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(VSEGEI)

INTERNATIONAL SCIENTIFIC FORUM «GULF OF FINLAND – NATURAL DYNAMICS AND ANTHROPOGENIC IMPACT», DEVOTED TO 50TH ANNIVERSARY OF TRILATERAL GULF OF FINLAND CO-OPERATION

ABSTRACTS

Russia, St. Petersburg, October 17–18, 2018

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The book contains the abstracts for presentations from the International Scientific Forum «Gulf of Finland – natural dynamics and anthropogenic impact», devoted to 50th anniversary of Trilateral Gulf of Finland Co-operation (17–18 October 2018, St. Petersburg, Russia). The presentations are devoted to current environmental problems of the Gulf of Finland including marine and environmental geology, hazardous geological processes, geo- and biodiversity, environmental friendly exploration of natural resources, marine and coastal ecosystems conservation, sedimentological and geochemical processes within the Gulf of Finland basins, monitoring of hazardous substances in ecosystems, fish and fishery, marine spatial planning.

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Dear colleagues and friends,

let me welcome you on behalf of the Federal Agency
on Mineral Resources of the Russian Federation, scientists
and the Administration of A.P. Karpinsky Russian Geological Research Institute!

It is a great honor for our Institute to host such an important event as the International Scientific Forum "Gulf of Finland – natural dynamics and anthropogenic impact", devoted to the 50th Anniversary of Trilateral Gulf of Finland Cooperation.

We are very happy that the conference, dedicated to the multidisciplinary research and environmental friendly management takes place in St. Petersburg – the city, which, due to its location on the coast of the Gulf of Finland, has always been very exposed to marine and coastal hazards. On the other hand, from the moment of its foundation by Peter the Great, St. Petersburg has been one of the most open and friendly Russian cities welcoming international cooperation in different spheres of life, including science.

Marine and coastal geology and mapping, as well as environmental research are among the most important directions of our Institute's activities. We pay special attention to marine and environmental geology of the Baltic Sea, an enclosed sea of Europe. Our Institute is deeply involved in international cooperation. Joint transboundary activity undertaken in the Gulf of Finland, together with the participation of geological surveys of Russia, Finland and Estonia, as well as institutes and universities of three countries represent one of the brilliant examples of scientific research, important, from practical point of view, for implementing environmental protection measures.

We hope that within the framework of the Trilateral Gulf of Finland Scientific Forum quite a few problems of risk management and protection of unique environment of the Gulf of Finland will be discussed by high-level representatives of the international scientific community.

Let me wish all of us to have fruitful discussions, interesting talks and new joint projects in the course of the Conference.

A.P. Karpinsky Russian Geological Research Institute
Director General,
Dr. *Oleg Petrov*

Surveys and initiatives to preserve the environment of the Gulf of Finland

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Nord Stream 2 is a new pipeline through the Baltic Sea, which will transport natural gas over 1,230 km from the world's largest gas reserves in Russia via the most efficient route to consumers in Europe. The route for the pipeline starts in the southern Gulf of Finland with its landfall in the Kingisepp district. The Nord Stream 2 project is being implemented in the safest possible way with full awareness of local ecological and environmental conditions. Nord Stream 2 conducted comprehensive studies and surveys as part of the EIA process and well beyond in the Kurgalsky peninsula and the Gulf of Finland to ensure responsible project implementation and to elaborate compensation and offset measures. The works were carried out in accordance with an established international methodology and covered the entire territory of the reserve. Nord Stream 2 is highly aware of its responsibility to preserve the nature and developed the Environmental and Community Initiatives (ECo-I) Strategy. Key focus areas have been defined through consultations with the regional and municipal authorities, community elders and locals, scientific community and NGOs.

Systematization of the biodiversity of the Gulf of Finland in the zone of critical salinity, the study of brackish-water species in order to elucidate the similarities and differences in the evolution of their faunas and their role in brackish-water ecosystems

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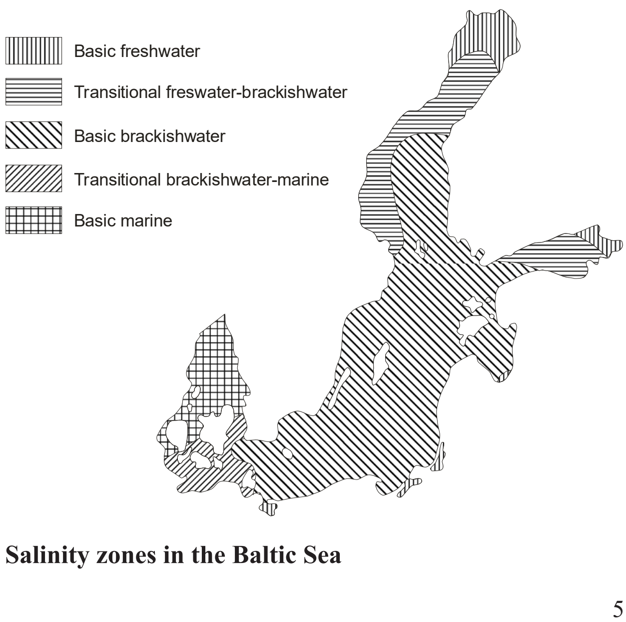
Water salinity is one of the major abiotic environmental factors influencing hydrobionts. Ascertainment of specificity of the attitude of aquatic animals and plants to this factor is important to understand both autoecological and synecologilal rules.

Salinity 5–8 ‰ of oceanic waters has a critical biological effect. For the first time about this spoke in the first half of the XX century, the German zoologist A. Remane [1]. Then V. V. Khlebovich formulated the main principals of the theory of critical salinity [2]. The ideas of A. Remane and V. V. Khlebovich found a continuation in the works of O. Kinne, who proposed the term horohalinicum [3, 4]. On the critical nature of salinity range of 5–8 ‰ impact on biodiversity have pointed other researchers also.

This first barrier salinity or α-horohalinicum is a universal barrier when passing through which a number of significant biological properties change at different levels of biological integration. It is the upper limit of freshwater fauna distribution and the lower boundary of marine fauna distribution and is also the core of brackish waters.

Later it was a formulated conception of relativity and plurality of water barrier salinity zones. According to this conception [5], zones of barrier salinities are relative, on the one hand, to the degree of the osmoregulatory capacities of hydrobionts and, on the other hand, to the water chemical composition. There are several zones of barrier salinities and they are not of equal importance. Barrier salinity zones revealing in the hydrosphere supposes first studying the osmoregulatory capacities of hydrobionts. The purpose of this study is to reveal types of osmotic relations of internal media with the environment, to find experimental limits of salinity tolerant ranges and to analyse data on salinity boundaries of hydrobiont distribution in nature. There are known at least four barrier salinities proposed for oceanic waters [6]: α-horohalinicum – 5–8 ‰, β-horohalinicum – 22–26 ‰, γ-horohalinicum – 45–50 ‰ and δ-horohalinicum – 0.5–2 ‰, the upper limit of stenohaline freshwater species distribution.

The hydrosphere of our planet can be conditionally divided into freshwater, brackish water, marine, and hyperhaline zones. Between these four basic zones, there are transitional zones. Based on the following main principles of relativity and plurality of salinity barrier zones [5, 6], the following approximate ranges of all basic and transitional salinity zones were suggested for oceanic waters. Freshwater zone is from fresh water up to 2 ‰; brackish-water zone is from 5 ‰ up to 8 ‰, coinciding with α-horohalinicum; marine zone is from 26 ‰ up to 40 ‰; hyperhaline zones is >50 ‰. Transitional between freshwater and brackish water zone is from 2 ‰ up to 5 ‰; transitional between a brackish water and a marine zone is from 8 ‰ up to



Salinity zones in the Baltic Sea

26 ‰; transitional between marine and hyperhaline zone is from 40 ‰ up to 50 ‰.

In the Baltic Sea all these four barrier salinities, 4 basic and 3 intermediate zones can be found. Nowadays the Baltic Sea is the only marine water body where basic brackish water salinity zone (i.e. critical salinity zone or α-horohalinicum) covers more than half of its area (62 %) is the Baltic Sea [6]. In this regard, the Baltic Sea can be called "critical" sea.

The Baltic Sea is young and was a cold lake in glacial times. It still retains many features of a lake. It is a semi-closed, shallow, brackish water body with a smooth salinity gradient, and unique fauna and flora. The biodiversity of the Baltic Sea is relatively low but is unique [6]. The biodiversity of this young sea was formed in postglacial times, with a highly heterogeneous composition. It consists of three main components: marine, freshwater and brackish water. The first group is the main portion of the Baltic Sea biota. It includes relicts of previous geological times and immigrants from remote marine water bodies. The second group includes a large number of Baltic Sea inhabitants that arrived with the freshwater inflows. The third group is represented by a large number of species and is divided into two subgroups:

1. Ancient brackish water arctic relicts (pseudorelicts-immigrants) formed in glacial times in relatively fresher water areas of the Arctic basin that migrated into the Baltic Sea in postglacial times from the northeast and east, possibly via fresh waters; and
2. Brackish water forms originated from freshwater forms.

