>	
Mixed	10	Copepoda	1117.5	1875.0	2150.0	1625.0	56.9	17.4	11.9	45.1

Shannon Index for zooplankton observed in shallow waters with a high fish density can also be associated with grazing. The point is that fish choose the most visible and/or numerous food items (Murdoch, 1969; Murdoch et al., 1975). Due to their grazing, the degree of dominance of one species decreases, as a result of which the value of the Shannon Index increases (Krylov et al., 2016).

Open shallow water devoid of vegetation (type I) was characterized by the minimum quantitative indicators of planktonic invertebrates only at the end of the growing season. However, in July, the abundance of zooplankton in this type of coastal area was practically at the same level as in areas of type II and IV, and the biomass exceeded the values recorded in shallow waters of type IV. Apparently, this was due to the high water temperature and minimal pressure on the part of juvenile fish, avoiding open areas of shallow waters to protect them from wind, waves and predators.

The trophic structure of zooplankton changed quite naturally. First, in autumn, due to the previous accumulation of detritus on the substrate during the growing season, the proportion of swimming-crawling and creeping-swimming invertebrates in the zooplankton of all studied shallow water areas increased. Secondly, open areas without thickets showed the maximum proportion of swimming organisms, and areas overgrown with macrophytes were dominated by those associated with the substrate. At the same time, in connection with the greatest protection from wave and wind effects, as well as control by predators, among the floating and substrate-associated organisms, the maximum proportion in the summer season was represented by cladocerans.

## Conclusions

The species composition of zooplankton in Meshinsky Bay of the Kuibyshev Reservoir during the study period was represented by 66 species (Rotifera – 36, Cladocera – 20, Copepoda – 10). In summer, at 6 studied stations, 53 species were recorded, the average number of which was  $29.5 \pm 17.1$  thousand ind./m<sup>3</sup> and biomass –  $680.9 \pm 439.4$  mg/m<sup>3</sup>, in autumn – 40 species with a population of  $7.2 \pm 2.6$  thousand ind./m<sup>3</sup> and biomass  $22.7 \pm 10.9$  mg/m<sup>3</sup>.

In summer and autumn, planktonic invertebrates that forage from the water column are most represented in open shallow water areas devoid of vegetation, and those foraging from the surface of the substrate – in closed shallow waters overgrown with either submerged or air-water and submerged higher aquatic plants.

Closed shallow waters, overgrown mainly with one species of plants from the group of submerged leaves with floating leaves on the water surface, were

characterized in both seasons by the highest quantitative indices of zooplankton. Open shallow waters devoid of vegetation were characterized by the minimum values of abundance and biomass only in October. In summer, the lowest quantitative indicators of the development of planktonic invertebrates were recorded in an area with a high species diversity of higher aquatic plants.

A significant role in the formation of quantitative indicators and structure of zooplankton is played by control from above. Closed areas where aerial-aquatic plants grew (separately or in combination with submerged ones), on average, were characterized by low numbers and biomass of zooplankton. A number of structural and quantitative indicators of the community indicate that this is due to strong pressure from juvenile fish. The protected shallow area, overgrown with dense thickets of one submerged aquatic plant species with leaves floating on the surface, was characterized by the highest quantitative indices of zooplankton. This may be due to the density of the vegetation cover, which prevents the penetration of fish and their juveniles.

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