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Littoral Communities of the Neva River Estuary: Structure and Dynamics of Quantitative Characteristics under Anthropogenic Pressure.

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ABSTRACT

The estuary of the Neva River has been studied as a model object, experiencing great anthropogenic load due to the dredging work.The muddy water tail has spread along the northern shore of the Gulf of Finland on 150 km since extensive dredging work and land reclamation projects in the Neva River estuary the were undertaken. A drastic decline of water transparency was detected in the aquatory, which affected the bottom fauna. Structure and composition of macrozoobenthos littoral communities at the northern shore of the Neva River estuary were studied at 6 sites each summerbetween 2009-2011. 57 species were found, chironomids is the most numerous group (28 species). Bivalves, gastropods, trichopterans, dipterans (*Ceratopogonidae*) were present in solitary samples.Alien species significantly affect local benthic communities, their introduction aligned with disappearance of water hogfish (*Asellusaquaticus*)and indigenous amphipods species, which previously were common for the Neva River estuary.

Keywords: littoral, Neva River estuary, macrozoobenthos, anthropogenic impact

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INTRODUCTION

Environmental conditions of the littoral communities' formation and functioning in the Neva River estuary attract the attention of many researchers.Studies of the Neva Bay benthic fauna have been conducted for over a hundred years. The first knowledge about zoobenthos and its existence conditions can be found in the works of A.S. Skorikov (1910) [11], where the characteristics of the soils and benthic organisms of this reservoir are given. Recently, the interest in studying the communities mentioned above has grown dramatically due to the anthropogenic impact on the Neva estuary.

An estuary is a partly enclosed waterbody, funnel-shaped enlargement of the river mouthwith a free connection to the open sea (or to a lake)and thereforeexposed to the sweep of the tides;marine water is mixed there with the fresh water of the continental runoff and usually is markedly desalinated. As a result of fresh and salt water mix in the reservoir, salinity gradients are created, which in turn determines the change in many physical-chemical and biological characteristics.Estuaries can be considered as transition zones or ecotones between freshwater and marine habitats, but many of their most important physical and biological characteristics are not transitional, and are unique. In these peculiar habitats, specific flora and fauna are formed, and the continuous transport of allochthonous substances creates very special biological conditions for production [5, 17].

According to the classification proposed in 1969 by E. Odum and coauthors [5], the Neva River estuary can be classified as the type "natural ecosystems of the temperate zone coasts with seasonal programming". Estuaries of this type are characterized by regular seasonal bursts of primary productivity, reproductive and behavioral activity of animals. They are often regulated in time, or "programmed seasonally." Here, the softer tides, waves and currents are not a cause of additional stress to the ecosystem, but are an additional energy source, resulting in zones more distant from the shore receiving an inflow of organic material and nutrients from the fertile shallow zones [5].

The Neva Bay (a half-closed shallow waterbody), along with adjoining two straits the eastern part of the Gulf of Finland, form the estuary of the Neva River. The estuary receivesin its waters a wide range of pollutants associated human economic activity in this area. It is believed by many authors [1, 2, 4],that the reason for the complex evolution of the Neva Bay zoobenthos (its composition, structure, quantitative parameters) should be sought in anthropogenic impact on the water body.

The Neva River estuary is the most eutrophicated part of the Baltic Sea. As a result of water level fluctuations and storms, the filamentous algae detach from substrates and accumulate in the coastal zone up to a depth of 1 m. During decomposition of the algae, the phenomena of hypoxia occur and the quality of the habitats of benthic organisms worsens. This destabilizes communities and the abundance of species is reduced.

As studies by researchers from Zoological Institute of Russian Academy of Sciences showed[2, 18], eurybiontic forms (chironomids, amphipods) dominate in littoral zoocenoses of the eastern part of the Gulf of Finland. According to their findings, the success of the amphipods alien species is due to eutrophication. Amphipods, being r-selected species, are characterized by a high tolerance, short life cycle, intense reproduction, and a wide food spectrum.

The issue of studying and forecasting the ecological state of the Neva Bay and the eastern part of the Gulf of Finland is pressing in connection with the construction of the Saint-Petersburg Flood Prevention Facility Complex (Saint-Petersburg Dam) [4]. In recent years the situation has worsened: large-scale dredging works were carried out, as well as large areas of reclaimed land appeared, in particular, the territory of Vasilyevsky Island was increased. The muddy water tail extended from the site of work along the northern coast over 150 km. A sharp decrease in water clarity was recorded in the springs and autumns of 2005-07 (up to 20-30 cm throughout and up to 5 cm in certain parts of the water area), which had a large effect on the state of the water body inhabitants, in particular, the benthic fauna [9].

Thus, the study of the Neva River estuary littoral communities must take into account not only the originality (uniqueness) of the estuary environment, but also a significant anthropogenic pressure.Anthropogenic pressure on the Neva River estuary ecosystems is particularly increased in the early

21th century in connection with the construction of the Saint-Petersburg Passenger Port and the new land reclamation at the western tip of Vasilyevsky Island. In this regard, the aim of our work was to study the structural characteristics of the littoral zone macrozoobenthos of the Neva River estuary at the northern shore areas experiencing significant anthropogenic pressure.

MATERIALS AND METHODS

Composition and structure of littoral macrozoobenthos communities were studied in order to analyze anthropogenic impacts on living ability of coastal communities. Samples were taken at six stations located along the northern shore on a different, ever-increasing distance from the place of the most intense supply of disturbed sediment in water (fig. 1).

Fig 1: Location of sampling stations in the Neva River estuary

Quantitative macrozoobenthos samples were collected according to the procedure used in similar studies [2], in the summers of 2009-11, three samples at each station at a depth of 0.5 m using a tube sampler.The water temperature was measured at each station.

