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Article

The state of benthic and planktonic invasive species in adjacent to St. Petersburg waters of the Gulf of Finland in 2018 as against the data for 2014

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Abstract. In 2018, a total of 45–57 zooplankton and 23–81 benthos taxa, as well as 0–6 alien zooplankton and 3–7 invasive zoobenthos species were found in different parts of the water area of the Gulf of Finland adjacent to St. Petersburg. From 2014 to 2018, aboriginal zooplankton and zoobenthos communities in the studied area remained relatively unchanged, while the populations of invasive species changed significantly. The range of some alien planktonic species extended to the east, i.e. to the Neva Bay, which could be due to their transfer from the adjacent areas of the Gulf of Finland. As compared to 2014, in 2018, a smaller number of invasive species in zoobenthos (only 10 species versus 14), as well as a significant reduction in the range or abundance of some invasive benthic species were recorded.

Keywords: Neva Bay, Kurortny District, invasive species, zoobenthos, zooplankton, spatial distribution, dynamics, monitoring

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Научная статья

Распространение видов-вселенцев в планктонных и донных сообществах Финского залива на акватории, прилегающей к г. Санкт-Петербург, в 2018 г. и сравнение с аналогичными данными за 2014 г.

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Аннотация. В ходе мониторинга водных сообществ акватории Финского залива, прилегающей к г. Санкт-Петербург, в 2018 году на разных участках было обнаружено от 45 до 57 таксонов зоопланктона и от 23 до 81 таксонов бентоса, в том числе от 0 до 6 чужеродных видов зоопланктона и от 3 до 7 чужеродных видов зообентоса. Проведенные исследования показали, что за период с 2014 по 2018 гг. исходные сообщества зоопланктона и зообентоса на исследованной акватории сохранили относительную стабильность, в то время как состояние популяций видов-вселенцев существенно изменилось. Ареал отдельных планктонных чужеродных видов расширился на восток – на акваторию Невской губы, что могло быть связано с их заносом из Финского залива. Число чужеродных видов в зообентосе в 2018 г. снизилось и составило 10 видов (в 2014 г. – 14 видов).

Для некоторых чужеродных видов донных беспозвоночных установлено существенное сокращение ареала или обилия по сравнению с 2014 г.

Ключевые слова: Невская губа, Курортный район, чужеродные виды, зоопланктон, зообентос. состояние, распределение, динамика, мониторинг

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Introduction

Invasion of new species of animals and plants into aboriginal communities as a result of human activity is often referred to as “biological pollution”. The Gulf of Finland is considered to be one of the main “hot spots” at the Baltic Sea in terms of the level and risk of “biological pollution” (Alimov et al., 2000). The eastern area of the Gulf of Finland is a part of the northern European invasion corridor, through which new species enter the Baltic Sea (Panov et al., 2007). Transcontinental water transport routes from the basins of the White, Black and Caspian Seas, as well as transoceanic corridors from the Far East, South Asia, Australia, North and South America are located here. In the future, navigation intensification in the region caused by the ports’ construction in the eastern part of the Gulf of Finland and growth of international shipping via St. Petersburg will sharply increase the risk of alien species introduction (Alimov et al., 2000).

This paper presents the results of monitoring of alien species of zooplankton and zoobenthos in the eastern part of the Gulf of Finland in 2018. The aim of this work is to study the population dynamics of alien zooplankton and zoobenthos species, including the corresponding recipient communities, to assess the impact of invading species on the native fauna, and to continue the search for alien zooplankton and zoobenthos species in the Neva Bay and in the adjacent to St. Petersburg water areas of the Gulf of Finland.

The status of invading species populations and recipient communities in the eastern part of the Gulf of Finland in 2004–2014

The monitoring of invading species and recipient communities in the eastern part of the Gulf of Finland has been carried out since 2004, with most of the data obtained in 2007–2008 and in 2014 (Orlova, 2017). In 2018, several parts of the Gulf of Finland near St Petersburg, significantly differed in hydrological regime, were surveyed: the littoral zone of the Neva Bay, the open part of the Neva Bay, the littoral zone of the Kurortny District, the shallow-water part of the Kurortny District and the deep-water part of the Kurortny District (Fig. 1).

Zooplankton

In the Neva River estuary, zooplankton is mainly represented by the organisms brought here by the Neva River and other watercourses. In the apical part of the estuary, freshwater and euryhaline species, less often brackish-water ones prevail in zooplankton. Among them, phytophilic taxa are numerous, especially in the littoral zone, small reservoirs, streams and ponds of the coastal area. Due to shallow depths, relatively high water temperature and low water exchange rates, zooplankton taxonomic diversity is the highest in the upper freshwater part of the Neva estuary (Neva Bay). The fauna of coastal macrophyte thickets is particularly rich and diverse (Telesh et al., 2008).

In the open part of the Neva Bay in the last few decades, the average summer zooplankton biomass ranged from 0.02 to 0.7 g/m³, in the thicket zone – from 1 to 3 g/m³. In the areas where zooplankton experienced a longstanding strong technogenic pressure, its abundance varied during the vegetation period from 0.1 to 16 thous. ind./m³ and biomass – from 0.003 to 0.212 g/m³. In the years of intensive hydraulic engineering works, these values dropped to 1–2 thous. ind./m³ and 0.012–0.018 g/m³. When the engineering work intensity decreased, they increased to 7–11 thous. ind./m³ and 0.082–0.091 g/m³, respectively. According to the data for 2007–2013, the average zooplankton density during the vegetation period made up 5.34 thous. ind./m³, and the biomass – 0.054 g/m³ (Vypolnenie rabot..., 2018). In the 1990s, zooplankton biomass in the Neva Bay ranged as 0.02–1.65 g/m³ (Telesh et al., 2008). In 2015–2018, zooplankton abundance in the open part of the Neva Bay varied from 7 to 142 thous. ind./m³, averaging 33 thous. ind./m³, and biomass – up to 0.4 g/m³, averaging 0.3 g/m³ (Zhigulsky et al., 2020). As a rule, alien species were not registered in the zooplankton of the Neva Bay (Monitoring..., 2008; Okazanie uslug..., 2014).

In the Kurortny District, zooplankton is represented by euplankton species from freshwater, brackish-water and marine complexes. The freshwater complex includes the same species found in the open part of the Neva Bay. The brackish-water and marine complexes are represented *by Eurytemora affinis* (Poppe, 1880), *Limnocalanus macrurus macrurus* G.O. Sars, 1863, *Microsetella norvegica* (Boeck, 1865), species from the genera *Acartia* Dana, 1846, *Podon* Lilljeborg, 1853, and *Evadne nordmanni* Lovén, 1836, *Cercopagis pengoi*, *Keratella quadrata* (Müller, 1786), *Synchaeta baltica* Ehrenberg, 1834, *S. monopus* Plate, 1889, etc.

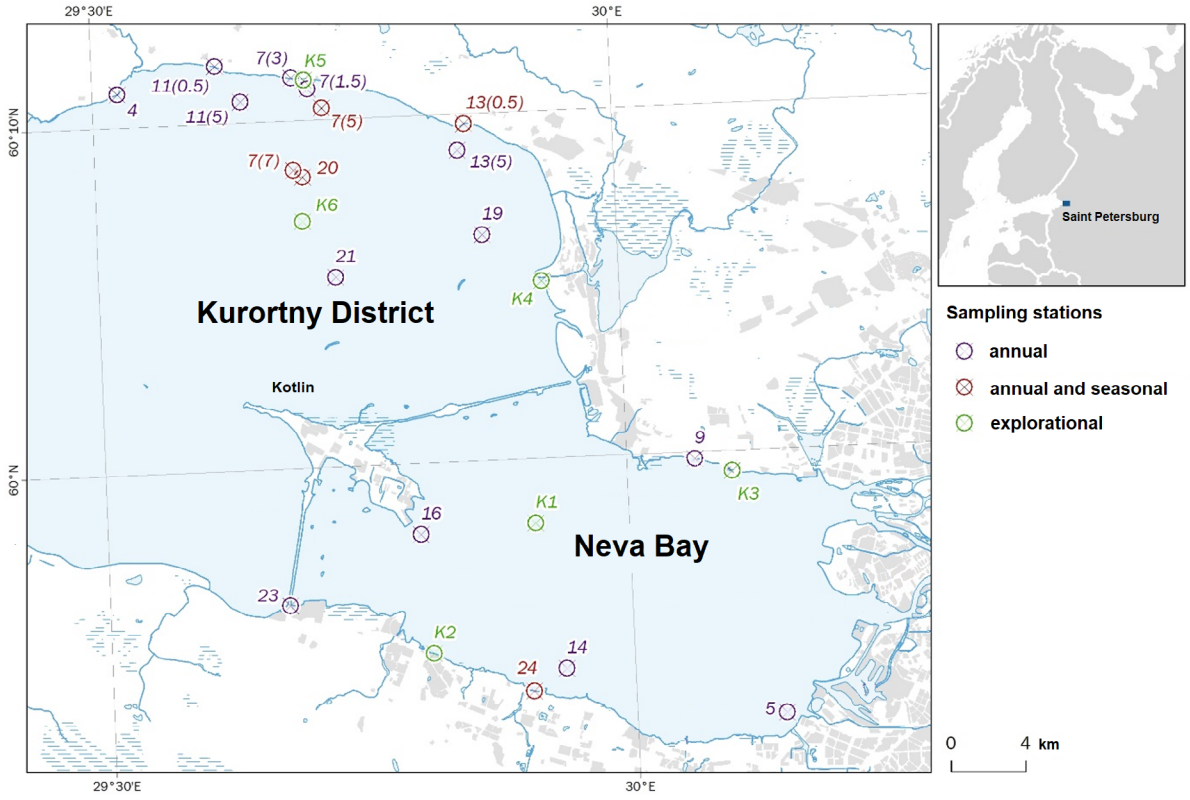

Fig. 1. Location of sampling stations.

The abundance of zooplankton in the shallow-water eastern part of the Gulf of Finland (including the Kurortny District) in 2011–2015 ranged from 0.61 to 101.34 thous. ind./m^3, and its biomass as 0.029–1.753 g/m^3. The maximum density was most often noted in late spring and early summer (June), the maximum biomass – in the second half of summer (August). On average, during the vegetation season, zooplankton biomass varied from 0.20 (2015) to 0.50 g/m^3 (2013). The average zooplankton biomass for 2011–2015 was 0.358 g/m^3. Rotifers and copepods usually had the highest abundance, and crustaceans prevailed in terms of biomass. Copepods were most numerous throughout the open water period and in winter, while cladocerans joined them in summer (usually in August) (Vypolnenie rabot..., 2018).