The Gulf of Finland is one of the most freshened parts of the Baltic Sea. The freshwater zone in the Gulf of Finland occupies inflowing rivermouths and also adjoining areas of shallow gulfs. The absence of pronounced high and low tides in the Baltic Sea contributes to a stable existence of δ-horohalinicum. In the Gulf of Finland this barrier salinity is well distinguished in its eastern part. Many freshwater plants and animals live only here never being observed in the Baltic Sea proper. These waters are shallow. Barrier salinity, δ-horohalinicum, prevents freshwater organisms from invading other parts of the Baltic Sea. The brackish-water zone and α-horohalinicum is in the Gulf of Finland its western part. It is occupied by brackish-water ecosystems, which exhibit the poorest species number. Some of them are descendants of inhabitants of a glacial lake in the Ice Age that existed where the modern sea is now located. This zone occupies the deepest part of this gulf. Between these two zones there is transitional zone with salinity 2–5 ‰. Both freshwater and brackish-water organisms can live in it. Thus the waters of the Gulf of Finland have a smooth salinity gradient. Both freshwater and brackish-water faunas exist here. Biodiversity of this part of the Baltic Sea is relatively low but it is unique in its own way and needs special measures to preserve it.

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Effect of eutrophication, toxic pollution and dredging on biodiversity of benthic animals, and water quality of the Neva Estuary

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Intensification of eutrophication processes in the Neva Estuary at the end of the 20th and the beginning of the 21st centuries particularly pronounced in the coastal zone of the Resort zone of the eastern Gulf of Finland, as a result of technogenic impacts in connection with the intensification of navigation, undoubtedly affected structural characteristics of benthic animal communities. 188 taxa of benthic animals were recorded in the Neva Estuary in 1994–2017.

The Neva estuary condition has been studied by members of the Zoological Institute of the Russian Academy of Sciences since 1982. The long-term studies carried out by the Zoological Institute of the Russian Academy of Sciences have shown that the state of biological communities of the eastern Gulf of Finland are directly related to quality of water and bottom sediments reflecting such anthropogenic impacts as eutrophication of open and coastal waters of the Gulf of Finland and their contamination by toxic substances. During the study period (1982–2017) the number of species, species diversity, abundance, biomass and production of benthic animals in the Neva Bay and in the eastern part of the Gulf of Finland were largely determined by toxic pollution (heavy metals, oil products and mercury in water and bottom sediments), and by the rate of primary production in the ecosystem. Indicator species of -meso and polysaprotoxobic waters became predominant among the widespread oligochaetes and chironomid larvae [1, 3].

During the last decades the substitution of chemical water quality control by biological one goes on in many countries and in Russia as well, and the priority of biological indices became evident for ecosystem state assessment [2]. Methods of ecosystem state and water quality assessment based on structural characteristics of benthic communities have been applied traditionally and successfully in the entire world. We used integrated index IP' specially devised for water-bodies and rivers of north-western Russia to assess the water quality and a state of ecosystems of the Neva Estuary. On the average water quality of the Neva Bay assessed from IPʹ values was relatively stable during 1994–2017. It was assessed as «polluted» with exceptions for 2006 and 2015 caused by large-scale dredging works.

Results of the statistical analysis showed that in 1994–1997 the number of species in the Neva Bay was determined largely by toxic pollution (heavy metals, oil products, and mercury in the water and bottom sediments) and to a lesser extent by primary production values of the ecosystem [1].

Results of the multi-regression analysis show that in 2003–2004 the number of species and species diversity of bottom animals in the Neva Bay declined with increased primary production and chlorophyll "a" concentration. The values of Shannon's Index of species diversity for benthic animals in the Neva Bay were determined equally by values of primary production and chlorophyll "a" concentrations [1]. Toxic pollution did not have a suppressive impact on biomass and production values of benthic animals in 1994–2005, the density and biomass of zoobenthos increased with growing pollution.

In 2005–2009 a study was conducted on the influence of hydrophysical and hydrochemical parameters of the Neva Estuary on zoobenthos structural characteristics and on the values of calculated indices. Statistical analysis showed that with growing concentrations of oil products, lead, zinc, caesium (Cs 137), and chromium in near-bottom waters and bottom deposits of the Neva Bay a decline of species richness and species diversity of benthic animal was observed. In comparison with the 1990s, the concentration of zinc in near-bottom waters increased notably from 2005 to 2009 and its negative impact on species richness and species diversity of benthic animals grew significantly. At high concentrations of caesium, chromium and arsenic in 2005–2009 low values of species richness and species diversity of benthic animals were recorded [3].

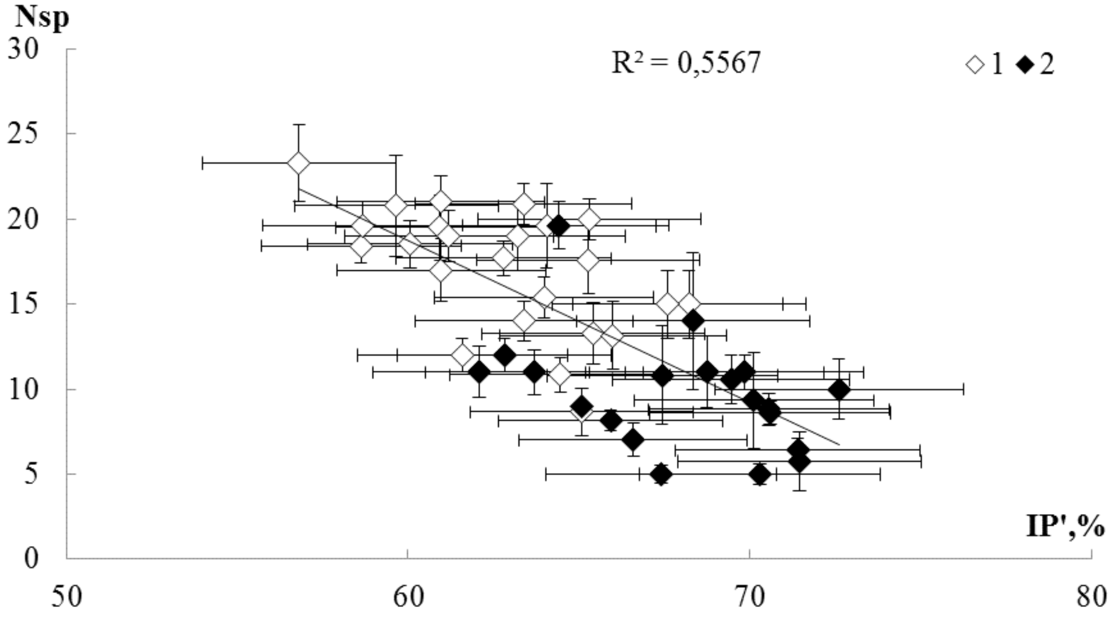
Research period had been accompanied by a revival of the industry of St.Petersburg, construction of ports, active navigation, development of Sea facade and completion of the construction of the St.Petersburg Flood Prevention Facility Complex and a large-scale hydrotechnical works: building of a Marine Multifunctional Reloading Complex (MMRC) "Bronka" and approach fairway to it. During dredging, a large amount of suspended matter is produced, which is carried over considerable distances, substantially worsening the conditions of existence of both benthos and phytoplankton. In 2006–2009 construction of the Sea facade of St. Petersburg led to a sharp decline of the average biomass of benthic animals in the Neva Bay from

95 to 17 in 2006 and to 6 g/m² in 2007. Species richness and species diversity of benthic animals over the major part of the Neva Bay declined in 2006–2007, but increased in 2008–2009 to a level observed in 2005. The last years (2012–2017), accompanied by a large-scale hydrotechnical works: the building of the Marine Multifunctional Reloading Complex (MMRC) "Bronka" and approach fairway to it. Average for the Neva Bay values of IP' increased during these stage from 62.8 ± 2 in 2012 to 67,6 ± 3 % in 2015. The state of the ecosystem of the Neva Bay in 2015 markedly deteriorated and was assessed also as in 2006 as "crisis", and waters as "polluted-dirty" (4–5th class). The number of species of benthic animals in the fourth stage regularly declined from 18 ± 1 to 15 ± 2 sp./m², but Index of species diversity almost did not change (from 2.8 ± 0.2 to 2.7 ± 0.2 bit/ind.).