Data on salinity were obtained from the literature [12], the salinity of the studied estuary area increases with decrease of river runoff influence (i.e. from Ol'gino station to Smoljachkovo station). Fresh water spreads to the west, and the brackish waters in the form of a wedge moves eastward.The salinity of the water at the bottom of the Neva estuary changes from east to west, from 0.3‰ to 8.5‰.

Sediments on the sampling stations are presented by the sands of different grain size with admixed gravel and pebbles.Everywhere there are thickets of higher aquatic plants represented mainly by reeds and rushes.

EXPERIMENTAL

The macrozoobenthos samples were viewed in the laboratory under a binocular microscope in the counting chamber.The selected animals were separated by taxonomic groups (*Amphipoda, Isopoda, Bivalvia, Gastropoda, Chironomidae, Ceratopogonidae, Diptera* (others), *Ephemeroptera, Trichoptera, Odonata, Hirudinea*and*Oligochaeta*), counted and weighed within the accuracy of 0,0001g. All animals were identified to species.

For each sample, the abundance and biomass of animals were counted per square meter and the standard errors of the mean were calculated.

To detect differences in abundance and biomass of macrozoobenthos communities between different sampling dates as well as between stations, the data were compared by the method of multidimensional scaling using a Bray-Curtis coefficient. This method is used to reduce the dimensionality of the original data (data reduction).

Community similarity in this analysis is considered as a proportion of the number of matched individuals with respect to the average number of individuals. The multidimensional scaling task is to construct a data distribution in space of two scales. Emerging axes can be interpreted as a kind of implicit factors, the values of which determine the distinctions between the objects themselves. In applying the method of multidimensional scaling, each sample is placed on a "map" that allows to demonstrably see the "closeness" of any characteristics of studied samples, and the accuracy of the resulting picture can be assessed by the stress level [14, 15].

Preliminarily abundance and biomass indices have been transformed by calculating the root of the fourth degree, which allows to take into account in the analysis not only the dominant groups, but also smaller ones. The analysis was performed in the program PAST 3, the program, as well as recommendations for the statistical data processing were kindly provided by the staff of the Department of Ichthyology and Hydrobiology of Saint-Petersburg State University.

RESULTS AND DISCUSSION

Structure and dynamics of littoral communities

All studied coastal ecosystems are characterized by a lack of clear boundaries, short food chains, and similar trophic structure. Nearby ecosystems along the coastline gradually run into each other.Here, tidal energy increases communities' productivity by replacing a part of the energy used for respiration, which would otherwise be spent on the transfer of mineral substances, as well as on the transport of food and wastes.

The basis of the energy of all six communities mostly is formed by detritus accumulating in bottom sediments and coming in with waves. Chironomids families/subfamilies *Ortyocladiinae*, *Cyironomidae (Diptera)*and ephemerans family*Caenidae*dominate among detritophages.*Naididae* (oligochaetes) play a special role, because they consumedetritus of both vegetable and animal origin, and diatoms, protozoa, various microorganisms, and bacteria as well; the process of mineralization of organic matter is greatly accelerated in their faeces. Thus oligochaetes affect the rate of sludge production and bottom sediments mineralization and play a significant role in the cycle of matter in reservoirs [16].Predators of the first order are presented mainly by amphipods, which, in turn, are an important food source for fish. The latter maintain their energy not only due to the first order predators, but also due to detritophages of this and neighboring littoral communities.With increase of depth and with distance from the shore the nature of communitieschanges slightly; here, here do not play a prominent role in community functioning.

During the course of the research carried out in 2009-11, 57 representatives of macrozoobenthos species were found. The species composition of the littoral communities varies slightly. The ratio of the number of species at different stations with the number of families (see table 1) allows us to evaluate the diversity of conditions and their favorableness for different species at different stations. Let us consider these and other parameters for each station in more detail.

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Taxa				Stations					
				Ol'gino	Gorskaja	Komarovo	Zelenogorsk	Ushkovo	Smoljachkovo
PhylumAnnelida	ClassClitellata	SubclassOligochaeta OrderNaidomorpha	FamilyNaididae	3	4	4	4	3	4
			FamilyEnchytraeidae	1	1	1	1	1	1
		OrderLumbricomorpha	FamilyLumbriculidae	1	1	1	1	1	1
		SubclassHirudinea	FamilyErpobdellidae	1					1
			FamilyGlossiphoniidae						1
PhylumMollusca	ClassBivalvia	OrderLuciniformes	FamilySphaeriidae	1			1	1	
			FamilyEuglesidae	1	1		1		1
	ClassGastropoda	OrderEctobranchia	FamilyValvatidae			1	1		
		OrderViviparIformes	FamilyViviparidae	1					
		OrderRissoiformes	FamilyBithyniidae	1					
		OrderLymnaeiformes	FamilyPlanorbidae				1		
PhylumArtropoda	ClassMalacostraca	OrderMysida	FamilyMysidae			1	1		
		OrderAmphipoda	FamilyGammaridae	1	1				
			FamilyPontogammaridae			1	1	1	1
	ClassInsecta	OrderTrichoptera	FamilyHydroptilidae	1		1	1	1	1
			FamilyHydropsychidae	1				1	
		OrderEphemeroptera	FamilyCaenidae	4	1	2	4	2	4
			FamilyBaetidae					1	1
			FamilyPolymitarcyidae	1	1				1
			FamilyEphemerellidae	1		1			
		OrderDiptera	FamilyChironomidae						
			SubfamilyDiamesinae	1	1		1		1
			SubfamilyOrthocladiinae	9	7	4	6	5	11
			Subfamily Chironominae, Tribe Tanytarsini	3	4	3	4	2	4
			Subfamily Chironominae, Tribe Chironomini	5	8	3	7	3	9
			SubfamilyTanypodinae		1	1	1		
			FamilyCeratopogonidae	1	1				
		OrderColeoptera	FamilyHaliplidae				1		
Total:				**38**	**32**	**24**	**37**	**22**	**42**