In 200–2014, six alien species were recorded in zooplankton of the Kurortny District: 3 euplanktonic crustaceans – *C. pengoi, Evadne anonyx*, *Acartia (Acanthacartia) tonsa* and 3 meroplanktonic organisms – veligers of bivalves *D. polymorpha*, larvae of polychaetes of the genus *Marenzelleria* Mesnil, 1896 and barnacles *Amphibalanus improvisus*. *Marenzelleria* larvae were recorded in 2008 and were not registered in 2014. Their absence in 2014 could be related to the replacement *of M. neglecta* Sikorski & Bick, 2004 by *M. arctia* (Maksimov, 2018), reproduction of which in the eastern part of the Gulf of Finland is still poorly investigated. The cladocerans *Cornigerius maeoticus maeoticus* (Pengo, 1879), found in the studied water area in 2004–2006, were not recorded in 2007 and 2008 (Monitoring..., 2008; Okazanie uslug..., 2014). Abundance of alien species in the eastern part of the Gulf of Finland in 2014 was low, with the exception for *C. pengoi* in July samples, accounting for a small share in the total zooplankton density and biomass (Okazanie uslug..., 2014).

Zoobenthos

The state of macrozoobenthos in the eastern part of the Gulf of Finland in the 2000s was studied in sufficient detail (Balushkina et al., 2008; Berezina et al., 2008; Maksimov, 2014, 2015, 2018; Maksimov et al., 2014; Orlova, 2017; Orlova et al., 2008; Susloparova et al., 2013; etc.). Special studies conducted in 2004–2014 showed that in the water area adjacent to St. Petersburg, invading species played a significant role in benthic communities, and the number of alien species increased year-to-year (Orlova, 2017).

Since 2002, alien amphipods *Gmelinoides fasciatus* and *Pontogammarus robustoides* have prevailed in the littoral zone (depth: 0–2 m) of the Neva Bay in terms of both density and biomass. In 2002–2005, their average summer density increased from 2.5 to 3.5 thous. ind./m^2, while in 2008 it decreased to 1–2 thous. ind./m^2. In 2014, the abundance of *G. fasciatus* in some sites of the Neva Bay reached 540 ind./m^2, and *P. robustoides* – 467 ind./m^2; they amounted to more than 40% of the zoobenthos biomass. The highest amphipod abundance was observed along the southern coast of the Neva Bay (Okazanie uslug..., 2014). Leeches (4.5 g/m^2), mollusks (3.2 g/m^2), mayflies (1.5 g/m^2) and oligochaetes (1 g/m^2) had the highest biomass in aboriginal zoobenthos communities along the northern coast of the Neva Bay. Caddis flies (12 g/m^2), chironomids (9 g/m^2), mayflies (3 g/m^2), and oligochaetes (1.1 g/m^2) were abundant in the southern part of the Neva Bay (Berezina et al., 2008).

In the open part of the Neva Bay in 2005–2006 and 2008, bivalve mollusks formed a significant part of the zoobenthos biomass, while oligochaetes and chironomids were accounted for the main part of zoobenthos density. Here, the bivalve mollusks from the families Unionidae, Sphaeriidae, and Pisidiidae were recorded in 2005–2006, however, in 2008 only Pisidiidae were found in the samples. In 2014, oligochaetes prevailed in the Neva Bay in terms of both density and biomass. Alien species did not play a significant role in benthic communities; only the oligochaetes *Potamothrix moldaviensis* were regularly encountered in 2008 and 2014. In 2014, the alien nemerthines *Prostoma puteale* were found in the Neva mouth, and polychaetes of the genus *Marenzelleria* (presumably, *Marenzelleria arctia* (Chamberlin, 1920)) – near the southern gates (southern navigation gates of the Flood Protection Facility), where they formed up to 20% of benthos biomass. Unidentified juvenile decapods were also noted (Okazanie uslug..., 2014).

In the littoral zone of the Kurortny District, zoobenthos was represented by the same groups as in the Neva Bay. In the early 2000s, amphipods (up to 15.6 g/m^2) and chironomids (4.2 g/m^2) prevailed in terms of biomass. During this period, three species of alien amphipods were found: *G. fasciatus, P. robustoides, and Gammarus tigrinus* (Berezina et al., 2008). Throughout the shallow littoral zone, invading species contributed most of the total biomass. The biomass of the Ponto-Caspian invader *P. robustoides* and

the Baikal invader *G. fasciatus* reached 10.7 g/m^2 and 10.6 g/m^2, respectively. Density of *P. robustoides* at some locations made up 2500 ind./m^2, *G. fasciatus* – 2900 ind./m^2, *G. tigrinus* – 1200 ind./m^2. Previously, single individuals of the alien amphipods *Echinogammarus warpachovsky* (G.O. Sars, 1894) and *Chelicorophium curvispinum* (G.O. Sars, 1895) were also recorded here (Monitoring..., 2008), but in 2014 they were not registered any more. Apparently, their naturalization did not occur.

In 2003–2014, in the shallow-water zone of the Kurortny District, the typical fouling organisms (*Dreissena* and *Cordylophora*), vagile epifauna (gastropods, leeches, caddisfly and mayfly larvae), and burrowing forms (annelids) dominated in the biotope of stony and mixed sediments. In 2014, benthos density (up to 25 thous. ind./m^2) and biomass (over 3 kg/m^2) were high here. The latter was formed due to populations of key alien species*, Dreissena polymorpha*, which amounted to 40 to 99% of the total (Okazanie uslug..., 2014; Orlova et al., 2008). Apart from *Dreissena* and *Cordylophora*, the most common alien species were the polychaetes *Marenzelleria*, the gastropods *Potamopyrgus antipodarum*, and the olygochaetes *P. moldaviensis*. In 2014, the hydroids *Gonothyraea loveni* were also registered; previously, they were found in the Russian part of the Gulf of Finland only near the Finland border (Antsulevich, 2012).

In the early 2000s, oligochaetes and chironomid larvae prevailed in zoobenthos of the deep-water zone of the Kurortny District; other benthic groups (nemerthines, turbellariae, polychaetes, mollusks, and crustaceans) were rare (Monitoring..., 2008). Significant interannual variability of benthos abundance was observed in this area until the early 2000s. The highest biomass, more than 50 g/m^2, was recorded during the years of *Chironomus plumosus* (Linnaeus, 1758) larvae dominance (Maksimov, 1997). After introduction of polychaetes of the genus *Marenzelleria*, such significant fluctuations were no longer observed. The average benthos biomass varied insignificantly, from 10 to 15 g/m^2 and chironomid biomass did not exceed 5 g/m^2. It was suggested (Maksimov, 2014) that the introduction of polychaetes could negatively affect the *Chironomus* abundance because of food competition since these organisms have the same feeding type (suspension/deposit feeders). Note that similar relations between these benthic organisms were recorded earlier in other water basins. Thus, a decrease in the chironomid abundance in the Vistula Bay occurred after *Marenzelleria* invasion (Ezhova et al., 2005; Rudinskaya, 2000; Zmudzinski, 1996). In the Caspian and Aral Seas, an introduction of polychaetes of the genus *Nereis* had negative effect on abundance of native chironomids (Filippov, 2005). Another factor that could negatively affect the *Chironomus* abundance was the increased water turbidity due to large-scale hydraulic engineering works carried out since early 2000s in the Neva estuary. This factor is considered to be the main reason of disappearance of the *Chironomus* dense population in the Neva Bay in 2006-2007 (Maksimov, 2014).

In 2014, in the deep-water zone of the Kurortny District, four alien species were found: polychaetes of the genus *Marenzelleria*, oligochaetes *Potamothrix moldaviensis* and *P. vejdovskyi*, and gastropods *P. antipodarum*. In some areas, the share of invasive polychaetes in the total macrozoobenthos biomass reached 70%. Other alien species played a smaller role in the benthos; their share in the total density and biomass, as a rule, did not exceed 10% (Okazanie uslug..., 2014).

Expected spread of alien species after 2014

The monitoring results of 2008–2014 suggested further expansion of alien species in the studied area. It was expected (Okazanie uslug..., 2014) that zooplankton may be replenished with pseudopopulations of species living west of the studied water area. In particular, these could be the ctenophore *Mertensia ovum* (Fabricius, 1780) and brackish-water crustacean *Heterocope caspia* G.O. Sars, 1897, *Calanipeda aquaedulcis* Krichagin, 1873, *Podonevadne camptonyx* (G.O. Sars, 1897), *Cornigerius maeoticus hircus* (G.O. Sars, 1902), and *Cercopagis neonilae* G.O. Sars, 1902.

The habitat expansion of the species (*G. tigrinus and Ch. Curvispinum)* naturalized in the Gulf of Finland in the east direction, i.e. to the Neva Bay, the Neva River and the lakes of its basin was expected (Okazanie uslug..., 2014). It was assumed that their distribution could happen through transfer by a ballast water and on ship hulls, including natural dispersal.

The introduction of the shrimp *Palaemon elegans* Rathke, 1836 and several species of bivalves into the studied water area seemed also highly probable. The shrimp *P. elegans* has been recorded in the

shallow coastal eastern part of the Gulf of Finland since 2013. The first single findings of this species were confined to the islands of the Vyborg Bay and the reef at the tip of the Kurgalsky Peninsula. In 2014, numerous shrimps of different age, including early juveniles and females with clutches of fertilized eggs, were already recorded in the Vyborg Bay. That year, this species was also found easternmost at the southern coast near the Lebyazhye village, where 11 juveniles of *P. elegans* were caught by juvenile fish seine (Okazanie uslug..., 2014).

Another potential invader – the bivalve *Mytilopsis leucophaeata* (Conrad, 1831), native to the brackish waters of the Atlantic coast of Central America, was found in 2014 in the complex impact zone of the Leningrad Nuclear Power Plant (Orlova, 2017). Perhaps, a regular migration of *Mytilopsis* larvae east of the Koporskaya Bay occurred during strong upwellings and floods. Temperature and salinity might be the factors limiting naturalization of this species, but taking into account the extreme plasticity of the Dreissenidae family, the local settlements of this species could also appear with time in sites of heated water discharge in the Neva Bay (Okazanie uslug..., 2014).

The following marine bivalves were also considered able to invade the eastern part of the Gulf of Finland: Cyrenidae (*Corbicula fluminea* (O.F. Müller, 1774) and *Corbicula fluminalis* (O.F. Müller, 1774)), Cardiidae (*Monodacna colorata* (Eichwald, 1829)), Mytilidae (*Limnoperna fortunei* (Dunker, 1857)), Mactridae (*Rangia cuneata* (G.B. Sowerby I, 1832)) (Okazanie uslug..., 2014). The latter species is currently expanding in the south-eastern Baltic, including the Kaliningrad region, and has already formed dense self-sustaining populations in the Vislin Bay (Naumenko et al., 2014).

Materials and methods

Plankton and benthos monitoring, including exploratory monitoring of alien species in the Neva Bay and the Gulf of Finland near St. Petersburg, was conducted in 2018 according to the accepted methodology[1]. The taxonomy of the identified freshwater invertebrates is given in accordance with the Fauna Europaea[2] (2014), and of marine species – in accordance with the WoRMS[3] (2023).