The average number of benthic animals in the water area of the Neva Bay decreased more than 2 times (from 15054 ± 3549 to 6832 ± 2138 ind./m²), that was associated with large-scale hydraulic works in this period. The average biomass of macrozoobenthos of the Neva Bay in 1994–2015 successively decreased more zhen 10 times, from 16.313 ± 3.430 in 1994 to 1.5 g/m² in 2015, which was associated with a reduction in the biomass of small Pisidiidae bivalves, and oligochaetes.

Habitat conditions of animals in the eastern part of the Gulf of Finland were less favorable than in the Neva Bay. As a consequence of the geochemical barriers, more than 70 % of pollutants entering the Neva estuary settled in that area [5]. A water saltiness 5–7 ‰, which was recorded in the deep area of the eastern part of the Gulf of Finland, negatively influenced both freshwater and brackish-water animals [4]. This influence was worsened by abrupt and nonperiodic changes of salinity. In low reliefs, where heavier saltwater accumulates, an oxygen deficiency was detected for many years [6]. This was the reason that the species composition and abundance of macrozoobenthos in the eastern part of the Gulf of Finland were determined by a combination of natural and anthropogenic factors that were unfavorable for their development.

Average values of Integrated Index IP' varied in 1994–2017 from 65.9 ± 1.9 to 72.6 ± 3.3 %, (except 2012–2013 and 2016–2017) characterizing on the average the state of the Resort zone of the eastern Gulf of Finland as "crisis", and waters as "polluted-dirty" (4–5th class of waters), one class lower than the waters of the Neva Bay. In the Resort zone of the eastern Gulf of Finland mean values of the IP′ integrated index changed during the period 2012–2013 from 63.7 ± 5 to 65.1 ± 4 % and during the period 2016–2017 from 62.1 ± 2 to 62.8 ± 5 %, characterizing the state of the ecosystem as "critical" and water quality as "polluted", as well as the water of the Neva Bay. In 2014–2015 the state of this part of the estuary significantly worsened and assessed as "crisis", and the water as "polluted-dirty." As a consequence of pollution species, diversity of benthic animals in the Resort zone of the eastern part of the Gulf of Finland was notably lower than in the Neva Bay. As a result of more intensive pollution (IP′) number of species of



Relationship of average number of species of benthic animals (*Nsp*) at one station and average Integrated index (*IP′*) in the Neva Bay (1) and Resort zone of the eastern Gulf of Finland (2) in 1994–2017 for 450 examined stations. Correlation coefficient R^2 = 0.56 (P – 0.05)

benthic animals (Nsp) at one station in the Resort zone of the eastern part of the Gulf of Finland was considerably lower than in the Neva Bay (figure).

The morphological anomalies in abundant species of oligochaetes and chironomids in the Neva Bay and the Resort zone of the eastern part of the Gulf of Finland were connected with toxic pollution of bottom sediments of the estuary, in particular by heavy metal and oil product pollution. It should be emphasized that in 1994–1995, as compared to the 1980s, the portion of anomalous individuals having morphological deviations increased in common oligochaete species Spirosperma ferox. Abnormalities were also noted in chironomid larvae. Apparently, the morphological abnormalities were caused by increasing toxicity of the habitat.

The studies conducted show a high extent of dependency of structural characteristics of benthic animals species composition, the number of species, abundance, biomass, Shannon species diversity index, and Integrated index IP' on hydrophysical and hydrochemical characteristics of water and bottom sediments. Integrated mean assessment of water quality over the entire Neva Bay during 22 years (1994–2017) remained relatively stable, waters (except in 2006 and 2015) were assessed as "polluted" (4th class), and state of the ecosystem as "critical".As compared to the Neva Bay habitat conditions of animals in the eastern Gulf of Finland were worse and were determined by a combination of natural factors unfavorable for development of benthic animals and anthropogenic impact. Average characteristics of benthic animal communities – species number and species diversity index showed a high value of dependency on pollution (IP′) in the Neva Bay and Resort District of the eastern Gulf of Finland.

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Reproductive disorders and malformed embryos of amphipods for control of environmental state in the Gulf of Finland

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The malformed amphipod embryos as a indicator for biological effects cover response at the organism level and bridge the contamination status to the state of the biota. "High" and "good" classes indicate that areas are not disturbed by hazardous substances, while "moderate", "poor" and "bad" indicate different degrees of disturbance by hazardous substances. The indication should be conducted with amphipods collected from contaminated and reference areas. The responses can be compared quantitatively to identify whether problems exist; and the levels of contaminants in environments can be related to the biological effect (proportion of malformed embryos in amphipods). Biological effects of toxicants on embryonic development variables in amphipods were obtained for the amphipod species: Gammarus tigrinus, Pontogammarus robustoides, Gmelinoides fasciatus in areas nearby two big cities (Helsinki and St Petersburg). Using this biomarker, study sites near St. Petersburg and Helsinki were classified as having low or moderate pollution. Embryos in the marsupium, which is clearly visible through the transparent exoskeleton of living females, were carefully dissected and examined under a stereo microscope for malformed and normal embryos (at least 20 females per site). The types of malformations in amphipods are described in detail in Sundelin et al. [1] while examples on malformations specifically in *G. fasciatus* can be found in [2, 3]. This study found a tendency to increase the frequency of malformations in amphipod embryos near eutrophied areas, ports and with an increase in the PAH content in bottom sediments (in the case of St Petersburg area). The results suggest that embryonic disorders variables in gammaridean amphipods are responsive and suitable tool that can be used as primarily indicator of sediment quality in different Baltic Sea regions.

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Long-term monitoring of the vascular plant flora of the Russian islands of the Gulf of Finland: dynamics of native and alien flora

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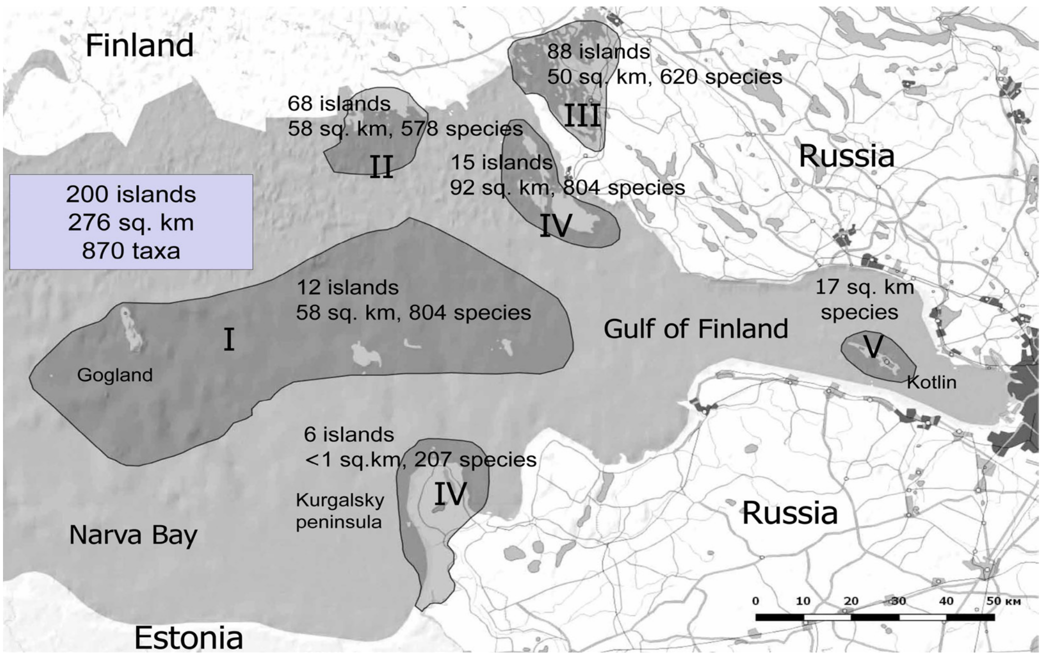
Numerous islands of the Gulf of Finland (Baltic Sea) are unique objects for phytogeographical research and study of the flora dynamics. Since 1994, the inventory and long-term monitoring of the flora of the islands of the Gulf of Finland (within Russia) have been carried out [1–7]. The study area (ca. 280 sq. km) comprises more than 200 islands, which can be divided into 6 main island groups: the outer islands; the skerry islands near the northern coast of the Gulf of Finland; the Berezovye Islands; the islands in the Vyborg Bay; the islands near Kurgalsky Peninsula, and the islands in the Neva Bay. According to the author's data, ca. 870 taxa of vascular plants (including noto- and microspecies) are known from the Russian islands of the Gulf of Finland.

Information on the flora of most of the islands until the 1990s was fragmentary and a thorough inventory of their flora was not carried out. An exception is a group of the outer islands from which there are significant herbarium collections, archive and literature data for a long period of time. Some of the outer islands were fairly well surveyed by Finnish and Estonian botanists before 1940. More than half a century later the floristic studies on the outer islands have been continued by the author [1, 8, 9].