Distribution of the number of species by families in littoral communities of the Neva River estuary

First of all, let us note that the conducted study did not show any significant changes in the species composition of macrozoobenthos on salinity gradient, increasing from Ol'gino station to Smoljachkovo station. Perhaps, under littoral conditions, the salinity change is not so expressed and does not play a fundamental role in the species' distribution. However, at the station nearest to Saint-Petersburg, Ol'gino, two typical representatives of the freshwater fauna were registered — gastropods *Viviparusviviparus* and *Bithynia tentaculata*, as well as the introduced amphipods species *Gmelinoidesfasciatus*, preferring under conditions of the Neva River estuary habitats with lower water salinity. The same species of amphipods lives at Gorskaja station. As the distance from Saint-Petersburg (starting from Komarovo station in the present study) increases,the composition of amphipod species changes: *Gmelinoidesfasciatus* is displaced by other alien species *Pontogammarusrobustoides*, which is tolerant to low salinity.

Alien species have a significant impact on the local benthic communities. So, water louses *Asellusaquaticus* havenot been found, which formerly were common in the Neva River estuary and reached here considerable number and biomass values[7]. The absence of water louses may partly be due to active predation by introduced amphipod species, which are characterized by low food selectivity [3, 19, 20].

Chironomids are particularly diverse at the littoral communities of the Neva River estuary northern shore: 28 species.Chironomid species composition does not differ significantly at different stations; individuals of genus *Diamesa sp.* are not registered at stations Komarovo and Ushkovo and individuals of species *Ablabesmyiaphatta*— at stations Ol'gino and Ushkovo. Chironomid communities are the most species-rich at stations Olgino, Gorskaja, and Smoljachkovo, and the lowest species diversity is observed at stations Komarovo and Ushkovo, which may be associated with a smaller total number of animals of this group at the indicated stations.

In single quantities in different sampling dates at studied stations occurred bivalves and gastropods (caddis flies) dipterans of the family *Ceratopogonidae*. A brackish-water crustacean *Neomysis integer* once was found at stations Komarovo and Zelenogorsk.Bivalves were represented by two species - *Sphaeriumcorneum* and *Euglesa sp.* at stations Zelenogorsk, Ushkovo and Smoljachkovo. Gastropods were found only at stations Ol'gino, Komarovo, Zelenogorsk, where species*Valvatadepressa*, *Viviparusviviparus*, *Bithynia tentaculata*, *Planorbisplanorbis* were observed.

The number of caddis flies is relatively high at stations Ol'gino and Ushkovo; animals in this group are represented by two species: *Agraylea multipunctata* and *Hydropsychecontubernails*. Rare individuals of caddis flies species *Agrayleamultipunctata* occurred at stations Komarovo, Zelenogorsk and Smoljachkovo;at Gorskaja station, animals of this group were not found at all. Dipterans of the family *Ceratopogonidae* are registered in small numbers at stations Ol'gino and Gorskaja.

At Ol'gino (the station nearest to Saint-Petersburg), a large number of taxonomic groups with the rank of family (18) were noted with a relatively small number of species (38), which corresponds to the diversity of conditions in this area of the estuary. At that, these conditions are not quite favorable for habitation of many species there.

At Gorskajastation, the number of families with respect to other stations is small — only 12 — while the number of species is only slightly inferior to those at Ol'gino station (32). Apparently, the living conditions are not sufficiently favorable here, since this part of the littoral is located in the immediate vicinity of the dam, therefore prominent accumulations of filamentous algae in the coastal and beach areas, the strong smell, and the oil film on the water surface were almost always registered during sampling. At this site were recorded only 2 species of ephemerans (*Caenismacrura* and*Ephoronnigridorsum*).

At Komarovo station, the total number of species is low — 24 from 12 families (subfamilies of the family *Chironomidae*). Here among all studied stations the smallest diversity of chironomids— 11 species — is observed, which may be associated with a low total number of macrozoobenthos at the given habitat.

Relatively large, compared to other stations, the number of macrozoobenthic species (38), which belong to 16 families, is customary for Zelenogorsk station. Apparently, habitat conditions are quite various here, which conduces cohabitation of significant number of different animal species. Once, in July 2009, a brackish-water crustacean was registered here; at that point, the total number of recorded species was relatively small, which might be related to the death of some animal species due to the inflow of water with a higher salinity.

There was asmall number of species and taxa of a higher rank found at Ushkovo station, which stands out from other stations for its peculiar of the environmental conditions. The soil here is represented by a coarse loose sand, and the depth increases rapidly at the coast.

At the station most remote from Saint-Petersburg, Smoljachkovo, the maximum number of species was registered at 42, while the number of families and subfamilies (for *Chironomidae*) is only 14. Such abundance of species here is determined by the large number of chironomid species (25) (table 1). Here and at Ushkovo station,ephemeran species *Baetisvernus*were registered, which prefer cleaner habitats.Scuds are encountered here only occasionally, perhaps, by now the stabilization of the population of recently found alien species in the new habitat has not happened yet.

Thus, at all studied stations chironomids and oligochaetes dominate in abundance and biomass, having high resistance to adverse environmental conditions: oxygen deficiency, eutrophication, sedimentation, and chemical and bacterial contamination [10], as well as amphipods and ephemerans(fig. 2, 3). At all stations of the northern shore of the Neva River estuary, with greater distance from Saint-Petersburg, there is a tendency to reduction of abundance and biomass of all groups of benthic animals from 2009 to 2011.