Zooplankton

Zooplankton samples were collected and processed using the standard methods (Metodicheskie rekomendatsii..., 1982). Quantitative zooplankton samples were taken by the Juday plankton net (inlet diameter 25 cm, sieve No. 70). At each station, 2 samples taken for quantitative studies were fixed with 40% formaldehyde to a final concentration of 4%. Qualitative zooplankton samples were taken by a large plankton net (inlet diameter 50 cm, sieve No. 70). For species identification, we used a light microscope at magnification of 10x, 20x, 40x, 70x or 100x (oil immersion), depending on the size of taxonomically significant morphological structures of the studied organisms.

In total, zooplankton samples were collected at 17 stations: 11 quantitative and 6 qualitative (exploring). At 8 quantitative stations, sampling was made once in the middle of the vegetation period, while at 3 quantitative and 6 qualitative stations – several times during the vegetation season (hereinafter referred to as “seasonal” stations). Overall, 62 quantitative and 18 qualitative zooplankton samples were collected and processed in 2018 (Table 1).

Zoobenthos

Zoobenthos samples were collected and processed using the standard methods (Abakumov, 1983; Metodicheskie rekomendatsii..., 1983). On dense sands, in the zone of the basin accumulation, a Van Veen grab with a sampling area of 0.1 m^2 was used. On gravel sands (stations 7(7), 13(5), see Fig. 1), the samples were collected by a diver. Samples from stony and mixed sediments in the shallow-water zone

[1] Methods for alien species monitoring in the Neva Bay and the Eastern part of the Gulf of Finland. Order of the Committee for nature use, environmental protection and ecological safety of St. Petersburg dated March 28, 2008 No. 36-r, Appendix.

[2] Fauna Europaea, 2014. Web page. URL: https://fauna-eu.org/ (accessed: 20.10.2023).

[3] World Register of Marine Species (WoRMS), 2023. Web page. URL: https://www.marinespecies.org (accessed: 20.10.2023).

were collected solely by a diver using a 25×25 cm frame and tools for scraping large boulders. Samples from the frame or scrapings were placed by the diver in sieve bags (sieve No. 23) and delivered to the boat. To estimate mollusks abundance, we used a 100×100 cm frame or made a visual assessment along a stretched rope (Metodika..., 2008).

On soft sediments (sand and mud), samples were collected using the rod grab with a sampling area of 0.025 m^2. In reed thickets, quantitative samples were taken using a thicket sampler, made of iron pipe with a diameter of 0.4 m and a height of 1.4 m with a hacksaw blade attached to the lower edge (Metodika..., 2008).

At each quantitative station, 3 samplings were implemented. All samples were washed through a nylon sieve No. 23 with a mesh size of about 0.4 mm and then fixed with 4% formaldehyde.

All in all, zoobenthos samples were collected at 25 stations: 19 quantitative and 6 qualitative (exploring) ones (Fig. 1). Samples were taken at 14 quantitative stations once in the middle of the vegetation period, and at 5 quantitative and 6 qualitative stations – several times during the vegetation season. A total of 108 quantitative and 18 qualitative zoobenthos samples were collected and processed in 2018 (Table 1).

Table 1. The number of samples collected during monitoring of alien species of zooplankton and zoobenthos in 2018. Quant – quantitative stations, Qual – qualitative stations.

Station no.	Zone	Samples per sampling		Quant/ Qual	Samples per season		Date of sampling
		Zoo-plankton	Zoo-benthos		Zoo-plankton	Zoo-benthos	
				Neva Bay			
9	Littoral	–	3	Quant	–	3	11.07.2018
23	Littoral	–	3	Quant	–	3	05.07.2018
							17.06.2018
							04.07.2018
24	Littoral	–	3	Quant	–	15	14.08.2018
							01.09.2018
							17.10.2018
							25.05.2018
К2	Littoral	1	1	Qual	3	3	05.07.2018
							01.09.2018
							25.05.2018
К3	Littoral	1	1	Qual	3	3	11.07.2018
							01.09.2018
14	Open part	2	3	Quant	2	3	04.07.2018
16	Open part	2	3	Quant	2	3	04.07.2018
5	Open part (port of St.Petersburg)	2	3	Quant	2	3	17.08.2018
							20.05.2018
		1	–	Qual	3	–	11.07.2018
К1	Open part						29.09.2018
							20.05.2018
		–	1	Qual	–	3	11.07.2018
							21.09.2018
Quantitative samples					6	30	
Qualitative samples					9	9	
Total					15	39	

Station no.	Zone	Samples per sampling		Quant/ Qual	Samples per season		Date of sampling
		Zoo-plankton	Zoo-benthos		Zoo-plankton	Zoo-benthos	
Kurortny District							
4	Littoral	–	3	Quant	–	3	05.07.2018
7(0.5)	Littoral	–	3	Quant	–	3	05.07.2018
7(1.5)	Littoral	–	3	Quant	–	3	28.06.2018
11(0.5)	Littoral	–	3	Quant	–	3	05.07.2018
13(0.5)	Littoral	–	3	Quant	–	15	17.06.2018 11.07.2018 14.08.2018 01.09.2018 17.10.2018
K4	Littoral	1	1		3	3	20.05.2018 11.07.2018 03.10.2018
K5	Littoral	1	1	Qual	3	3	20.05.2018 04.07.2018 03.10.2018
7(3)	Shallow-water	2	3	Quant	2	3	28.06.2018 20.05.2018
7(5)	Shallow-water	2	–	Quant	6	–	28.06.2018 03.10.2018
		–	3	Quant	–	15	28.06.2018 11.07.2018 31.08.2018 03.10.2018 17.10.2018
7(7)	Shallow-water	2	–	Quant	20	–	17.06.2018 28.06.2018 11.07.2018 01.08.2018 14.08.2018 31.08.2018 03.10.2018 11.10.2018 17.10.2018 29.10.2018
		–	3	Quant	–	9	20.05.2018 11.07.2018 03.10.2018
11(5)	Shallow-water	2	3	Quant	2	3	28.06.2018
13(5)	Shallow-water	2	3	Quant	2	3	04.07.2018
19	Deep-water	2	3	Quant	2	3	04.07.2018

Station no.	Zone	Samples per sampling		Quant/ Qual	Samples per season		Date of sampling
		Zoo-plankton	Zoo-benthos		Zoo-plankton	Zoo-benthos	
20	Deep-water	2	–	Quant	20	–	17.06.2018 28.06.2018 11.07.2018 01.08.2018 14.08.2018 31.08.2018 03.10.2018 11.10.2018 17.10.2018 29.10.2018
		–	3	Quant	–	12	11.07.2018 14.08.2018 03.10.2018
21	Deep-water	2	3	Quant	2	3	17.10.2018 04.07.2018
K6	Deep-water	1	1	Qual	3	3	20.05.2018 11.07.2018 03.10.2018
	Quantitative samples				56	78	
	Qualitative samples				9	9	
	Total				65	87	
	All zones						
	Quantitative samples				62	108	
	Qualitative samples				18	18	
	Total				80	126	

Results

Zooplankton

Littoral zone of the Neva Bay

In the littoral zone of the Neva Bay (depth: 0–2 m), only qualitative zooplankton samples were collected at seasonal stations K2 and K3 located near the southern and northern shores of the Neva Bay. The littoral zone had the highest zooplankton species diversity among all locations studied in 2018. In total 57 taxa were identified here (Table 2). Most common species were rotifers *Euchlanis dilatata* Ehrenberg, 1832, *Asplanchna priodonta* Gosse, 1850, *Keratella cochlearis* (Gosse, 1851) and representatives of the genus *Polyarthra* Ehrenberg, 1834, as well as cladocerans *Bosmina (Eubosmina) coregoni* Baird, 1857.

Among the alien species, only copepods *Eurytemora carolleeae* and bivalve mollusk larvae (most likely of the genus *Dreissena*) were recorded in the littoral zone. Both were registered at st. K2 only in autumn.

Open part of the Neva Bay

The open part of the Neva Bay was characterized by a slightly lower zooplankton species diversity compared, to the littoral zone (48 species). Rotifers *K. cochlearis, Synchaeta pectinata* Ehrenberg, 1832, *Polyarthra* sp., and cladocerans *B. coregoni* were among the most common species. The average zooplankton density was 54.1 thous. ind./m^3 and average biomass – 0.141 g/m^3 (Table 3). Rotifers prevailed in zooplankton in terms of density. Cladocerans prevailed in terms of biomass at st. 14, rotifers – at st. 16, and copepods – at st. 5 (in the port).

A single alien species – cladocerans *C. pengoi* (with density of 71 ind./m^3 and biomass of 0.007 g/m$^{3)}$ was found in this zone at st. 14. With consideration of all three quantitative stations located in the open part of the Neva Bay, the share of this alien species was 0.04% in the total zooplankton density and 1.7% in the total biomass (Table 4).

Littoral zone of the Kurortny District

In the littoral zone of the Kurortny District, zooplankton was collected only at qualitative stations K4 and K5 located in the eastern and western parts of the coast, respectively. In this zone, species diversity of zooplankton was the least (45 species), as compared to other studied sites (Table 2). Cladocerans *B. coregoni*, copepods *E. affinis* (Poppe, 1880), and rotifers *K. cochlearis* were the most common species.

Only one alien species was found in zooplankton in this area – copepods *E. carolleeae*, which was recorded only in July at st. K5.

Shallow-water area of the Kurortny District

The shallow-water zone of the Kurortny District had a relatively large species diversity of zooplankton – 55 taxa (Table 2). The most characteristic species were rotifers *K. cochlearis and Polyarthra* sp., as well as cladocerans *B. coregoni* and copepods *E. affinis*. The average density of zooplankton in summer was 161.1 thous. ind./m^3 and average biomass – 3.378 g/m^3. Rotifers and copepods prevailed in terms of density, while cladocerans had the highest biomass.

In the study area, five alien species were registered: *C. pengoi, A. tonsa, E. carolleeae,* larvae of polychaetes *Marenzelleria* and larvae of bivalves (probably *Dreissena*). Copepods *E. carolleeae* were the most numerous at all stations during almost all observation periods. Another copepod species, *A. tonsa,* was found only at stations 7(5) and 7(7) in autumn. Cladocerans *C. pengoi* were recorded singly at station 7(5) in June and at station 7(7) in July. Larvae of polychaetes and bivalves were recorded in plankton once each: polychaetes – in May at station 7(5), bivalves – in August at station 7(7). In total, the share of alien species in zooplankton was insignificant and amounted to about 2% in density and 5% in biomass.