The outer island group includes 12 islands (Gogland, Moschny, Bolshoy Tuters, Seskar, Maly Tuters, Maly, Kokor, Sommers, Nerva, Severny Virgin, Yuzhny Virgin, and Rodsher) located at the center of the Eastern Gulf of Finland, with a total area of about 60 sq. km. The islands differ in their area, bedrock, and topography, history of land use, flora and vegetation. This island group has been chosen as a model object for a long-term monitoring of the vascular plant flora.

The outer islands are located at the interfaces between two large geological structures the Baltic Shield and the Russian Plate. Part of the islands (Gogland, Bolshoy Tuters, Sommers, Nerva) lies on the Baltic Shield and are composed of crystalline rocks (mainly rapakivi granites). On some islands gabbro-diorites, quartz porphyries, quartzite, and granite-gneisses are represented. On the islands situated on the Russian Plate (Moschny, Seskar, Maly Tuters, etc.), the bedrock is covered with a layer of Quaternary sediments.

Until 1939, 4 main large outer islands (Gogland, Moschny, Bolshoy Tuters, Seskar) were densely populated: Moschny 1300, Gogland 1000, Bolshoy Tuters 546, Seskar 848 people (according to the population census in 1920). Currently, the population of the large islands (lighthouse keepers,



The study area

foresters, border guarders, and naval staff) does not exceed several dozen people. Small islands are uninhabited.

The flora of the outer islands is rich and original due to their variable rocks, topography, and landscapes, and through the ages, it has been the object of greatest interest.

In the history of floristic research of the outer islands, 3 main periods can be divided:

1. Early studies (1835–1940) by A.G. Schrenk, Karl von Baer, M. Brenner, E. Häyrén, B. Olsoni, J. Jalas, M. Ilvessalo, A. Nylander, G. Vilberg etc. on 4 main islands (Gogland, Bolshoy Tuters, Moschny, Seskar);

2. Detailed studies (1992–1998) by Russian (M. Boch, V. Simachev, N. Tzvelev, E. Glazkova) and Finnish botanists (R. Lampinen, P. Uotila, J. Suominen, P. Alanko, M. Piirainen etc.) on 8 islands;

3. Recent floristic research (2004, 2009–2017) by E. Glazkova on all 12 outer islands.

The data from the period from the early 1800s until the present time has been analyzed and changes in the flora have been discussed. For the whole period of floristic investigations 804 taxa of vascular plants (616 native and 188 alien species) have been found.

Over the past 25 years, 110 native taxa have been found on the islands for the first time. However, 29 of them are noto-, micro-species or critical taxa (*Euphrasia, Hieracium, Pilosella, Taraxacum, Rosa subcanina*[1], *Juncus fisherianus, J. hylanderi, Juniperus niemanii, Picea fennica,* etc.). Two new species – *Crepis czerepanovii* и *Hieracium inulifrons* were described for the first of time from the outer islands [1, 11].

Most of native species found for the first time in 1990–2000s are rare not only on the islands, but also on the mainland coast (*Carex buxbaumii, Cochlearia danica, Corydalis intermedia, Eleocharis parvula, Galium intermedium, Helictotrichon pratense, Isoëtes echinospora, Lathyrus linifolius, Saxifraga tridactylites*, etc.). Among common species newly discovered on the islands, a group of aquatic plants (16 species: *Batrachium eradicatum, Ceratophyllum demersum, Elatine hydropiper, Lemna trisulca*, several species of *Potamogeton* and *Sparganium*, etc.) deserves attention. They could spread to the islands by means of marine hydrochory and epizoochory.

18 indigenous species (e.g., *Bistorta vivipara, Gentianella amarella*, *Leontodon hispidus*, *Neottia nidus-avis*, *Viola rupestris*) known from the islands until 1944 have not been found later. Some species that are decreasing nowadays in the Baltic Region (*Polygonum oxyspermum, Peplis portula*) probably became extinct on the outer islands. On the other hand, some rare native species (*Crambe maritima, Euphorbia palustris, Dactylorhiza baltica, Ononis arvensis*) have recently reached the islands. All of them occur near the northern or north-eastern limits of their distribution area and tend to expand their range in the Leningrad Region in recent decades. For example, *Crambe maritima* was first discovered in the Leningrad Region on Maly Tuters in 1972 by H.-E. Rebassoo [12]. In the 1990s this species was found on Moschny, recently it has spread widely on both Maly Tuters and Moschny, and reached Bolshoy Tuters and Zapadny Berezovy islands [1, 7, 9]. The expansion of this species to the east of the Gulf of Finland can be caused by climate changes, in particular, milder winters in recent years.

The most significant changes have been revealed in the alien flora of the outer islands. Many anthropophytes (20 species), including 12 weeds (*Agrostemma githago, Bromus arvensis, B. secalinus, Camelina sativa, Euphorbia helioscopia, Lamium amplexicaule, Lolium multiflorum, L. remotum, Neslia paniculata, Sinapis alba*, etc.) and 8 ruderal plant species (e.g., *Aethusa cynapium, Chenopodium bonus-henricus, Ch. urbicum, Potentilla reptans*) became extinct. On the other hand, 64 species were found in 1990–2000s for the first time. Many of them reached the islands during the Second World War (e.g., *Carex praecox, Lotus ambiguus, Rumex confertus, Trifolium arvense*) and in the post-war period (*Chrysaspis aurea, Geranium pusillum, Potentilla intermedia, P. norvegica, Puccinellia distans, Trifolium montanum,* etc.). Among the newly discovered alien species 24 are cultivation escapers (e.g., *Calendula officinalis*, *Malva moschata*, *Saponaria officinalis*).

In the 2000s due to the decline of the permanent population of the islands, a number of neophytes remarkably decreased. For the last 10 years, only 17 new alien species were found. The North American species (e.g., *Conyza canadensis, Epilobium pseudorubescens, Juncus tenuis, Oenothera rubricaulis*) are particularly active in recent decades, and some of them have been already naturalized on the islands of the Gulf of Finland.

Most of the alien species spread to the islands by means of anthropochory, but also marine agestochory (dispersal via marine traffic) and ornithochory play an important role in the propagation of plant diasporas.

As the main fairway passes in vicinity of the outer islands, seeds of some alien species reached the islands with ballast waters. One of the most striking examples is the finding of *Beta maritima* on Maly Tuters, for the first time in Russia [13]. The nearest locations of this species in the Baltic

[1] Names used as accepted in Manual of the vascular plants of North-West Russia [11].

Region are known 1000 km to the west, in the south of Sweden (Skåne) and on the Danish island of Bornholm. It is noteworthy, that this species was also introduced with ballast at the end of the 18th century in Scandinavia, where it is now widely spread and naturalized. In the locations of *B. maritima* on the eastern coast of Sweden and in southern Finland the species disappeared the following year, while on Maly Tuters it survived during several years. However, during the monitoring investigations in 2009–2011 and 2014, *B. maritima* was not found on the island and probably became extinct.

Many alien species are brought to the islands by birds. Small outer islands are uninhabited and a real paradise for birds. Here there are large seabirds' colonies (e.g., gulls, terns, cormorants). Moreover, the islands are stopover sites for many migratory birds. The birds transport germs of alien species to the islands from ruderal habitats on the mainland coast or from the neighboring islands. Some of these alien plants are dangerous invasive species.

The most interesting example is a potentially dangerous invasive species *Lepidium latifolium*, which recently tends to expand its secondary distribution range in the Leningrad Region. For the first time *L. latifolium* was discovered on the Russian islands of the Gulf of Finland in 2005 on the ruderal habitats on Kotlin Island in the Neva Bay. In 2012, this species in plenty was found on the seashore meadow on a small islet Khangeloda near Kurgalsky Peninsula [6], and 4 years later the species reached the western shore of the Kurgalsky Peninsula. In 2016 it was recorded already on Severny Berezovy Island, and one year later was discovered for the first time on Moschny, where invades natural seashore meadow communities. Apparently, *L. latifolium* has found suitable habitats on the islands of the Eastern Gulf of Finland, similar to those within its vast distribution area. It is possible to expect an expansion of this invasive species in North-West Russia in the nearest future.

Further long-term monitoring research on the islands of the Gulf of Finland should be targeted to get new data on the dynamics of alien and native flora and to provide an effective protection of the island ecosystems.