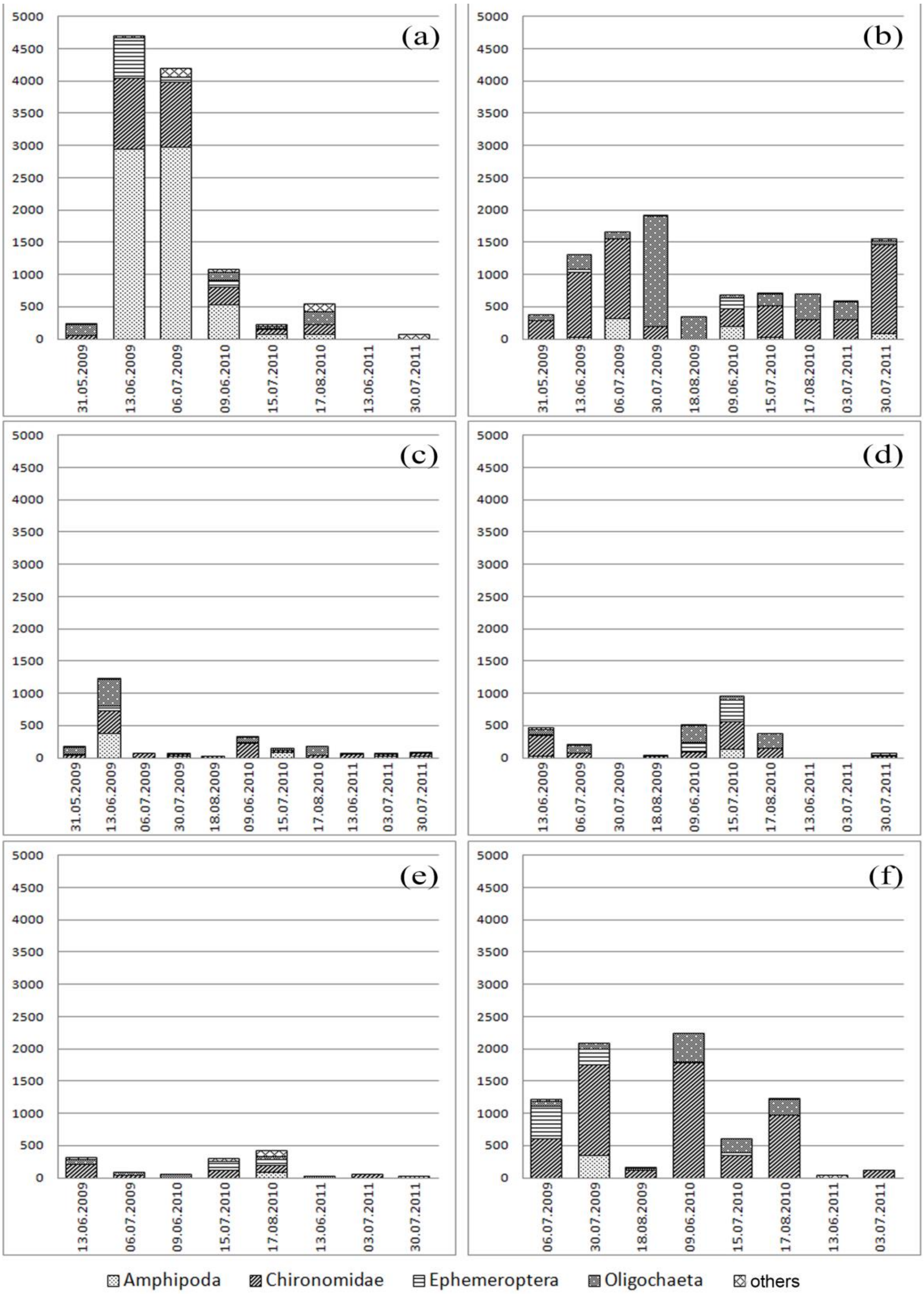

Fig 2: Abundance of macrozoobenthos groups at studied stations, ind./m² (the group "others" unites *Bivalvia, Ceratopogonidae, Coleoptera, Gastropoda, Hirudinea, Mysida, Trichoptera*).

Abundance and biomass of various macro zoobenthos groups vary considerably during the summer season. So, in 2009 abundance and biomass of amphipods at stations Olgino and Gorskaja was at a maximum in July. Air and water temperatures in summer 2010 were unusually high, and probably because of this, amphipods achieved maximum values of quantitative indicators as early as by June. In July 2010, the amphipod abundance and biomass decreased, coinciding with the emergence of imagos of chironomids and ephemerans and, accordingly, with the deterioration of forage base of amphipods. In 2011 abundance and biomass of amphipods are maximal in July (fig. 2, 3).