Deep-water zone of the Kurortny District

Zooplankton species diversity in the deep-water zone of the Kurortny District and in the shallow-water zone was similar – 52 species (Table 2). Cladocerans *B. coregoni* and *Daphnia (Daphnia) cristata* G.O. Sars, 1861, copepods of the genus *Thermocyclops* Kiefer, 1937, and rotifers *K. cochlearis* were

Table 2. Number of species and frequency of occurrence of the main groups of zooplankton in 2018.

Taxonomic group	Zone				
	Neva Bay		Kurortny District		
	Littoral	Open part	Littoral	Shallow-water	Deep-water
	Number of species				
Cladocera	16	16	14	18	14
Copepoda	12	7	13	17	17
Rotifera	28	25	18	18	19
Polychaeta	–	–	–	1	1
Bivalvia	1	–	–	1	1
Total	57	48	45	55	52
	Frequency of occurrence, %				
Cladocera	100	100	83	100	100
Copepoda	100	100	100	100	100
Rotifera	100	100	100	100	100
Polychaeta	–	–	–	6	20
Bivalvia	17	–	–	6	7

Table 3. Average density (ind./m³) and biomass (mg/m³) of the main groups of zooplankton in the summer of 2018. "0" – the taxon was recorded only in qualitative samples.

Taxonomic group	Zone		
	Neva Bay	Kurortny District	
	Open part	Shallow-water	Deep-water
	Density		
Bivalvia	–	0	0
Cladocera	411	25 181	11 536
Copepoda	3 066	71 771	21 678
Polychaeta	–	0	0
Rotifera	50 664	64 191	28 747
Total	**54 141**	**161 142**	**61 961**
	Biomass		
Bivalvia	–	0	0
Cladocera	61	2 234	1 050
Copepoda	19	1 092	346
Polychaeta	–	0	0
Rotifera	61	53	32
Total	**141**	**3 378**	**1 429**

Table 4. Average density (ind./m³) and biomass (mg/m³) of alien zooplankton species in 2018. "0" – the species was recorded only in qualitative samples.

Species/taxon	Zone		
	Neva Bay	Kurortny District	
	Open part	Shallow-water	Deep-water
	Density		
Bivalvia larvae	–	0.0	0.0
Cercopagis pengoi (Ostroumov, 1891)	23.8	5.4	25.0
Evadne anonyx G.O. Sars, 1897	–	–	2.1
Acartia tonsa Dana, 1849	–	0.0	0.0
Eurytemora carolleeae Alekseev & Souissi, 2011	–	2847.1	79.3
Marenzelleria sp. (larva)	–	0.0	0.0
Total	**23.8**	**2852.5**	**106.4**
% of total	**0.04**	**1.8**	**0.1**
	Biomass		
Bivalvia larvae	–	0.0	0.0
Cercopagis pengoi	2.4	0.5	0.6
Evadne anonyx	–	–	0.0
Acartia tonsa	–	0.0	3.0
Eurytemora carolleeae	–	170.8	9.4
Marenzelleria sp. (larva)	–	0.0	0.0
Total	**2.4**	**171.4**	**13.1**
% of total	**1.7**	**5.1**	**1.5**

found at almost all stations. The average zooplankton density during summer was 62 thous. ind./m^3 and average biomass – 1.429 g/m^3. Rotifers and cladocerans contributed most of total density, while copepods prevailed in terms of biomass.

Six alien zooplankton species were found in this zone: *C. pengoi, E. anonyx*, *A. tonsa*, *E. carolleeae*, larvae of polychaetes *Marenzelleria* and larvae of bivalves (probably *Dreissena*). Among them, the copepods *E. carolleeae* were the most numerous. Another copepod species*, A. tonsa, was* found only at st. 20 in autumn. Single cladocerans *C. pengoi* were recorded only at st. 21, *E. anonyx* – at st. 19. Polychaete larvae were registered at st. 20 in August and October, and bivalve larvae – at the same station in mid-August. In general, the share of alien species in zooplankton was small, amounting to 0.1% of the total density and 1.5% of the total biomass.

Zoobenthos

Littoral zone of the Neva Bay

In 2018, the benthos in the Neva Bay littoral zone had the highest species diversity among all studied locations: 81 taxa (Table 5). The most common species were mollusks *Sphaerium corneum* (Linnaeus, 1758), oligochaetes *Potamothrix hammoniensis* (Michaelsen, 1901), *Chaetogaster diaphanus* (Gruithuisen, 1828), *Dero digitata* (Müller, 1774), *Spirosperma ferox* Eisen, 1879, and larvae of Ceratopogonidae.

The average macrozoobenthos density made up 662 ind./m^2 and average biomass – 3.45 g/m^2. Oligochaetes (89% of the total density), chironomids, and isopods had the highest abundance (Table 6). Oligochaetes (up to 70% of the total biomass), leeches, and gastropods prevailed in terms of biomass.

Three alien species were registered: the oligochaetes *Potamothrix heuscheri* and *P. moldaviensis*, and amphipods *P. robustoides* (Table 7). Together, they amounted to about 2% of the total macrozoobenthos density and 3% of the total biomass. Oligochaetes *P. heuscheri* were identified both at the southern and northern coasts of the Neva Bay, whereas *P. moldaviensis* – only at the southern coast at st. 24, in late summer and autumn. We found Amphipods *P. robustoides* only at qualitative station K2 located at the southern coast of the Neva Bay.

Open part of the Neva Bay

Macrozoobenthos of the open part of the Neva Bay was characterized by a significantly lower species diversity (37 species), compared to the littoral zone (Table 5). The most common species were oligochaetes *P. hammoniensis* and *S. ferox*, including chironomids *Procladius (Holotanypus) ferrugineus* Kieffer, 1918. The average macrozoobenthos density made up 1348 ind./m^2 and average biomass – 135.5 g/m^2. Oligochaetes had the highest abundance (up to 97% of the total), and bivalves prevailed in terms of biomass (up to 99% of the total).

Three alien species were found in this area: bivalve mollusks *D. polymorpha*, and oligochaetes *P. moldaviensis* and *P. vejdovskyi* (Table 7). They accounted for about 10% of the total macrozoobenthos density and 18% of the total biomass. Oligochaetes *P. moldaviensis* were recorded in single specimens only at st. K1, *P. vejdovskyi* and *D. polymorpha* – only at st. 14.

Littoral zone of the Kurortny District

Macrozoobenthos of the littoral zone of the Kurortny District in 2018 was characterized by a relatively high species diversity – 61 species (Table 5). The most common species were oligochaetes *Cognettia glandulosa* (Michaelsen, 1888) and *Lumbricillus lineatus* (Muller, 1774), bivalves *Unio pictorum* (Linnaeus, 1758) and unidentified nematodes. The average macrozoobenthos density was 429 ind./m^2 and average biomass – 181.2 g/m^2. The most numerous were chironomids (up to 79% of the total density). Bivalve mollusks prevailed in terms of biomass (up to 99.8% of the total) (Table 6).

Six alien species were found here: bivalve mollusks *D. polymorpha*, oligochaetes *P. heuscheri* and *P. moldaviensis*, amphipods *G. tigrinus, G. fasciatus and P. robustoides*. Together, they amounted to 9% of the total macrozoobenthos density and 31% of the total biomass (Table 7). Bivalves *D. polymorpha* were found only at st. 7(1.5), while oligochaetes *P. heuscheri* – only at st. 7(0.5), *P. moldaviensis* – 7(1.5) and K4. Both oligochaete species were extremely rare. Amphipods *G. tigrinus* were recorded at stations 11(0.5) and 7(1.5), *G. fasciatus* – only at qualitative station K4, and *P. robustoides* – at st. 13(0.5) in October.

Table 5. Number of species and frequency of occurrence of the main groups of zoobenthos in 2018.

Taxonomic group	Zone				
	Neva Bay		Kurortny District		
	Littoral	Open part	Littoral	Shallow-water	Deep-water
	Number of species				
Coleoptera	1	–	–	–	–
Ephemeroptera	–	1	–	1	–
Arachnida	1	–	1	–	–
Bivalvia	4	4	5	4	–
Gastropoda	10	7	4	5	3
Oligochaeta	35	17	20	20	14
Polychaeta	–	–	–	1	1
Amphipoda	2	–	5	1	–
Isopoda	1	–	–	–	–
Megaloptera	1	–	1	1	–
Mysida	–	–	–	1	–
Trichoptera	3	–	1	1	–
Hirudinea	6	1	2	4	–
Ceratopoganidae	1	–	1	–	–
Chironomidae	15	6	19	11	4
Mermithidae	1	1	1	1	1
Pediciidae	–	–	1	–	–
Total	81	37	61	51	23
	Frequency of occurrence, %				
Coleoptera	20	–	–	–	–
Ephemeroptera	–	25	–	20	–
Arachnida	40	–	29	–	–
Bivalvia	80	75	57	60	–
Gastropoda	80	75	29	60	75
Oligochaeta	100	100	100	100	100
Polychaeta	–	–	–	20	25
Amphipoda	40	–	57	20	–
Isopoda	40	–	–	–	–
Megaloptera	40	–	14	20	–
Mysida	–	–	–	20	–
Trichoptera	40	–	14	20	–
Hirudinea	60	25	57	80	–
Ceratopoganidae	60	–	29	–	–
Chironomidae	100	100	100	100	100
Mermithidae	20	25	57	80	50
Pediciidae	–	–	14	–	–

Table 6. Average density (ind./m³) and biomass (mg/m³) of the main groups of zoobenthos in the summer of 2018. "0" – the taxon was recorded only in qualitative samples

Taxonomic group	Zone				
	Neva Bay		Kurortny District		
	Littoral	Open part	Littoral	Shallow-water	Deep-water
	Density				
Coleoptera	0	–	–	–	–
Ephemeroptera	–	9	–	3	–
Arachnida	0	–	3	–	–
Bivalvia	9	40	127	281	–
Gastropoda	22	453	3	13	22
Oligochaeta	351	788	108	444	1 236
Polychaeta	–	–	–	0	0
Amphipoda	4	–	5	3	–
Isopoda	76	–	–	–	–
Megaloptera	13	–	2	3	–
Mysida	–	–	–	0	–
Trichoptera	0	–	0	2	–
Hirudinea	40	4	6	7	–
Ceratopoganidae	4	–	0	–	–
Chironomidae	142	53	168	204	249
Pediciidae	–	–	8	–	–
Total	**662**	**1 348**	**429**	**959**	**1507**
	Biomass				
Coleoptera	0.00	–	–	–	–
Ephemeroptera	–	0.43	–	0.01	–
Arachnida	0.00	–	0.00	–	–
Bivalvia	0.16	103.85	170.04	164.61	–
Gastropoda	0.72	29.81	10.65	0.15	0.12
Oligochaeta	0.87	1.31	0.15	1.04	1.65
Polychaeta	–	–	–	0.00	0.00
Amphipoda	0.00	–	0.04	0.01	–
Isopoda	0.54	–	–	–	–
Megaloptera	0.01	–	0.01	0.01	–
Mysida	–	–	–	0.00	–
Trichoptera	0.00	–	0.00	0.01	–
Hirudinea	0.78	0.03	0.05	0.05	–
Ceratopoganidae	0.00	–	0.00	–	–
Chironomidae	0.37	0.11	0.22	0.75	4.00
Pediciidae	–	–	0.05	–	–
Total	**3.45**	**135.54**	**181.20**	**166.63**	**5.78**

Table 7. Average density (ind./m³) and biomass (mg/m³) of alien zoobenthos species in 2018. "0" – the species was recorded only in qualitative samples.