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Effects of environmental variables on midsummer dinoflagellate community in the Neva Estuary

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Dinoflagellates account for most of the harmful phytoplankton species but relatively little is known about the specific responses of different species to environmental variables. In this study, the effect of temperature and eutrophication on dinoflagellate community composition and biomass in the Gulf of Finland was investigated. 21 dinoflagellate species were recorded in the plankton of the Neva Estuary at different times since the mid-19th century. 13 distinct species were observed in the present investigation and 9 of them could be identified to species level. 14-year long data of midsummer dinoflagellate biomass was statistically analyzed in Neva Estuary to show the changes in dinoflagellate species in relation to environmental factors. Biomasses of *Dinophysis norvegica* (Clapared & Lachmann 1859), *Prorocentrum lima* ((Ehrenberg) F. Stein 1878) and *Peridinium aciculiferum* (Lemmermann 1900) had very similar positive relationships with salinity, temperature, phosphorus and suspended particulate organic matter concentrations while the biomass of the other common species *Peridinium cinctum* ((Müller) Ehrenberg 1832) and *Peridinium* sp. mostly showed quite opposite trends. Current climate fluctuations leading to changes in temperature, salinity, nutrient and organic matter runoff from the catchment area could significantly affect the composition and productivity of the dinoflagellate community. Biomass of *Glenodinium* sp. and *Peridinium* sp. positively correlated with primary production and biomass and chlorophyll *a* concentration, but did not show a positive relationship with phosphorus. This may be due to the fact that these species in the conditions of the Neva Estuary, apparently, are more consumers than producers of organic matter, feeding on algae and cyanobacteria of phytoplankton. Therefore, to interpret the relationships between the dinoflagellate biomass and environmental variables one should take into account that the species of this group is characterized by mixotrophy and, consequently, their biomass may depend not only on the conditions of autotrophic, but also heterotrophic nutrition.

Anthropogenic carbon as a basal resource in the benthic food webs in the Neva Estuary (eastern Gulf of Finland)

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Organic pollution is a serious environmental problem for the coastal zones of seas. Organic matter discharges from municipalities into the Baltic Sea contributed with 33 % (29000 t) of total direct discharge [1]. On the other hand, organic matter is a major control for food webs [2]. This is especially actual for the Neva Estuary, which is the recipient of discharges of treated and untreated wastewaters of St.Petersburg (the largest megalopolis in the Baltic Region) from the sources that are located mainly in the Neva Bay. We analyzed stable isotope composition of carbon and nitrogen of different origin in suspended organic matter (seston) in the Neva Estuary and in the tissues of macroinvertebrates and fish to test a hypothesis that allochthonous organic carbon derived from St. Petersburg wastewaters is a significant basal resource of carbon for the benthic food webs. The Stable Isotope Bayesian mixing model (SIAR) showed that seston enriched by wastewaters was a main source of carbon for the most of macroinvertebrate consumers in the upper (Neva Bay) and middle parts of the Neva Estuary and for fish in the Neva Bay. This is a result of high organic pollution of the estuary and the dominance in the zoobenthos species that are preadapted to or even benefit from organic pollution. Contrary to expectations, the contribution of the allochthonous predominately natural carbon discharged by the Neva River waters in the feeding of benthic invertebrates and fish was relatively low in the Neva Bay and negligible in the middle part of the estuary. Autochthonous carbon produced by phytoplankton was a significant source of carbon only for indigenous crustaceans, *M. affinis* and *S. entomon*, in the middle part of the estuary, and for filtering mollusk *U. pictorum* and oligochaete *S. lacustris* in its upper part. The main consumers of the carbon derived from wastewaters were tubificid worms, chironomid larvae *C. plumosus,* and alien polychaete *M. arctia,* which currently dominate in the zoobenthos of the estuary. Therefore, food web dynamics in the upper parts of the Neva Estuary to a large extent depends on the carbon derived from the wastewaters of St.Petersburg.

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Feeding of abundant coastal fish species in the eastern Gulf of Finland

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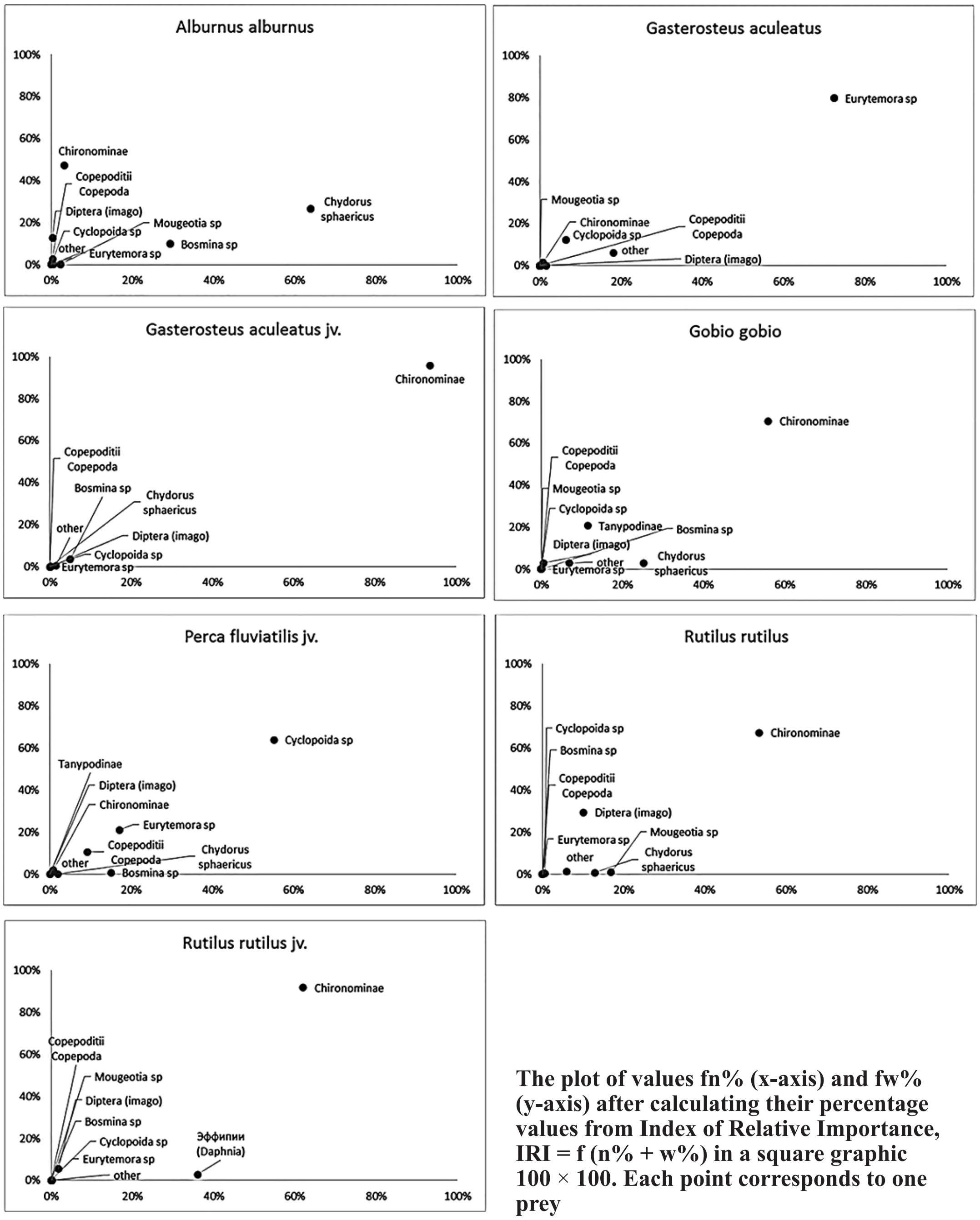
The assessment of the feeding habits of animals is fundamental in many aspects of ecology, from understanding prey selection and competition to revealing patterns of energy transfer between or within ecosystems [1, 5, 12, 13]. Direct observation of stomach contents represents a first step towards comprehending the mechanisms that regulate trophic relationships, with the objective of understanding the energetic requirements of each species [8]. Diet of pelagic mass fish species are fairly well studied [5, 9–11], what cannot be said about coastal communities, there are only a few publications devoted to individual species [2, 6, 7, 15, 16], besides the papers devoted to invasive species such as round goby (*Neogobius melanostomus*) [3, 4, 14]. This is especially true for the coastal communities of the



The plot of values fn% (x-axis) and fw% (y-axis) after calculating their percentage values from Index of Relative Importance, IRI = f (n% + w%) in a square graphic 100 × 100. Each point corresponds to one prey

Neva estuary located in the eastern part of the Gulf of Finland that have been studied rather poorly and require further study.

In this paper, we present diet of the most frequently encountered fish species in a coastal ecosystem on the scale of the eastern Gulf of Finland. The aim of the study was to assess the feeding of adults and juveniles fish, based on the intestinal tracts content analyses. We assessed the feeding niche of sticklebacks, roach, bleak, gudgeon and perch. Accurate diet determination of fishes will provide more detailed modern information on coastal food webs.