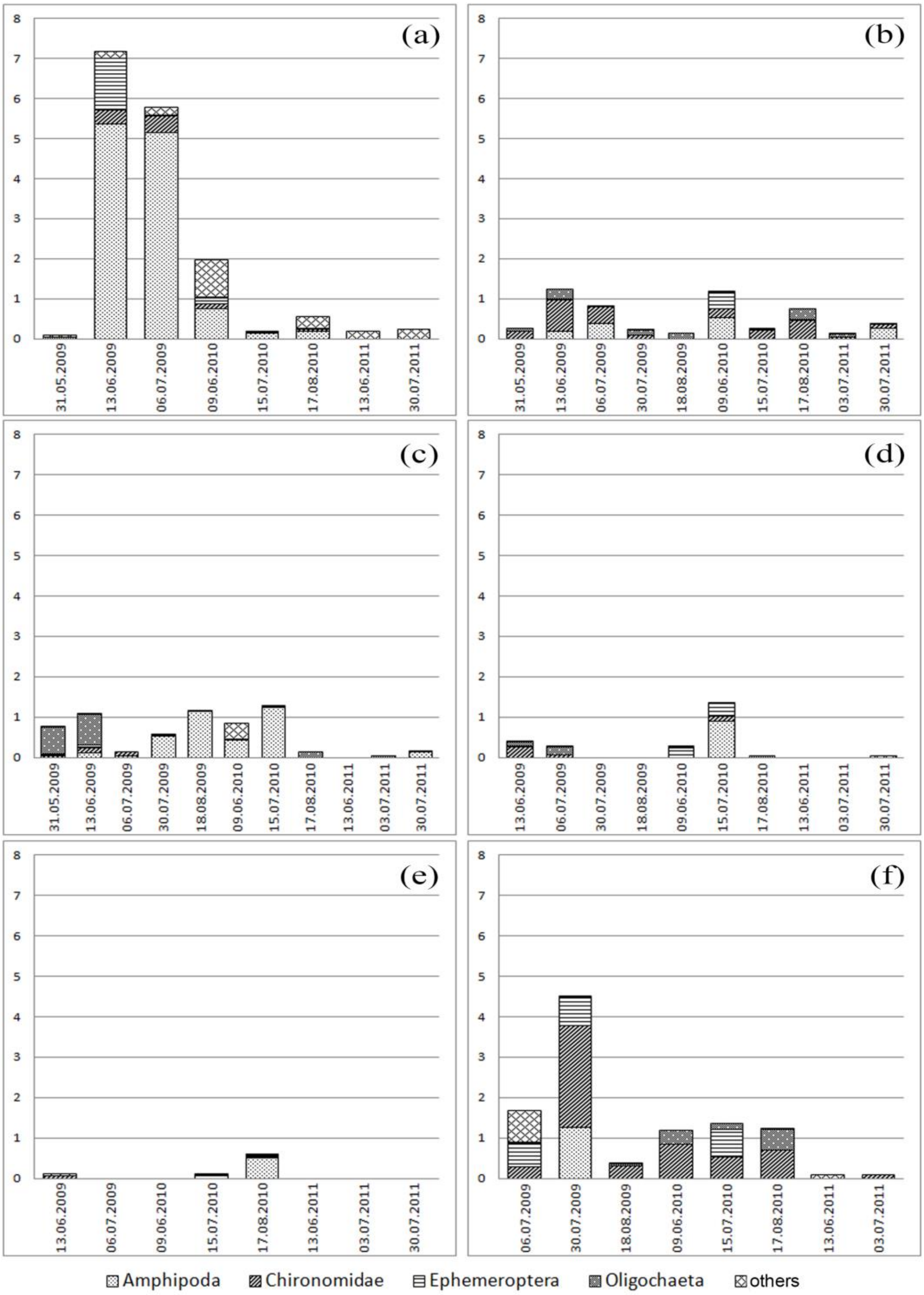

Fig 3: Biomass of macrozoobenthos groups at studied stations, g/m^2 (the group "others" unites *Bivalvia, Ceratopogonidae, Coleoptera, Gastropoda, Hirudinea, Mysida, Trichoptera*).

At Komarovo station in 2009 the maximal abundance of amphipods is registered in June (fig. 2, 3) and the maximal biomass — in August —that is associated with the emergence of a large number of juveniles in early summer and the gradual growth of individuals by the end of the season. In July and August, the biomass of amphipods made up the bulk of the biomass of macrozoobenthos in this habitat; adult individuals of this species differ in significant size from other benthic faunal forms.The sharp decline of animal abundance at Komarovo station in early July 2009 (fig. 2) could partly be due to the emergence of chironomidimagos and also because of the pressure from a large number of predatory amphipods. In search of a better forage base, amphipods migrate out of this habitat or perish because of the lack of food, thereby their abundance also decreases. It is shown in the literature on the Neva estuary littoral communities [17] that in the last decade the maximum level of benthic animal mortality is observed in July and August, during hypoxia period. Researchers [17] show that hypoxia affects not only sensitive species, but also organisms such as amphipods to which the *r*-strategy pertains. In 2010-11,maximum abundance and biomass of amphipods was registered in July, in the first half of the summer their biomass exceeded the biomass of all other macrozoobenthos groups.By the end of the 2010 summer season, the biomass of amphipods at Komarovo station was sharply reduced, while the abundance and biomass of oligochaetes had increased, perhaps due to the deterioration of living conditions for amphipods.

At the station Smoljachkovo, amphipods have been found only once — at the end of July 2009, while these animals were not detected at the neighboring station Ushkovo in 2009 (fig. 2, 3). Abundance and biomass of amphipods varies at different stations at different sampling time; often animals of this group were not registered in samples at all. The following pattern is observed at all stations: when the abundance of amphipods is high, the abundance of oligochaetes is small, and vice versa.

The abundance of chironomids at stations Ol'gino, Gorskaja, Komarovo, Zelenogorsk,Smoljachkovo changes little, if at all, from June to July 2009, while the biomass increases somewhat due to the larvae growth: insect emergence takes place in July-August. In 2010-11, the emergence of chironomidimagos is registered by mid-July; in August the young of the second generation appears at some stations (fig. 2, 3). At the station Ushkovochironomid emergence occurs a little bit later.

Chironomid biomass decline at Gorskaja station in early July 2009 with an increasing abundance (fig. 2, 3) may be associated with the appearance of a certain number of juveniles of these insects and larger individual predation by amphipods. In support of this hypothesis is the fact that by the beginning of July abundance and biomass of amphipods increases markedly.Herewith the similar indices of oligochaetes population decrease, because they can be eaten out by amphipods.