Taxon	Zone				
	Neva Bay		Kurortny District		
	Littoral	Open part	Littoral	Shallow-water	Deep-water
	Density				
Dreissena polymorpha (Pallas, 1771)	–	31	118	271	–
Gammarus tigrinus Sexton, 1939	–	–	5	–	–
Gmelinoides fasciatus (Stebbing, 1899)	–	–	0	3	
Marenzelleria sp.	–	–		0	4
Pontogammarus robustoides (Sars, 1894)	0	–	0	–	–
Potamopyrgus antipodarum (J.E. Gray, 1843)	–	–	–	0	4
Potamothrix heuscheri (Bretscher, 1900)	13	–	8	190	–
Potamothrix moldaviensis Vejdovský & Mrázek, 1903	38	0	3	4	1 584
Potamothrix vejdovskyi (Hrabě, 1941)	–	107	–	27	376
Tubificoides pseudogaster (Dahl, 1960)	–	–	–	–	0
Total	**51**	**138**	**134**	**495**	**1 969**
% of total	**2**	**10**	**9**	**52**	**34**
	Biomass				
Dreissena polymorpha	–	23.63	46.76	64.25	–
Gammarus tigrinus	–	–	0.04	–	–
Gmelinoides fasciatus	–	–	0.00	0.01	–
Marenzelleria sp.	–	–	–	0.00	0.06
Pontogammarus robustoides	0.00	–	0.00	–	–
Potamopyrgus antipodarum	–	–	–	0.00	0.04
Potamothrix heuscheri	0.05	–	0.01	0.26	–
Potamothrix moldaviensis	0.06	0.00	0.00	0.00	1.78
Potamothrix vejdovskyi	–	0.18	–	0.26	0.40
Tubificoides pseudogaster	–	–	–	–	0.00
Total	**0.11**	**23.81**	**46.81**	**64.79**	**2.28**
% of total	**3**	**18**	**31**	**39**	**20**

Shallow-water zone of the Kurortny District

Macrozoobenthos in the shallow-water zone of the Kurortny District in 2018 had a relatively high species diversity – 51 species (Table 5). The most common species were oligochaetes *Isochaetides michaelseni* (Lastočkin, 1936), *S. ferox*, chironomids *Glyptotendipes (Glyptotendipes) paripes* (Edwards, 1929), and unidentified nematodes. The average macrozoobenthos density was 959 ind./m^2 and average biomass – 166.6 g/m^2. Oligochaetes were most numerous (up to 74% of the total), and bivalves prevailed in terms of biomass (up to 99.8% of the total) (Table 6).

Seven alien species were found: bivalves *D. polymorpha*, gastropods *P. antipodarum*, oligochaetes *P. heuscheri, P. vejdovskyi* and *P. moldaviensis*, polychaetes of genus *Marenzelleria*, and amphipods *G. fasciatus*. Together, they contributed 52% to the total macrozoobenthos density and 39% to the total biomass. Bivalve mollusks *D. polymorpha* were repeatedly recorded in large numbers at stations 7(3) and 7(5). A single specimen of gastropods *P. antipodarum* was found in May at st. 7(7). Oligochaetes *P. heuscheri* were abundant at st. 13(5) and sporadically found at st. 7(3). In summer, *P. moldaviensis* were recorded in small numbers at st. 11(5), in contrast to spring and autumn (up to 170 ind./m^2) at st. 7(5). *P. vejdovskyi were* recorded only at st. 7(7) in amount of 133 ind./m^2. Polychaetes were recorded only at station 7(5) in August and October. Amphipods *G. fasciatus* were repeatedly registered, but in single specimens during seasonal samplings at st. 7(5).

Deep-water zone of the Kurortny District

Macrozoobenthos of the deep-water zone of the Kurortny District in 2018 showed the lowest species diversity – 23 species (Table 5). The most common species were the oligochaetes *P. moldaviensis* and *Psammoryctides barbatus* (Grube, 1860), as well as the chironomids *Ch. plumosus.* The average macrozoobenthos density made up 1507 ind./m^2 and average biomass – 5.78 g/m^2. The most numerous group (82% of the total density) was oligochaetes, chironomids prevailed in terms of biomass (up to 81% of the total value) (Table 6).

Five alien species were found in this zone: gastropods *P. antipodarum*, oligochaetes *P. vejdovskyi*, *P. moldaviensis* and *Tubificoides pseudogaster*, and polychaetes of the genus *Marenzelleria*. Together, they amounted to about 34% of the total density and 20% of the total macrozoobenthos biomass. The oligochaetes *P. moldaviensis* was the most common alien species at all stations and abundant in all seasons. *P. vejdovskyi* were also numerous (225 ind./m^2) only in autumn at st. 20. *T. pseudogaster* were recorded in a single specimen only at qualitative station K6. Polychaetes *Marenzelleria* spp. were recorded late summer in single specimens and only at seasonal station 20.

Discussion

Zooplankton

In 2018, the average abundance and biomass of zooplankton in the Neva Bay were within their natural fluctuations for the previous period (Vypolnenie rabot..., 2018; Zhigulsky et al., 2020). Widespread freshwater species dominated in zooplankton, as before. In 2008 and 2014, no alien species were found in the Neva Bay. In 2018, three alien species were recorded here: cladocerans *C. pengoi* in the open part, and copepods *E. carolleeae* and larvae of bivalves (most likely of the genus *Dreissena*) - in the littoral zone. The finding of cladocerans *C. pengoi* at st. 14, located near the southern gate, was most likely due to their transfer from the adjacent water area of the Gulf of Finland, where they were previously recorded (Okazanie uslug..., 2014). Earlier, copepods *E. carolleeae* were not distinguished from *E. affinis* and without the appropriate investigations it is hardly possible to specify the time of their appearance in the Neva Bay. The presence of *Dreissena* larvae in the Neva Bay in 2018 is quite clear, since their colonies were recorded in the Neva Bay as in 2014 as in 2018.

Zooplankton density and biomass in the Kurortny District in 2018 slightly exceeded those for 2011–2015. As before, rotifers and copepods were most numerous in summer plankton, and cladocerans had the highest biomass. In 2018 and 2008–2014, the same alien species were recorded, with the exception for larvae of barnacles *A. improvisus*. In contrast to 2014, we also recorded copepods *E. carolleeae* (numerous) and larvae of polychaetes *Marenzelleria* (single specimens) in the plankton.

Thus, a total of six alien zooplankton species were recorded (2018) in the studied area: *C. pengoi, E. anonyx, A. tonsa, E. carolleeae, D. polymorpha* (larva), *Marenzelleria* sp. (larva). *A. improvisus* larvae, which were recorded here in 2014, were not registered in 2018. These larvae are usually found west of the study area, where they could be accidentally transferred in 2014 due to flooding (Table 8). Not identified in 2014, alien copepod *E. carolleeae* were found in the area under consideration in 2018. As mentioned above, copepods *E. carolleeae* were not previously distinguished from *E. affinis* and without the appropriate research it is hardly possible to specify the time of their appearance in the Neva Bay.

It should be noted that the zooplankton composition in the eastern part of the Gulf of Finland is usually unstable and changes easily both due to the appearance of new invaders or pseudopopulations of species living west of the considered area. Newly naturalized benthic species with planktonic larvae can also be responsible for such changes. Thus, the source of new planktonic organisms could be a bivalve mollusk *M. leucophaeata*, which is currently intensively spreading in the Gulf of Finland (Orlova, 2017). However, in 2018, no larvae of this species were observed in the plankton of the studied water area. Obviously, this species has not penetrated the studied waters yet; when the larvae of this species were in the water column, the hydrological regime did not facilitate their transfer from the adjacent areas of the Gulf of Finland.

Zoobenthos

The obtained results suggest that the native benthic communities of the Neva Bay remained relatively stable in 2014–2018. On the contrary, the state of populations of alien species changed greatly.

In the littoral zone of the Neva Bay in 2018, as in previous years, native species were represented by oligochaetes, chironomids, leeches, bivalves and gastropods. As compared to 2014, the zoobenthos abundance decreased slightly. At the same time, the abundance of invading species in this zone decreased significantly. For instance, in the early 2000s, density of alien amphipods *G. fasciatus* and *P. robustoides* in the littoral zone of the Neva Bay reached thousands of individuals per square meter (Berezina and Panov, 2003), and in 2014 – hundreds of individuals per square meter (Okazanie uslug..., 2014). In 2018, *G. fasciatus* was not recorded in the littoral zone of the Neva Bay at all, and *P. robustoides* was found in single specimens and only in qualitative samples. In 2008–2014, alien species contributed most of biomass throughout in the Neva Bay littoral zone (Okazanie uslug..., 2014), but in 2018 their share dropped to several percent.

In the open part of the Neva Bay, the zoobenthos structure did not differ significantly in 2018 from that in 2014 (Okazanie uslug..., 2014). As in the previous years, oligochaetes were most numerous, while gastropods and bivalves prevailed in biomass. Invaders did not play a significant role in the benthic communities, and their number slightly decreased. Thus, in 2018, alien nemerthines, polychaetes, amphipods *G. fasciatus*, and decapods, which were previously registered in the Neva Bay, were no more recorded here (Table 8).

In the littoral zone of the Kurortny District, the average biomass of oligochaetes and chironomids dropped by more than an order of magnitude in 2018 as compared to 2014 (from 2 and 5 g/m^2 in 2014 to 0.1 and 0.2 g/m^2 in 2018, respectively). Bivalves and gastropods began to play a major role in benthos. The invading species, which contributed most to the total biomass in 2014, also played a significant role in benthic communities in 2018, although they did not dominate everywhere as before. In the littoral zone of the Kurortny District, as in the Neva Bay, the biomass of alien amphipods decreased significantly with maximum of 0.2 g/m^2 in 2018 against 12.5 g/m^2 in 2014 (Okazanie uslug...,, 2014).