The research material was obtained in the areas of in the Neva estuary. 5 fish species (*Rutilus rutilus, Alburnus alburnus, Gasterosteus aculeatus, Gobio gobio, and Perca fluviatilis*) inhabiting the coastal zone of eastern Gulf of Finland in the area of the estuary of the Neva River in July was investigated. These species in numerous were collected in different study area and were presented in food samples in different age stages. The samples were collected with help of beach-seine net (length 10 m, wings 1.5 m high, the bag – 3 m, a mesh-size 10 mm on the wings and from 0.5 to 4 mm on the bag), in selected habitats (depths from 0 to 1.5 meters). Fishes in samples were fixed with 4 % formaldehyde. Bleak and gudgeon were presented by only adults fish, perch – only juveniles, roach, and stickleback both adult and juvenile. Altogether, the intestinal tracts of 505 fishes were investigated. We examined the role of particular prey components in the feeding patterns of fish using its frequency of occurrence (F) and a relative wet mass (Ii) (Hyslop, 1980). These data were analyzed in terms of frequency of occurrence, quantity, and weight in fish intestinal tracts, and were presented as the index of relative importance (IRI) (Pinkas et al. 1971). Individual data categories were expressed as percentages

Organisms from 8 major taxonomic groups: crustaceans (Copepoda, Cladocera, Ostracoda and Amphipoda), molluscs (Bivalvia and Gastropoda), and insects (Chironomidae and other Diptera) were found in the intestinal tracts of fishes. From the total 505 of intestinal tracts, 56 were empty; in remaining 449 intestinal tracts, 36 prey types were identified. Six prey types from them constituting more than 85 % of the total intestinal tracts contents. Chironomids, diptera (imago), cladocerans and copepods (each by 2 different prey items) were the most frequently prey items in the food of all the investigated fish species.). Data about the diet of each fish species in this paper is given in separately (figure).

For a formalized estimate of heterogeneity diet of different species of fish at all study area, we used the Principal component analysis (PCA) for the relative proportion of all prey items in non-empty stomachs (Ii%). Two clouds of points are located separately; they formed by samples of perch juveniles and adult sticklebacks from all stations. The main feature of diet composition perch juveniles is abundance of different planktonic prey (Cyclopoida sp, copepoditii Copepoda, *Daphnia cucullata*). The diet of adult sticklebacks distinguish the presence of unique and great variety of relatively uncommon prey items (e.g. eggs of themselves sticklebacks and *Polyphemus pediculus*) and also the propensity to consume *Eurytemora sp.* Clouds of other fish species overlap and in the diet on all study area is dominated by benthic organisms (the most important food resource are chironomids varia).

Based on the feeding data analyses, in the ichthyocenosis of the coast of the Gulf of Finland, there are fishes planktonic-feeding (perch), benthic-feeding (roach and gudgeon) and omnivorous (three-spined stickleback and bleak).

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Advances in ringed seal (Pusa hispida botnica) sea-use studies in the Gulf of Finland

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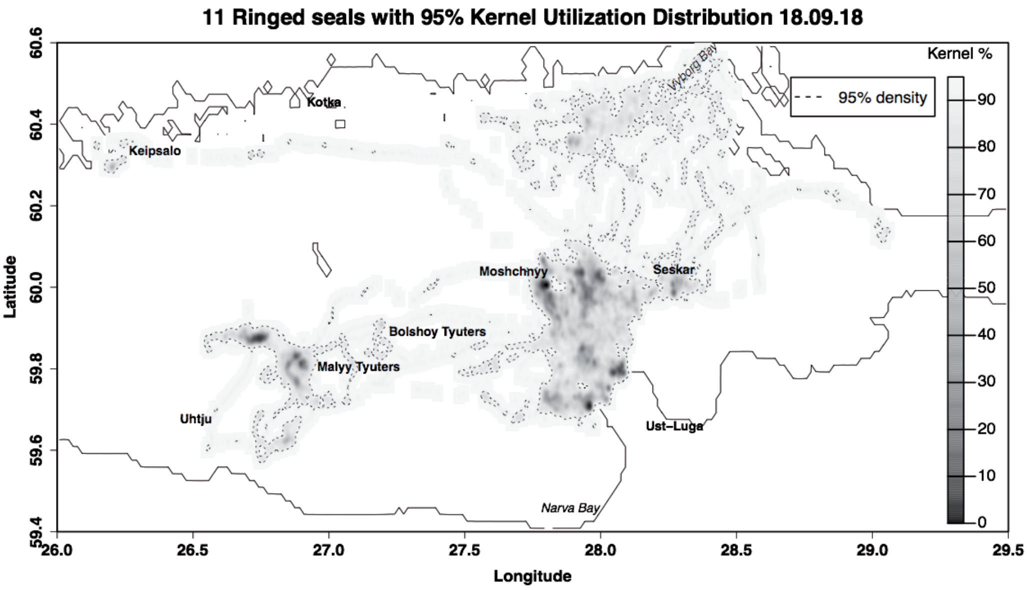
The historically abundant and continuously distributed Baltic ringed seal [1] has suffered a substantial population decline in the southern distribution range, its current distribution is split into sub-populations of the Bothnian Bay, Finnish SW Archipelago, the Gulf of Riga and the Gulf of Finland. The modern regular occurrence of the species in the Gulf of Finland is limited to waters East of the 25°30′ (Porvoo) longitude, regular haul-outs (resting places) of the seals in the ice-free period are only found in the Russian sea area near offshore islands of the gulf and at coastal reefs of the Kurgalski peninsula area. Reasons of the population decline remain unknown, but the critically low numbers (estimated max. 113 in 2018) and restricted distribution in the Gulf of Finland make the population susceptible to anthropogenic and natural pressure factors which have a potential of further negative impact on the seals.

Using telemetry tags is the only method which allows measuring seal behaviour in their offshore habitats. In the Gulf of Finland, limited numbers of tags have been earlier deployed in 1998–1999 (4 specimen) and in 2014 (5 specimen). The findings from the earlier studies pointed towards very high area-fidelity of the marked individuals in terms of haul-outs, movement routes and foraging area. As obligatory ice-breeders, limited ice fields of the Northeastern part of the gulf was used by the seals. The major shortcoming of the previous studies is very small sample size which limits the application of the gathered data.

To increase the sample size and achieve bigger spatiotemporal coverage, the study has been continued in 2017. Since June 2017 eleven more ringed seals have been marked: three females and six males in 2017 and two females in 2018. The preliminary findings from those tags add to the knowledge of sea use bu the ringed seals in the Gulf of Finland (figure)

As the project is still on-going the detailed dive data is not yet analysed but based on the distribution and 2D movement data following general conclusions can be outlined:

(1) The seals stay in the Eastern part of the Gulf (East of 26° E), none of the marked left the area so probably the exchange of individuals with other sea areas is extremely limited. None of the ringed seals, marked West of this longitude have entered the sea area. This implies that the degree of isolation of the



Kernel Utilisation Distribution of 11 ringed seals marked with telemetry tags in the Gulf of Finland in 2017/2018

population in the Gulf is high, consequently, recovery by strong immigration is unlikely.

(2) The resting areas of the marked (haul-outs) are limited to the Moshnyi-Seskar-Tiskolskii/Kurgalskii Reef area and Malyi Tyters during the ice-free period where most of the seal locations are recorded. In the context of major shipping routes of the Eastern Gulf of Finland, the seals are located in areas further from shipping activity, some activities are recorded on shipping routes but their nature and relation to the presence of ships need further study.

(3) The ringed seals prefer underwater channels, reefs, and slopes as foraging areas, deeper offshore waters are used during intensive feeding in summer months but only two seals have been caught and seasonal comparisons lack data.

(4) Movements to the Northern coast of the sea area is related to exploratory movements in early winter when ice (i.e. breeding platform) formation is expected.

(5) The (ringed) seals are sentinel species for the ecosystem in the Gulf of Finland [2]. The telemetry study provides input data to a wide range of anthropogenic impact, climate-related and trophic web studies.

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The shell color polymorphism of the littoral mollusks *Bradybaena fruticum* (Mull.), associated with micropollution by HM of the south-eastern part of the Gulf of Finland

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The largest polymorphism is characterized by a micropopulation inhabiting the shores of a lake in the park of the Ropsha (continental area). The most numerous mollusks are of a brown morph with a spiral dark brown stripe (f = 0.60). They are, obviously, homozygous and dominant in gene of pigment and band. The most rare morphs are pure light yellow forms (f = 0.0007). These snails are heterozygous, recessive in color and banding. Intermediate position is occupied by heterozygous yellow-pink without stripe, yellow-pink striped and pink without stripe (f = 0, 15, 0, 085 and 0, 24, respectively). In the investigated coastal locations of south-eastern part of the Gulf of Finland, only one brown-striped homozygous morph of the mollusk dominant under the initial polymorphism in the reference location of Ropsha. According to the analysis by ISP spectrometry, it is statistically shown that the light yellow and lacking longitudinal band heterozygous recessive forms significantly more accumulate in the shell and internal tissues of TM, than homozygous dominant, having a brown color and one longitudinal band. The amount of accumulation of the content of TM in the shell, are arranged as follows:

$$Sr > Fe > Mn > Zn > Cu > Ni.$$

Obviously, recessive, heterozygous forms of mollusks without stripe are more sensitive to HM. Therefore, they are eliminated by natural selection. They are not observed in zones with anthropogenic influence and the presence of HM. In hepatopancreas, Mn, Zn and Fe, the concentration of which is much higher than in the shells of all identified morphs.