In June 2009 and 2010 at stations Ol'gino, Gorskaja, Komarovo, Zelenogorsk abundance and biomass of ephemerans is high (fig. 2, 3), then, by July, these indices decline drastically due to the emergence of the insects imagos.

In general, it may be noted that, in 2009, 2010, and 2011, there's a trend of reduction inmacrozoobenthos abundance and biomass on salinity gradient from station Ol'gino to Ushkovo station.At the same time, at the most remote station (Smoljachkovo) macrozoobenthic quantitative indicators increase again to about values of indicators at Ol'gino station community (fig. 2, 3), and in 2010 the abundance of animals at Smoljachkovo exceeded that at Ol'gino by a factor of 3-5.

The anthropogenic impact on littoral communities

The environmental situation in the Neva River estuary is constantly changing. The most significant changes in the ecosystems of the estuary are caused by such factors as direct anthropogenic impact (destruction of habitats, specifically the construction of the dam and new land reclamation from the sea), eutrophication, alien species invasion, and toxic pollution.

The consequences of intensive dredging and land reclamation work begun in 2005 are of particular interest. Almost across all water area of the estuary abnormally high levels of turbidity are observed, the removal of polluted waters to the eastern part of the Gulf of Finland increased [8].

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The Laboratory of Freshwater and Experimental Hydrobiology of Zoological Institute of the Russian Academy of Sciences kindly provided data on abundance and biomass of macrozoobenthos at stations Ol'gino and Zelenogorsk in 1999 and 2003-05. This allows us to evaluate changes in the composition and structure of the littoral communities due to the negative impact of hydraulic works carried out at the western tip of Vasilyevskyisland.

From 1999 to 2011 at Ol'gino station there has been a gradual decrease in abundance (from 15-20 thousands of ind./m^{2}in 1999 toa hundred of ind./m^{2}in 2011) and in biomass (from 20-25 g/m^{2}in 1999 to 10-15 g/m^{2}in 2003-2004 and to 1-3 g/m^{2}in 2009-2011) of all macrozoobenthic groups (fig. 4).Research carried out in 2002 and 2004-2005showed the dominance of chironomids and amphipods in littoral communities, as well as the decrease in macrozoobenthos biomass in comparison with 1985 and 1999, at that time no local species of amphipod *Gammaruslacustris* was present in samples, apparently it was displaced by introduced species of amphipods *Gmelinoidesfasciatus* [2].

It is noted in the literature [6] that environmental changes in 2007-08 had different reasons. In 2007, they were mainly related to the hydraulic works in the Neva Bay, while in 2008,they were associated with a mild, almost ice-free winter. For 2008, the transparency increase and the reduction of the content of inorganic fraction in the suspended matter were in character, while in the ravage, the elevated turbidity and high concentration of nutrients remained, the massive algal nuisance (micro- and filamentous algae) was observed, accompanied by the accumulation of detritus in the water column and by the suffocation at the bottom at night time.

Macrozoobenthos studies in the Neva Bay, held in August 2007, showed that the biomass and diversity of benthos declined sharply, particularly in the eastern part of the Neva Bay. Such low indices were recorded for the first time in the last 100 years since the beginning of the Neva Bay benthos study. Such negative changes have occurred also in the adjacent part of the Gulf of Finland.

Until 2004,chironomids and oligochaetes dominated in benthic communities. Later, amphipods became dominant;while there is a replacement of native amphipod species on introduced ones (in 2009-11 one amphipod species is registered —Gmelinoidesfasciatus), leeches have become extremely rare (one species is registered —Erpobdellaoctoculata), dragonflies and water louses are totally absent (fig. 4).

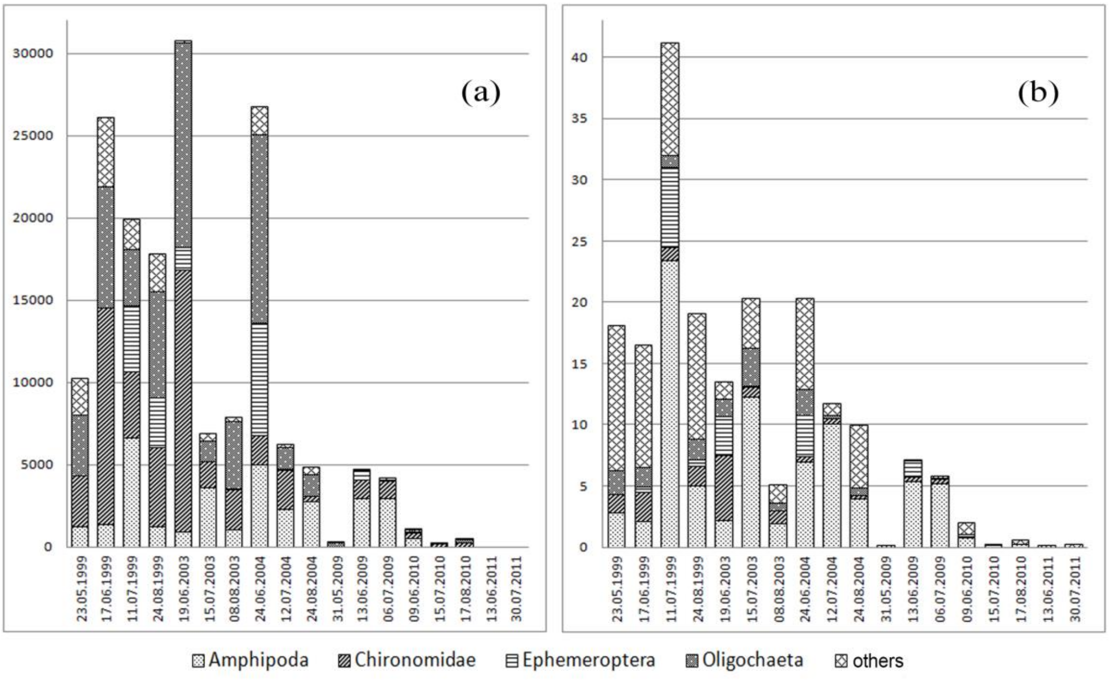
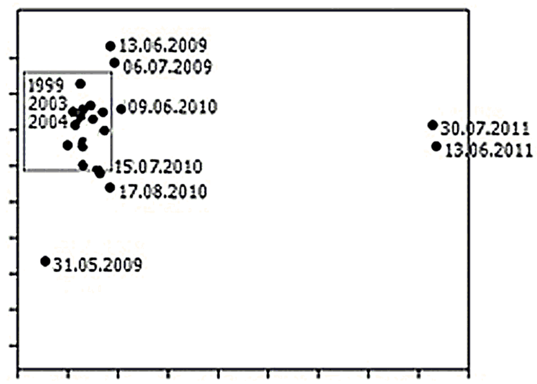