In the shallow-water zone of the Kurortny District, the zoobenthos density and biomass were also significantly lower in 2018 than in 2014. However, the prevailing groups were the same: oligochaetes and chironomids were most numerous, and bivalves had the highest biomass. As in the other zones, the number of invading species decreased slightly in 2018. Among the alien species registered here in 2014 (Okazanie uslug..., 2014; Orlova, 2017), hydroid polyps *Cordylophora caspia* and *G. loveni*, nemerthines, amphipods *P. robustoides,* and oligochaetes *T. pseudogaster* were not recorded in 2018. Polychaetes of the genus *Marenzelleria* were present in 2018 in the noticeably smaller numbers than in 2014 and were completely absent at all at standard stations in summer. Nevertheless, not recorded in 2014 alien oligochaetes *P. vejdovskyi* and found singly in this zone *P. heuscheri* (Okazanie uslug..., 2014) became abundant. *Dreissena*, as in previous years, formed a significant part of the benthic density and biomass.

Table 8. Alien species of benthos and plankton recorded in the Neva Bay and in the adjacent area of the Gulf of Finland in 2014 (according to: Provision of services.., 2014) and in 2018 (in brackets); + – single encounters, ++ – common species, +++ – mass species; ? – in 2014, the species was not distinguished from *E. affinis*.

№	Species	Zone				
		Neva Bay		Kurortny District		
		Littoral	Open part	Littoral	Shallow-water	Deep-water
				Benthos		
1	*Cordylophora caspia* (Pallas, 1771)	–	–	+	++	–
2	*Gonothyraea loveni* (Allman, 1859)	–	–	–	+	–
3	*Prostoma puteale* (Dugès, 1828)	–	++	–	++	+
4	*Marenzelleria* sp.	+	+	+	+ (+)	+ (+)
5	*Potamothrix moldaviensis* Vejdovský & Mrázek, 1903	– (++)	++ (+)	– (+)	++ (++)	++ (+++)
6	*Potamothrix vejdovskyi* (Hrabě, 1941)	–	+ (++)	–	– (+)	++ (++)
7	*Potamothrix heuscheri* (Bretscher, 1900)	+ (+)	–	+ (+)	+ (++)	+
8	*Tubificoides pseudogaster* (Dahl, 1960)	–	–	–	+	– (+)
9	*Gmelinoides fasciatus* (Stebbing, 1899)	++	++	++ (+)	+ (++)	–
10	*Pontogammarus robustoides* (Sars, 1894)	++(+)	++	++(+)	+	–
11	*Gammarus tigrinus* Sexton, 1939	–		+++ (++)	–	–
12	*Eriocheir sinensis* H. Milne Edwards, 1853	+	+	+	+	–
13	*Potamopyrgus antipodarum* (J.E. Gray, 1843)	–	–	++ (+)	++ (+)	+
14	*Dreissena polymorpha* (Pallas, 1771)	+	– (++)	++ (++)	+++ (+++)	+++
				Plankton		
1	*Cercopagis pengoi* (Ostroumov, 1891)	–	– (++)	–	++ (+)	+++ (+)
2	*Evadne anonyx* G.O. Sars, 1897	–	–	–	+	+ (+)
3	*Acartia tonsa* Dana, 1849	–	–	–	+ (+)	++ (+)
4	*Eurytemora carolleeae* Alekseev & Souissi, 2011	?* (+)	?*	?* (+)	?* (+++)	?* (++)
5	*Amphibalanus improvisus* (Darwin, 1854) (larva)	–	–	–	–	+
6	*Dreissena polymorpha* (Pallas, 1771) (larva)	– (+)	–	–	– (+)	+ (+)
7	*Marenzelleria sp.* (larva)	–	–	–	– (+)	– (+)

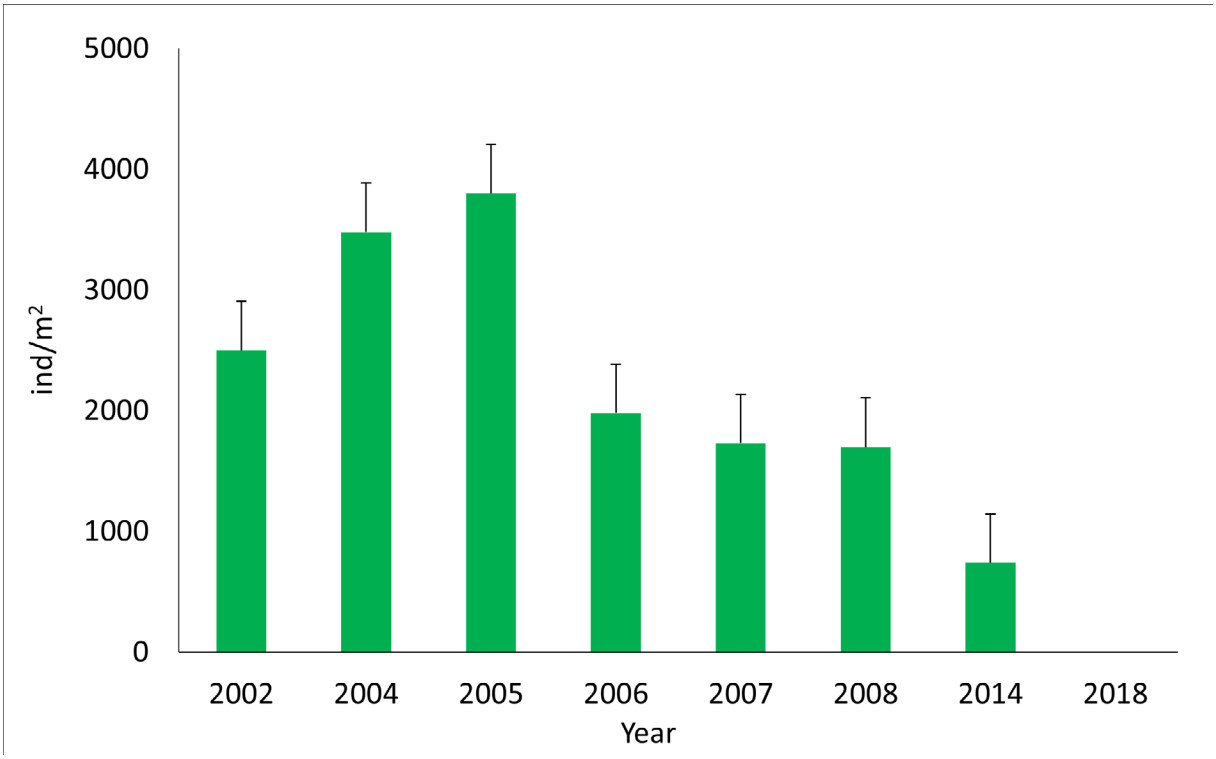

Fig. 2. Dynamics of the average summer density of alien amphipod in the Neva Bay (the Petrodvorets area) (Okazanie uslug..., 2014; Vypolnenie rabot, 2018).

In 2014–2018, density and biomass of benthic organisms in the deep-water zone of the Kurortny Districts considerably decreased, but the benthic structure remained unchanged: oligochaetes and chironomids formed the basis of zoobenthos abundance and biomass. Note that the same alien species were registered in 2018 and 2014, except for one new species – oligochaetes *T. pseudogaster*. Previously abundant Polychaetes *Marenzelleria*, (Maksimov, 2015, 2018; Okazanie uslug..., 2014) were not observed at standard stations in summer of 2018.

Thus, a total of 10 alien benthic species were identified (2018) in the studied area (Table 8): bivalves *D. polymorpha*, gastropods *P. antipodarum*, oligochaetes *T. pseudogaster, P. heuscheri, P. vejdovskyi* and *P. moldaviensis*, polychaetes of the genus *Marenzelleria*, amphipods *G. fasciatus, G. tigrinus* and *P. robustoides*. In 2018, a slightly lower number of alien taxa (14 alien benthic species) than in 2014 was recorded (Okazanie uslug..., 2014). It is noteworthy that no hydroids *C. caspia* or nemertines *P. puteale*, which were previously found in significant amounts in the shallow-water zone of the Kurortny District, were registered in 2018. Since the hydroid *G. loveni* and the Chinese crab *Eriocheir sinensis* were always very rare in the studied water area, their absence in the collections of 2018 is easily explained (Okazanie uslug..., 2014).

Potential intruders

Based on the previous monitoring results (Okazanie uslug..., 2014), further expansion to the east (the Neva Bay, the Neva River and the lakes of its basin) of the newly naturalized in the Gulf of Finland species of amphipods (*G. tigrinus* and *C. curvispinum*) was expected after 2014. Nevertheless, no eastward expansion of these species was recorded in 2018.

In addition to the above-mentioned species, the eastward spread of other benthic species, in particular, the shrimp *P. elegans* and bivalve mollusks *M. leucophaeata* living in the impact zone of the Leningrad NPP could be a highly probable event (Orlova, 2017). It was assumed that several new species of bivalve mollusks, such as *C. fluminea*, *C. fluminalis*, *M. colorata*, *L. fortunei,* and *R. cuneata*, would appear (Okazanie uslug..., 2014), but none of these species was found in 2018 in the study area. Only

later (in 2019), *R. cuneata* was recorded in the immediate vicinity, i.e. in the Koporskaya Bay (Orlova, 2019). Moreover, some alien species, which were numerous here in 2008-2014 (Okazanie uslug..., 2014; Orlova, 2017), were absent or very rare in 2018.

The reduced share of invading species in benthic communities in 2018 does not contradict the classical scheme of population dynamics of invading species in the new habitats. It is well known (Odum, 1971) that new species, when placed in suitable conditions in a new habitat, often demonstrate explosive population growth. Subsequently, one or another limiting environmental factor appears and thus prevents further population growth and maintains the abundance at a more or less constant level or even leads to abundance decrease. Such dynamics was recorded in the populations of amphipods *P. robustoides and G. fasciatus* in the Neva Bay (Fig. 2) or *M. neglecta* in the Vistula Bay (Ezhova et al., 2005, cit. by: Maksimov, 2018; Rudinskaya, 2000). The expansion of new species into the eastern part of the Gulf of Finland may be hindered by widespread use of new procedures for safe handling of ballast water in ports in accordance with international agreements[4].

On the other hand, alien species dynamics in the considered water area could also be related to changes in the anthropogenic pressure on the ecosystem of the Neva Bay and the Gulf of Finland. Previously, it was suggested (Okazanie uslug..., 2014; Orlova, 2017) that in the early 2000s native invertebrates in littoral communities were suppressed by intruders due to higher vulnerability of natives to worsened environmental conditions such as cyanobacteria and filamentous algae blooming, and hypoxia. These factors were amplified during the period of intensive hydraulic engineering works in the Neva Bay in early 2000s. Reduction of anthropogenic loads on the ecosystems of the Neva Bay and adjacent areas of the Gulf of Finland by 2018 could provide stabilization of the aquatic ecosystems and some restoration of native species populations.

In general, the present study suggests that the expected appearance of new benthic species, as well as further expansion of already naturalized alien species, did not occur in 2014–2018. Abundance of some alien benthic species found in 2008–2014 greatly declined. Many of them even disappeared in 2018. The findings of alien zooplankton species in the Neva Bay, probably, relate to their temporary transfer from the neighboring area of the Gulf of Finland.