Thus, in the processes of natural selection in littoral populations, the predominance of more resistant to HM forms is observed, which correlates with the detected chronic background contamination of the HM of the investigated locations in the south-eastern part of the Gulf of Finland.

The work is done with scientific equipment of the Resource Center «Ecological Safety Observatory» and «Chemical Analysis and Materials Research Centre», St. Petersburg State University Research Park.

Effects of endocrine-disrupting chemicals on microbiota inhabiting the Gulf of Finland

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In recent years, the technological environmental impact on the Gulf of Finland is increasing. The main sources of pollution in the Gulf of Finland are the discharge of untreated industrial wastewater, the flow of pollutants along with river runoff, dredging and direct contamination of seawater during the navigation of sea-going vessels. Large quantities of pollutants are involved in migration and sedimentation processes and can enter the trophic chains. During the Helsinki Convention, the list of substances dangerous to the Baltic Sea was defined. This list (HELCOM, 2010) includes endocrine-disrupting chemicals (EDCs) – nonyl- and octylphenols (NPs and OPs). NPs and OPs occur mainly in the environment as incomplete microbial transformation products of nonyl- and octylphenol polyethoxylates, which are widely used as surfactants in industrial processes and households. EDCs enter the environment through a variety of sources, including agricultural runoff, sewage effluent, and industrial effluents. The significant concentrations of NPs are found in surface waters (up to 644 µg l–1). Concentrations of NPs in bottom sediments can reach 3500 mg/kg.

The aim of this study was to evaluate the effects of endocrine disruptors – nonyl-and octylphenols on the microorganisms found in surface water and bottom sediments of the Gulf of Finland. It has been established that terrigenous micromycetes of genera *Acremonium, Aspergillus, Cladosporium, Fusarium, Penicillium*, isolated from bottom sediments of the coastal zone of the Gulf of Finland, show tolerance to the action of nonyl-and octylphenols compared to microalgae *Aphanizomenon flos-aquae, Microcystis aeruginosa, Nodularia spumigena, Planktothrix (Oscillatoria) agardhii, Trichormus (Anabaena) variabilis*, massively developing in the surface waters of the Gulf of Finland. One of the mechanisms of increased tolerance of micromycetes to alkylphenols (AP_s) is a decrease in the permeability of cell membranes. Under AP_s-induced stress conditions, cyanobacteria increase the synthesis of secondary odorous substances and microcystin, which impart undesirable odors and toxic properties to water and have allelopathic effects on aquatic organisms. AP_s cause significant changes in activity of hydrolytic enzymes in the terrestrial fungi involved in organic matter degradation in bottom sediments. In addition, oxidative stress induced by AP_s has been found to increase the synthesis of adaptive, including pathogenic, protection factors for terrigenous fungal cells, such as superoxide dismutase, catalase, protease, melanin-like pigments and polysaccharides.

This may lead to emergence fungal strains with enhanced virulence in aquatic microbiocenoses. The revealed type-specific activity of alkylphenols indicates the possibility of their regulatory role at the level of microbial communities, such as the regulation of succession and the stability of the functioning of microbiocenosis in the waters of the Gulf of Finland.

Experience on ecological status assessment based on adaptive potential diagnostics in selected invertebrates of the Baltic Sea sub-regions

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The aim of the present paper was to review the results obtained in our previous field and laboratory studies using cardiac monitoring system worked out in SRCES RAS for assessing environmental pollution in a few problem sub-regions of the Baltic Sea. Presentation is concerned also to the experience of development and approbation of proposed approach to the assessment of biological effects of environmental chemical stress based on evaluation of adaptive potential of indigenous species of the invertebrates from different in anthropogenic pressure fresh water, brackish water or marine areas, with the emphasize on sub-regions of the Baltic Sea (including estuary of the Neva River). The assessment of adaptivity was performed using method of physiological loading on different bivalve mollusks (*Anodonta anatina*, *Mytilus edulis*, *Mytilus trossulus* and *Macoma* (*Limecola*) *balthica)* based on measuring their heart rate recovery time after removal of stress load (salinity change) [1]. Rapid recovery (less than 50–60 min) signifies a good adaptive potential in different species, indicating good ecological status of the study site they inhabit [1–4].

The paper presents a number of examples demonstrating how methodology for the evaluation of invertebrate's physiological state can be used in ecosystem health assessment in the Baltic Sea Region.

In the Table we summarized the data obtained in our studies in different Sub-regions of the Baltic Sea and the Neva River with the indication of methods applied, species used and references to published data.

Sub-regions of the Baltic Sea and the Neva River (including estuary) studied using bioelectronic systems of cardiac monitoring and different methodological approaches [1, 2]

Species	Sub-regions of the Baltic Sea	Methods used, biomarkers	Salinity
Astacus leptodactylus	Neva River; Neva Bay	On-line monitoring of water toxicity; HR, ΔHR; $\Delta HR/\Delta t$	0–0,1 ‰
Astacus leptodactylus	Mesocosm studies; Tallinn Bay	Active bioindication method*; T_{rec}	3,8–5 ‰
Mytilus trossulus	Tallinn Bay	Caged mussels; T_{rec}	5–6 ‰
Macoma (Limecola) balthica	Tallinn Bay	Caged clams; T_{rec}	5–6 ‰
Mytilus edulis	the Belt Sea (western Baltic Sea)	Active bioindication method; T_{rec} ; CV_{HR}	13–15 ‰
Carcinus maenas	the Belt Sea (western Baltic Sea)	Active bioindication method; T_{rec}; CV_{HR}	13 ‰
Mytilus trossulus	the Bothnian Sea	Caged mussels; T_{rec}; CV_{HR}	3,5–4,2 ‰
Mytilus trossulus	the GoF	Caged mussels; T_{rec}; CV_{HR}	3,5–4 ‰
Macoma balthica	the Gulf of Riga	Active bioindication method; T_{rec}	3–6 ‰
Unio pictorum	Rivers and lakes of catchment area of the Gulf of Riga	Active bioindication method; T_{rec}	0–0,2 ‰
Anodonta anatina	Neva Bay; estuary of the Neva River	Active bioindication method; T_{rec}	0–0,2 ‰
Unio pictorum	Neva Bay; estuary of the Neva River	Active bioindication method; T_{rec}	0–0,3 ‰
Dreissena polymorpha	Neva Bay; estuary of the Neva River	Active bioindication method; T_{rec}	0–2 ‰

*Active bioindication method – the methodology with the use of functional loading.

Based on the results obtained, we believe that Trec and CVHR in mussels and crabs seemed to be a powerful tool and a useful endpoint for the evaluation of the health of aquatic organisms and, subsequently, the quality of water, where they live. The methodology could be useful also in the assessment of ecosystem health.

In our opinion, the results of field and laboratory studies obtained by the authors are rather good basis for further work in development and deployment in the Baltic Sea of a net of technologies and automated biomonitoring systems using benthic invertebrates as live monitors of environmental quality, in all spheres of modern water use. The major advantages of the considered system are: high extent of automation of monitoring, easy to create large networks of the continuous, automated control of the water environment, high reliability, simplicity in service, high degree of autonomy, durability and rather low cost.

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The amphipod *Gmelinoides fasciatus* as an example species used to investigate the Gulf of Finland biological systems by means of molecular genetic methods

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Anthropogenic pressure has a profound impact on the biological system of the Gulf of Finland. Ship industry is the major factor. Industrial and economic activities carried out to maintain the sustainability of the coastal areas are having an impact on the aquatic state of the littoral zone. Complex monitoring of the ecological situation is needed. Various genetic approaches are indispensable for complex assessment of water system state including investigations on water organisms. Genetic methods make it possible to estimate genotoxic effects of water pollution, and to give a forecast of the possible structural changes of the analyzed biosystem. It has to do with early recognition of various types of genetic disturbances caused by environmental factors, including those of anthropogenic origin. The monitoring is based on genetic test-systems, which include indicator species and criteria for measuring the deleterious effect on the genetic material. The amphipod Gmelinoides fasciatus is of great interest as an alien species, which went through successful adaptation at the Baltic Sea ecosystem. Due to its broad ecological plasticity this hydrobiont, initially originating from the Lake Baikal, got widespread in the water bodies of the North-West regions of Russia as the result of deliberate introduction. The attempt was made to investigate G.fasciatus as an indicator species and to use molecular genetic and cytogenetic approaches to characterize its genome and chromosome set with respect to adaptation and genetic monitoring studies. The research is being performed in the Resource Centre “Chromas” at the Research park of SPbSU and supported by RFBR grant 15-29-02526.