Fig 4: Abundance (a), ind./m^2, and biomass (b), g/m^2, of macrozoobenthic groups at Ol'gino station (the group "others" unites*Acroloxus*, *Bivalvia*, *Ceratopogonidae*, *Coleoptera*, *Gastropoda*, *Hirudinea*, *Isopoda*, *Trichoptera*, *Turbellaria*, *Zygoptera*).

Histograms shown in fig. 4 clearly demonstrate changes that have occured in littoral communities in the early 21st century. Nevertheless, data on abundance and biomass of animals were additionally analyzed by us using method of multidimensional scaling. It allows to take into account the more subtle differences in community structure and present the results in the form of a visual "map", where the proximity of points (in our study indicating sampling date) shows the similarity of communities at different timepoints. Conclusions of similarity or difference between samples are made by the level of stress, the value of which in the analysis shows their certainty. Gradations of stress level are set for the method of multidimensional scaling and are given in the specialized literature. The results of carried out multidimensional scaling (fig. 5) confirm the hypothesis that the structure of macrozoobenthos communities in 2011 is markedly different from that in the other years of observations, indices of abundance and biomass in some dates of 2009 and 2010 are slightly different.Fig. 5 shows that samplings in 1999, 2003-04, are located more compactly (for readability are encircled with a frame), and the points of other sampling dates dispersed by the "map" that allows us to speak about the instability of the littoral communities in these years.The axes can be interpreted as the effect of some factors, but in our case a lot of them affect the macrozoobenthos community, so the interpretation of the axes does not seem possible.



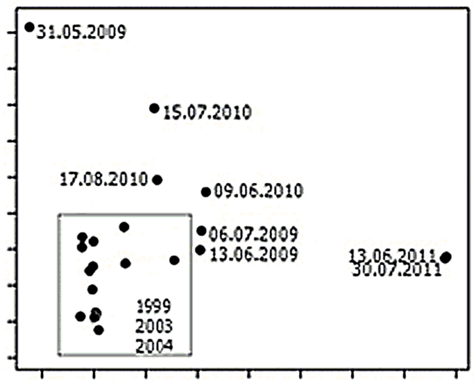


Fig 5: Comparison of macrozoobenthos communities at Ol'gino station using method of multidimensional scaling in different sampling dates: by abundance (left), the stress level is 0.14; by biomass (right), the stress level is 0.09.

Changeability of conditions in 2006-08 in varying degrees affected all observed groups of living organisms. Rivage biotopes underwent major changes at depths from the waterline down to 1.5 m. There, conditions were not favorable for the development of invertebrates, even for relatively eurybiontic invasive amphipods, and quantitative indicators of their populations in these years, especially in August, were significantly lower than in previous years [6].

Similar changes in the community composition and structure occurred at Zelenogorsk station. So, the average abundance of macrozoobenthos organisms decreases from 15-20 thousands of ind./m^2 in 2005 to 500-1000 ind./m^{2}in 2009-10 and up to few dozens ofind./m^2 in 2011, leeches disappear from communities (fig. 6).