Conclusion

In 2018, the structure of planktonic and benthic communities in the Neva Bay and the eastern part of the Gulf of Finland adjacent to St. Petersburg did not differ significantly from that existed in 2014. Abundance and biomass of zooplankton were slightly higher, while benthic abundance and biomass lower in 2018, as compared to the previous study period.

Unlike significantly changed populations of some alien species, the state of native zooplankton and zoobenthos communities in the studied area remained relatively stable. The number of alien species in zooplankton in 2018 and 2014 was the same. Some planktonic species have expanded to the east (to the Neva Bay), presumably, due to their transfer from the adjacent areas of the Gulf of Finland. In zoobenthos, a number of alien species was lower in 2018 than in 2014 – only 10 species versus 14. For some alien benthic species, a significant reduction in the range or abundance was recorded in 2018 compared to 2014.

References

Abakumov, V.A., 1983. Rukovodstvo po metodam gidrobiologicheskogo analiza poverkhnostnostnykh vod i donnykh otlozheniy [Guide to methods of hydrobiological analysis of surface waters and bottom sediments]. Gidrometeoizdat, Leningrad, USSR, 240 p. (In Russian).

Alimov, A.F., Orlova, M.I., Panov, V.Ye., 2000. Posledstviya introduktsiy chuzherodnykh vidov dlya morskoy ekosistemy i neobkhodimost' meropriyatiy po ikh predotvrashcheniyu [Consequences of alien species introductions for marine ecosystem and the need for measures to prevent them]. In: Matishov, G.G. (ed.), *Vidy-vselentsy v yevropeyskikh moryakh Rossii. Sbornik nauchnykh trudov [Invasive species in the European seas of Russia. Collection of scientific papers].* Kola Science Center RAS, Apatity, Russia, 12–23. (In Russian).

[4] International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004.

Antsulevich, A.Ye., 2012. Hydrozoa (gidroidy i gidromeduzy) morey Rossii [Hydrozoa (hydroids and hydromedusae) of the seas of Russia]. *Doctor of Sciences in Biology thesis.* St. Petersburg, Russia, 1083 p. (In Russian).

Balushkina, E.V., Maksimov, A.A., Golubkov, S.M., Tsyplenkina, I.G., 2008. Zoobentos otkrytyh vod estuariya reki Nevy [Zoobenthos of open waters of the Neva River estuary]. In: Alimov, A.F., Golubkov, S.M. (ed.), *Ekosistema estuariya reki Nevy: biologicheskoye raznoobraziye i ekologicheskiye problem [Ecosystem of the Neva River Estuary: biological diversity and environmental problems].* KMK Scientific Press Ltd, St. Petersburg – Moscow, Russia, 156–183. (In Russian).

Berezina, N.A., Panov, V.E., 2003. Establishment of new gammarid species in the eastern Gulf of Finland (Baltic Sea) and their effects on littoral communities. *Proceedings of the Estonian Academy of Sciences. Biology. Ecology* **52** (3), 284–304.

Berezina, N.A., Balushkina, E.V., Tsyplenkina, I.G., Pankova, E.S., 2008. Fauna makrobespozvonochnykh pribrezhnoy zony [Fauna of macroinvertebrates of the coastal zone]. In: Alimov, A.F., Golubkov, S.M. (ed.), *Ekosistema estuariya reki Nevy: biologicheskoye raznoobraziye i ekologicheskiye problemy [Ecosystem of the Neva River Estuary: biological diversity and environmental problems]*. KMK Scientific Press Ltd, St. Petersburg – Moscow, Russia, 202–211. (In Russian).

Ezhova, E., Żmudziński, L., Maciejewska, K., 2005. Long-term trends in the macrozoobenthos of the Vistula Lagoon, southeastern Baltic Sea. Species composition and biomass distribution. *Bulletin of The Sea Fisheries Institute* **1** (164), 55–73.

Filippov, A.A., 2005. Obshchiye vidy-vselentsy v donnykh soobshchestvakh Arala i Kaspiya i ikh vliyaniye na aborigennuyu faunu [Common invasive species in benthic communities of the Aral and Caspian Seas and their impact on the native fauna]. *Funktsional'naya morfologiya, ekologiya i zhiznennyye tsikly zhivotnykh [Functional Morphology, Ecology and Life Cycles of Animals]* **5**, 177–195. (In Russian).

Maksimov, A.A., 1997. Makrozoobentos vostochnoy chasti Finskogo zaliva. Ekosistemnyye modeli [Macrozoobenthos of the eastern part of the Gulf of Finland. Ecosystem models]. In: Davidan, I.N., Savchuk, O.P. (ed.), *Otsenka sovremennogo sostoyaniya Finskogo zaliva. Chast' II. Gidrometeorologicheskiye, gidrokhimicheskiye, gidrobiologicheskiye usloviya i dinamika vody Finskogo zaliva [Assessment of the current state of the Gulf of Finland. Part II. Hydrometeorological, hydrochemical, hydrobiological conditions and water dynamics of the Gulf of Finland].* Gidrometeoizdat, St. Petersburg, Russia, 405–416. (In Russian).

Maksimov, A.A., 2014. Makrozoobentos Nevskoy guby v usloviyakh intensivnykh gidrotekhnicheskikh rabot [Macrozoobenthos of the Neva Bay under conditions of intensive hydraulic engineering works]. *Regional'naya ekologiya [Regional ecology]* **35** (1–2), 39–47. (In Russian).

Maksimov, A.A., 2015. Mnogoletnyaya dinamika i sovremennoe raspredelenie soobshchestv makrozoobentosa v vostochnoy chasti Finskogo zaliva Baltiyskogo morya [Long-term dynamics and modern distribution of macrozoobenthos communities in the eastern part of the Gulf of Finland of the Baltic Sea]. *Biologiya morya [Marine Biology]* **41** (4), 269–278. (In Russian).

Maksimov, A.A., 2018. Zakonomernosti mezhgodovoy i mnogoletnei dinamiki makrozoobentosa (na primere vershiny Finskogo zaliva) [Patterns of interannual and long-term dynamics of macrozoobenthos (by the example of the tip of the Gulf of Finland)]. *Doctor of Sciences in Biology thesis.* St. Petersburg, Russia, 265 p. (In Russian).

Maksimov, A.A., Eremina, T.R., Lange, E.K., Litvinchuk, L.F., Maksimova, O.B., 2014. Rezhimnaya perestroyka ekosistemy vostochnoy chasti Finskogo zaliva vsledstviye invazii polikhet *Marenzelleria arctia* [Regime restructuring of the ecosystem of the eastern part of the Gulf of Finland due to invasion

of the polychaetes *Marenzelleria arctia*]. *Okeanologiya [Oceanology]* **54** (1), 52–52. (In Russian). http://www.doi.org/10.7868/S0030157413060063

Metodicheskiye rekomendatsii po sboru i obrabotke materialov pri gidrobiologicheskikh issledovaniyakh na presnovodnykh vodoyemakh. Zoobentos i yego produktsiya [Methodological recommendations for collecting and processing materials during hydrobiological studies in freshwater bodies. Zoobenthos and its production], 1983. Salazkin, A.A. et al. (ed.). State Scientific Research Institute of Lake and River Fisheries (GosNIORKh), Leningrad, USSR, 51 p. (In Russian).

Metodicheskiye rekomendatsii po sboru i obrabotke materialov pri gidrobiologicheskikh issledovaniyakh na presnovodnykh vodoyemakh. Zooplankton i yego produktsiya [Methodological recommendations for collecting and processing materials during hydrobiological studies in freshwater bodies. Zooplankton and its production], 1982. Vinberg, G.G., Lavrentieva, G.M. (ed.) State Scientific Research Institute of Lake and River Fisheries (GosNIORKh), Leningrad, USSR, 33 p. (In Russian).

Monitoring chuzherodnykh vidov. Itogovyy otchet [Monitoring of alien species. Final report], 2008. Alimov, A.F. et al. (eds.). Committee for Nature Use of St. Petersburg, St. Petersburg, Russia, 131 p. (In Russian).

Naumenko, E.N., Rudinskaya, L.V., Gusev, A.A., 2104. Vliyanie vidov-vselentsev na strukturu zooplanktona i zoobentosa v Vislinskom zalive Baltiyskogo morya [The influence of invasive species on the structure of zooplankton and zoobenthos in the Vistula Lagoon of the Baltic Sea]. *Regional'naya ekologiya [Regional Ecology]* **1**–**2** (35), 21–28. (In Russian).

Okazaniye uslug po obespecheniyu provedeniya monitoringa ob'ektov zhivotnogo mira v Finskom zalive v celyakh polucheniya operativnoy dostovernoy informatsii i prognoza rasprostraneniy i chislennosti novykh vidov na territorii, gde oni ran'she otsutstvovali. Itogovyy otchet [Provision of services to ensure monitoring of the fauna in the Gulf of Finland in order to obtain prompt and reliable information and make a forecast of distribution and abundance of new species in the areas where they were previously absent. Final report], 2014. Orlova, M.I. et al. (eds.). Committee for Nature Use of St. Petersburg, St. Petersburg, Russia, 154 p. (In Russian).

Orlova, M.I., 2017. Monitoring chuzherodnykh vidov Nevskoy guby i vostochnoy chasti Finskogo zaliva [Monitoring of alien species in the Neva Bay and the eastern part of the Gulf of Finland]. *Okruzhayushchaya sreda St. Peterburga [Environment of St. Petersburg]* **3** (5), 45–55. (In Russian).

Orlova, M.I., 2019. Pervaya nakhodka i invazionnyy status *Rangia cuneata* (Sowerby, 1831) (Mactridae, Bivalvia) v vostochnoy chasti Finskogo zaliva [First discovery and invasive status of *Rangia cuneata* (Sowerby, 1831) (Mactridae, Bivalvia) in the eastern part of the Gulf of Finland] *Regional'naya ekologiya [Regional Ecology]* **3** (57), 69–79. (In Russian).

Orlova, M.I., Ryabchuk, D.V., Spiridonov, M.A., 2008. Makrozoobentos melkovodiy [Macrozoobenthos of shallow waters]. In: Alimov, A.F., Golubkov, S.M. (ed.), Ekosistema estuariya reki Nevy: biologicheskoye raznoobraziye i ekologicheskiye problemy [Ecosystem of the Neva River Estuary: biological diversity and environmental problems]. KMK Scientific Press Ltd, St. Petersburg – Moscow, Russia, 184–201. (In Russian).