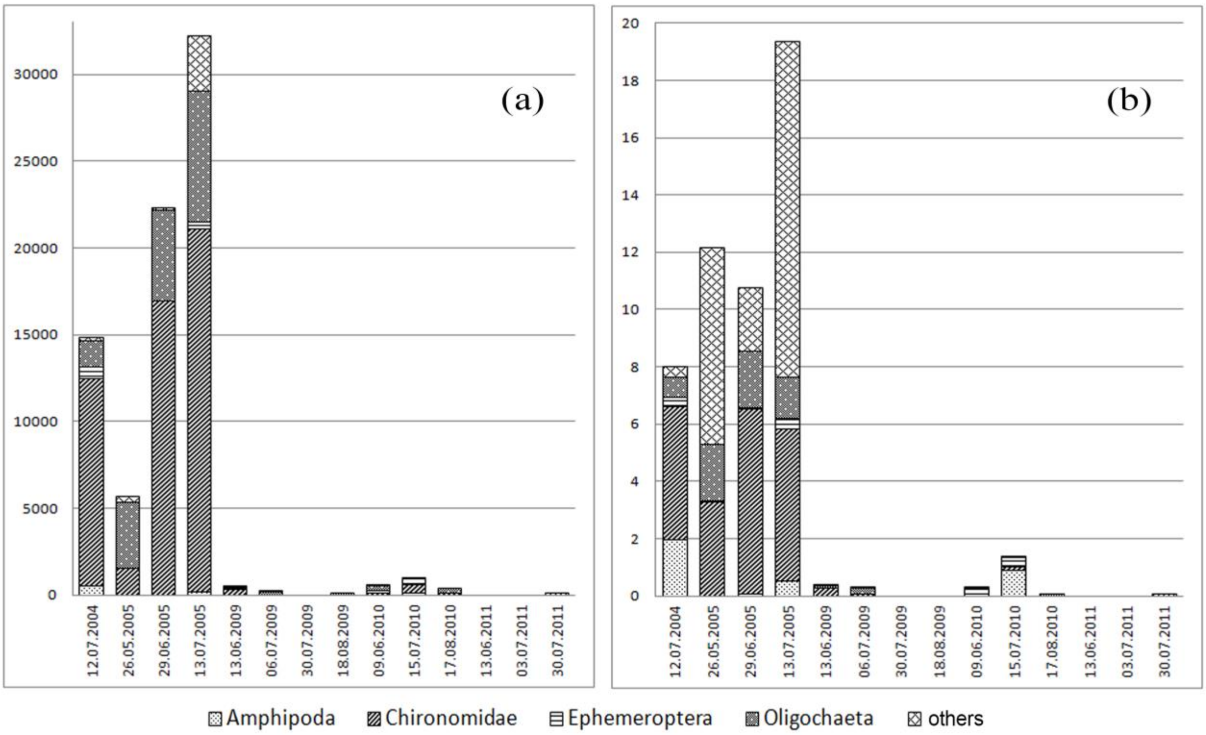


Fig 6: Abundance (a), ind./m², and biomass (b), g/m², of macrozoobenthic groups at Zelenogorsk station (the group "others" unites *Bivalvia*, *Ceratopogonidae*, *Coleoptera*, *Gastropoda*, *Hirudinea*, *Mysida*, *Trichoptera*).

Chironomids and oligochaetes dominate by abundance. Oligochaetes dominate by biomass in all years (in 2011 oligochaetes were not registered) and in 2010 dominate amphipods (*Pontogammarusrobustoides*). The average biomass of macrozoobenthos decreases from 8-10 g/m^2 to less than 1 g/m^2 (fig. 6).

Data on quantitative indicators of macrozoobenthos at Zelenogorsk station were also analyzed using the method of multidimensional scaling. However, a small number of sampling dates makes a graphical representation of the analysis result not as clear and interesting as for Ol'gino station, therefore it is not described in this paper, but the obtained stress level allows us to speak about the significance of differences at Zelenogorsk station communities at different times.

Through the example of stations (Ol'gino and Zelenogorsk) described above, we can see a significant change in the structure of macrozoobenthos communities, which is characteristic for the whole Neva Bay and for the eastern part of the Gulf of Finland. Namely, there is an ubiquitous sharp decline in abundance and biomass of all groups of macrozoobenthos, species richness is also reduced, and leeches and dragonflies are disappearing.

CONCLUSIONS

Substantial anthropogenic load, appearance of the new types of economic activity such as intensive flushes of the new land parts, and presence of the quantity of results from the previous investigations: all this makes the Neva River estuary an interesting and perspective object for the comprehensive research on littoral communities anthropogenic transformation processes.

Habitat heterogeneity of the Neva River estuary littoral creates conditions for communities formation, which keep generalities in spite of the difference of conditions. Research showed that during many years in the littoral communities of the northern shore of the Neva bay amphipods, chironomids and oligochaetes dominate by abundance as well as by biomass. Amphipods at all sites are represented by 2 alien species. One species (*Gmelinoidesfasciatus*) inhabit the communities of 2 sites nearest to Saint-Petersburg, while at the open part of the estuary lives another species (*Pontogammarusrobustoides*). Ephemerans are numerous, grandly functioning in the food chains by energy transfer from detritus to the second-order consumers of the second order (amphipods, fishes). Typical representatives of the freshwater fauna are not numerous and do not play a significant role in communities' functioning. So, leeches are extremely rare, dragonflies, water-slaters, and indigenous amphipods species are absent, what affirms the significant influence of alien amphipods species on the littoral communities.

The sites farthest from Saint-Petersburg (Ushkovo and Smoljachkovo) are characterized by prevalence of the species preferring rather clean habitats, at these sites values of number and biomass of animals are high. At the sites closer to Saint-Petersburg (Olgino and Zelenogorsk) the habitat conditions are not favorable enough, but diverse, the fact that a lot of taxonomic groups with a rank of family by rather small number of species enter into the composition of biotic communities attests to it.

Species composition of communities doesn't change substantially moving away from Saint-Petersburg along the salinity gradient. At the site closest to Saint-Petersburg (Olgino) 2 representatives of freshwater fauna are registered: gastropods *Viviparusviviparus* and *Bithynia tentaculata*. At the same, time there's a moderate upward drift of macrozoobenthos number and biomass moving away from Saint-Petersburg; these parameters increase again at the site farthest from the city (Smoljachkovo).
Comparison of the research results with the data published before allowed to ascertain, that from the start of hydroengineering work in the Neva River mouth the substantial changes occurred in the littoral communities structure. So, from 2009 to 2011, quantitative characteristics of macrozoobenthos communities declined drastically. It should be noted that moving away from the main pollution source,an insignificant increase of benthos fauna species diversity along with the increase of their number and biomass is observed. Over period of the study at the Neva River estuary,we did notregistered a trend to restoration of the quantitative characteristics of benthic communities. In other words, from the start of hydroengineering work number and biomass of macrozoobenthos littoral communities declined drastically and recovered very slowly when the anthropogenic load is removed (dropped).

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