Panov, V.E., Dgebuadze, Y.Y., Shiganova, T.A., Filippov, A.A., Minchin, D., 2007. A risk assessment of biological invasions in the inland waterways of Europe: the Northern Invasion Corridor case study. In: Gherardi, F. (ed.), *Biological invaders in inland waters: Profiles, distribution, and threats (Invading Nature – Springer Series In Invasion Ecology. Vol. 2)*. Springer, Netherlands, 639–656. https://doi.org/10.1007/978-1-4020-6029-8_35

Rudinskaya, L.V., 2000. Dinamika biomassy i chislennosti *Marenzelleria viridis* i yeye vliyaniye na strukturu bentosnogo soobshchestva Vislinskogo zaliva [Dynamics of biomass and abundance

of *Marenzelleria viridis* and its influence on the structure of the benthic community of the Vistula Lagoon]. In: Matishov, G.G., (ed.), *Vidy-vselentsy v yevropeyskikh moryakh Rossii [Invasive species in the European seas of Russia].* Kola Science Center RAS, Apatity, Russia, 193–202. (In Russian).

Susloparova, O.N., Shurukhin, A.S., Mitskevich, O.I., Tereshenkova, T.V., Khozyaykin, A.A., 2013. Otsenka vliyaniya intensivnykh gidrotekhnicheskikh rabot, provodimykh v posledneye desyatiletiye v pribrezhnykh rayonakh Nevskoy guby na yeye biotu [Assessment of the impact of intensive hydraulic engineering works carried out in the last decade in the coastal areas of the Neva Bay on its biota]. Uchonyye zapiski RGGMU [Scientific Notes of the Russian State Hydrometeorological University] **28**, 110–120. (In Russian).

Telesh, I.V., Golubkov, S.M., Alimov, A.F., 2008. The Neva Estuary ecosystem. In: Schiewer, U. (ed.), *Ecology of Baltic Coastal Waters (Ecological Studies. Vol. 197).* Springer, Germany, 259–284. https://doi.org/10.1007/978-3-540-73524-3_12 Vypolneniye rabot po sboru dannykh o novykh vidakh v Finskom zalive v celyah provedeniya monitoringa ob'yektov zivotnogo mira. Itogovyy otchet [Collection of data on new species in the Gulf of Finland for monitoring of the fauna. Final Report], 2018. Shabalin, N.V. et al. (eds.). Center for Marine Research, Lomonosov Moscow State University, Moscow, Russia, 230 p. (In Russian).

Zhigulsky, V.A., Shuisky, V.F., Chebykina, E.Yu., Fedorov, V.A., Panichev, V.V. et al., 2020. Plavni Nevskoy guby. Nauchno-issledovatel'skaya programma. Itogi I etapa [Floodplains of the Neva Bay. Research program. Results of the first stage]. Renome, St. Petersburg. Russia, 304 p. (In Russian).

Zmudzinski, L., 1996. The effect of the introduction of the American species *Marenzelleria viridis* (Polychaeta, Spionidae) on the benthic ecosystem of Vistula Lagoon. *Marine Ecology* **17** (1–3), 221–226. https://doi.org/10.1111/j.1439-0485.1996.tb00503.x

Список литературы

Абакумов, В.А., 1983. Руководство по методам гидробиологического анализа поверхностных вод и донных отложений. Гидрометеоиздат, Ленинград, СССР, 240 с.

Алимов, А.Ф., Орлова, М.И., Панов, В.Е., 2000. Последствия интродукций чужеродных видов для водных экосистем и необходимость мероприятий по их предотвращению. В: Матишов, Г.Г. (ред.), *Виды-вселенцы в европейских морях России.* Кольский научный центр РАН, Апатиты, Россия, 12–23.

Анцулевич, А.Е., 2012. Hydrozoa (гидроиды и гидромедузы) морей России. *Диссертация на соискание ученой степени доктора биологических наук,* Санкт-Петербург, Россия, 1083 с.

Балушкина, Е.В., Максимов, А.А., Голубков, С.М., Ципленкина, И.Г., 2008. Зообентос открытых вод эстуария реки Невы. В: Алимов, А.Ф., Голубков, С.М. (ред.), *Экосистема эстуария реки Невы: биологическое разнообразие и экологические проблемы.* Товарищество научных изданий КМК, Санкт-Петербург – Москва, Россия, 156–183.

Березина, Н.А., Балушкина, Е.В., Ципленкина, И.Г., Панкова, Е.С., 2008. Фауна макробеспозвоночных прибрежной зоны. В: Алимов, А.Ф., Голубков, С.М. (ред.), *Экосистема эстуария реки Невы: биологическое разнообразие и экологические проблемы.* Товарищество научных изданий КМК, Санкт-Петербург – Москва, Россия, 202–211.

Выполнение работ по сбору данных о новых видах в Финском заливе в целях проведения мониторинга объектов животного мира, 2018. Итоговый отчет. Шабалин, Н.В. и др. (ред.). Центр морских исследований МГУ им. М.В.Ломоносова, Москва, Россия, 230 с.

Жигульский, В.А., Шуйский, В.Ф., Чебыкина, Е.Ю., Федоров, В.А., Паничев, В.В., и др., 2020. Плавни Невской губы. Научно-исследовательская программа. Итоги I этапа. Реноме, Санкт-Петербург, Россия, 304 с.

Максимов, А.А., Еремина, Т.Р., Ланге, Е.К., Литвинчук, Л.Ф., Максимова, О.Б., 2014. Режимная перестройка экосистемы восточной части Финского залива вследствие инвазии полихет *Marenzelleria arctia*. *Океанология* **54** (1), 52–52. http://www.doi.org/10.7868/S0030157413060063

Максимов, А.А., 2014. Макрозообентос Невской губы в условиях интенсивных гидротехнических работ. *Региональная экология* **35** (1–2), 39–47.

Максимов, А.А., 2015. Многолетняя динамика и современное распределение сообществ макрозообентоса в восточной части Финского залива Балтийского моря. *Биология моря* **41** (4), 269–278.

Максимов, А.А., 2018. Закономерности межгодовой и многолетней динамики макрозообентоса (на примере вершины Финского залива). *Диссертация на соискание ученой степени доктора биологических наук*. Санкт-Петербург, Россия, 265 с.

Максимов, А.А., 1997. Макрозообентос восточной части Финского залива. Экосистемные модели. В: Давидан, И.Н., Савчук, О.П. (ред.), *Оценка современного состояния Финского залива. Ч. II. Гидрометеорологические, гидрохимические, гидробиологические условия и динамика вод Финского залива*. Гидрометеоиздат, Санкт-Петербург, Россия, 405–416.

Методические рекомендации по сбору и обработке материалов при гидробиологических исследованиях на пресноводных водоемах. Зоопланктон и его продукция, 1982. Винберг, Г.Г., Лаврентьева, Г.М. (ред.). ГосНИОРХ, Ленинград, СССР, 33 с.

Методические рекомендации по сбору и обработке материалов при гидробиологических исследованиях на пресноводных водоемах. Зообентос и его продукция, 1983. Салазкин, А.А., и др., (ред.). ГосНИОРХ, Ленинград, СССР, 51 с.

Мониторинг чужеродных видов, 2008. Итоговый отчет. Алимов, А.Ф., и др. (ред.) Комитет по природопользованию г. Санкт-Петербурга, Санкт-Петербург, Россия, 131 с.

Науменко, Е.Н., Рудинская, Л.В., Гусев, А.А., 2014. Влияние видов-вселенцев на структуру зоопланктона и зообентоса в Вислинском заливе Балтийского моря. *Региональная экология* **1**–**2** (35), 21–28.

Орлова, М.И., 2017. Мониторинг чужеродных видов Невской губы и восточной части Финского залива. *Окружающая среда Санкт-Петербурга* **3** (5), 45–55.

Орлова, М.И., 2019. Первая находка и инвазионный статус *Rangia cuneata* (Sowerby, 1831) (Mactridae, Bivalvia) в восточной части Финского залива. *Региональная экология* **3** (57), 69–79.

Орлова, М.И., Рябчук, Д.В., Спиридонов, М.А., 2008. Макрозообентос мелководий. В: Алимов, А.Ф., Голубков, С.М. (ред.), *Экосистема эстуария реки Невы: биологическое разнообразие и экологические проблемы.* Товарищество научных изданий КМК, Санкт-Петербург – Москва, Россия, 184–201.

Оказание услуг по обеспечению проведения мониторинга объектов животного мира в Финском заливе в целях получения оперативной достоверной информации и прогноза распространений и численности новых видов на территории где они раньше отсутствовали, 2014. Итоговый отчет. Орлова, М.И. и др. (ред.). Комитет по природопользованию г. Санкт-Петербурга, Санкт-Петербург, Россия, 154 с.

Рудинская, Л.В., 2000. Динамика биомассы и численности *Marenzelleria viridis* и ее влияние на структуру бентосного сообщества Вислинского залива. В: Матишов, Г.Г. (ред.), *Виды-вселенцы в европейских морях России.* Кольский научный центр РАН, Апатиты, Россия, 193–202.

Суслопарова, О.Н., Шурухин, А.С., Мицкевич, О.И., Терешенкова, Т.В., Хозяйкин, А.А., 2013. Оценка влияния интенсивных гидротехнических работ, проводимых в последнее десятилетие в прибрежных районах Невской губы на ее биоту. *Учёные записки РГГМУ* **28**, 110–120.

Филиппов, А.А., 2005. Общие виды-вселенцы в донных сообществах Арала и Каспия и их влияние на аборигенную фауну. *Функциональная морфология, экология и жизненные циклы животных* **5**, 177–195.

Berezina, N.A., Panov, V.E., 2003. Establishment of new gammarid species in the eastern Gulf of Finland (Baltic Sea) and their effects on littoral communities. *Proceedings of the Estonian Academy of Sciences. Biology. Ecology* **52** (3), 284–304.

Ezhova, E., Żmudziński, L., Maciejewska, K., 2005. Long-term trends in the macrozoobenthos of the Vistula Lagoon, southeastern Baltic Sea. Species composition and biomass distribution. *Bulletin of The Sea Fisheries Institute* **1** (164), 55–73.

Panov, V.E., Dgebuadze, Y.Y., Shiganova, T.A., Filippov, A.A., Minchin, D., 2007. A risk assessment of biological invasions in the inland waterways of Europe: the Northern Invasion Corridor case study. In: Gherardi, F. (ed.), *Biological invaders in inland waters: Profiles, distribution, and threats (Invading Nature – Springer Series In Invasion Ecology. Vol. 2)*. Springer, Netherlands, 639–656. https://doi.org/10.1007/978-1-4020-6029-8_35

Telesh, I.V., Golubkov, S.M., Alimov, A.F., 2008. The Neva Estuary ecosystem. In: Schiewer, U. (ed.), *Ecology of Baltic Coastal Waters (Ecological Studies. Vol. 197).* Springer, Germany, 259–284. https://doi.org/10.1007/978-3-540-73524-3_12

Zmudzinski, L., 1996. The effect of the introduction of the American species *Marenzelleria viridis* (Polychaeta, Spionidae) on the benthic ecosystem of Vistula Lagoon. *Marine Ecology* **17** (1–3), 221–226. https://doi.org/10.1111/j.1439-0485.1996.tb00503.x