The major determinants for populations of culturable bacteria in coastal sediments of the eastern Gulf of Finland, Baltic Sea

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Anthropogenic pressure on the coastal zone of the eastern Gulf of Finland leads to the accumulation of metals, hydrocarbons, and other pollutants in sediments [1, 2]. Sediment contamination is expected to affect the dynamics of biogeochemical processes driven by microorganisms [3, 4]. Benthic culturable bacteria actively participate in biomineralization of sediment organic matter and biotransformation of hazardous substances accumulated in sediments. Analyses of the microbial compartment might be useful in assessing the ecosystem vulnerability to anthropogenic changes [5, 6]. The spatial and temporal fluctuations of culturable heterotrophic bacteria were studied in coastal sediments collected monthly from three stations in the eastern Gulf of Finland in 2017–2018. Physicochemical parameters included sediment texture, organic matter, pH, Eh, ammonium, nitrates, phosphates, metals, hydrocarbons, phenols, water temperature, and salinity. The microbial indication was based on the evaluation of the dominance of microorganisms able to tolerate or degrade toxic substances. Viable counts of culturable heterotrophic bacteria, metal-tolerant, hydrocarbon-oxidizing, and phenol-oxidizing bacteria were made. Our analyses showed temporal and spatial fluctuations of culturable heterotrophic bacteria and special groups of pollutant-tolerant- and degrading bacteria. The main factor contributing to the temporal fluctuations of bacteria was water temperature. Spatial variations were more related to several sediment conditions, including sediment texture, redox conditions, and the level of pollution. Me-tolerant, hydrocarbon- and phenol-oxidizing bacteria were heterogeneously distributed in coastal sediments of the eastern Gulf of Finland with the higher average percentage of bacterial tolerance and degrading ability in samples collected at sites S1 and S2. The maximum abundance of metal-tolerant bacteria (site S1) exceeded the minimum value (site S3) by 20 times. Microbial abundance reflected changes occurring in environmental conditions, and adaptation of heterotrophic bacteria to sediment contamination. Observations on occurrence and activity of native microorganisms capable of toxicant tolerance are important not only to understand the extent of the pollution but also to realize the potential of the benthic community to detoxify some of the toxic substances. Results emphasize the importance of using microbiological methods for the assessment of the impact of human-induced pressure on the Gulf of Finland ecosystem.

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Aerial survey of ringed seals (Pusa hispida botnica) in the Gulf of Finland in 2018

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Currently, the Gulf of Finland is inhabited by an isolated population of ringed seals (Pusa hispida botnica Gmelin, 1788) [3]. The abundance of this population has been falling over a long time period. By 1980s the seal numbers have dropped from 3–4 thousand individuals to 200–300 individuals in the turn of the century. Aerial surveys carried out in the past seven years indicate that the general abundance in the Eastern part of the gulf, involving sea areas of three countries: Estonia, Russia, and Finland is extremely low and does not exceed some 100 individuals in the whole area. The results of aerial surveys carried out by us in the previous year are presented in Table 1

The counts of ringed seals in the Russian sea area have been carried out according to the method of [2] and the HELCOM recommendation from 2014 [1]. Accordingly, the results of 2010, 2012, 2017 and 2018 are comparable amongst each other and with the results obtained by other researchers in the Baltic sea area who use the same methodology.

General information. The survey was carried out in 2018 in 14th and 18th of April using aircraft Cessna 182. In the survey period, the snow lairs of seals had collapsed and all the seals were assumed to be visible on the open ice. Total ice extent left in the Russian sea area was involved in the study.

The survey was carried out using strip transects which were laid in meridional direction. The distance between the transects were approximately 5 kilometers. In the analysis the distances were based on GPS-measured coordinates. Flight altitude (90 meters), steady speed and distance to neighboring transect were controlled by the pilot using the onboard instruments. The average speed during the flight was 190–220 km/h. Total observation strip is 800 meters at the altitude of 90 meters. Every observed seal was photographed with a digital camera with GPS location for each picture. The species was identified from the photography using the coloration of the pelt, form of the neck area, pose of the animal in the picture and ice conditions, in comparison to the grey seal Halichoerus grypus (Fabricius 1791) which can be met in the ice area.

Results of the aerial survey: According to the agreement between Russian, Estonian and Finnish specialists the main survey in the Russian sea area where most of the ice was, supplementary surveys were performed in Finland and Estonia. As the Russian Survey aircraft could not cross national borders but ringed seal distribution is determined by spring ice, it was important to cover the total ice area to get an estimate of the haul-out population.

Russia: On the 14th of April from 05:25 to 10:26 (UTC) 2018,33 sq.km of ice was observed; length of the survey strip was 365.980 km. The total of 16 transects or meridional direction were flown; average distance between the transects was

Results of the ringed seal censuses in the Russian part of the Gulf of Finland in 2010–2018

Year	Survey length (km)	Area of survey sq.km	Ice area sq.km	% of surveyed ice	Ringed seals	
					Seen	Estimated number
2010	347,5	278	1193	23.3	6	16–34
2012	642,2	517	3916	13,2	12	72–94
2017	361,2	289	1640	17,7	9	44–57
	490,2	392	2451	16	13	71–90
2018	365,9	293	2081	14	10	64–76
	200	160	1191	13	13	89–101

5.68 km. The observed area was 293 sq.km which corresponds to the number of elementary segments of survey 8 1 sq.km each). During the survey, seven seals were seen from the right side and four seals from the left side of the aircraft- total being thus 11 animals. Though, one observation was omitted from the density calculations as it was seen outside of the observation strip. As a result, 10 individuals were used to calculate seal densities. Relative density of ringed seals in one segment (= 1 sq.km) was 0.034 ± 0.01 (mean ± SE, 95 % CI = 0.0196, SD = 0.18). Expected number of ringed seals, rounded to full individual was 70 seals with the 95 % CI from 64 to 76 individuals, i. e. with an error of 5 % the number is not lower than 64 or higher than 76.

On the 18th of April from 11:57 to 16:06 (UTC) second survey was carried out and 1191 sq.km. of ice was covered by 200 km of observation transect. Altogether the survey was divided into 11 meridional transects which were in an average 5.94 kilometers apart. The total observed area was 160.39 sq.km which corresponds to the number of elementary segments of the survey. During the survey, 12 seals were observed from the right and 11 from the left side, totaling 23 individuals. Though, from the density calculations, 10 individuals were omitted as they were seen outside the survey strip. So the calculations were based on 13 individuals. Relative density of ringed seals in a segment (=1 sq,km.) was 0.08 ± 0.02 (mean ± SE, 95 % CI = 0.039, SD = 0.27). Expected number of ringed seals, rounded to full animals, in the covered area was 95 individuals, with 95 % CI from 89 to 101 seals, i.e. with 5 % error 89 to 101 individuals in the survey area.

Estonia: In Estonia, the survey was carried out by Pro Mare. The flight in Estonia was planned to match the survey at Russian side to avoid double counts of seals in the border area or drifting ice fields.

According to the observed ice situation, some alterations to the method was allowed to achieve maximum visual observation coverage. Namely:

1. The flight altitude was maintained at a standard minimum allowed flight altitude of 150 meters (1000 ft.) to increase the field of sight as very few seals were expected to be on the ice in the area.

2. The main planned scheme of meridional courses and distances between neighboring transects was kept, but as the ice had become loose in large floes extensive coverage of open water was avoided to shorten the flight time.

3. To achieve maximum possible coverage of visual observations the observation was continuous covering also turns and transfers. The sectors were omitted and the whole visual range was scanned.

Visibility allowed to detect seals from far as determined by the visibility of waterfowl and ice structures, but no seals were seen during the flight. To check the known ringed seal site, Põhja Uhtju for potential animals a loop was flown around the reefs but no animals were detected there.

Finland: The Finnish survey was carried out in the ice area adjacent to Russian water close to Kotka. The flights on 12th and 13th of April 2018 were planned according to the HELCOM methodology in good weather conditions, but the short flight distances and compact ice-field allowed almost whole potential sea ice area covered. Full coverage of the area leads to total census rather than a calculated estimate from seal densities. The result is: on the 12 of April – 9 seals, on the 13 of April – 4 seals, in total –13 ringed seals have been seen in the Finish part of the Gulf of Finland.

Conclusions. As a result of the aerial survey, the estimated abundance of ringed seals in the Russian sea area was between 89 and 101 individuals. This is higher than the result from 2012 when the population was estimated to 72–94 individuals. In 2010 the result was four times lower, about 16-34 ringed seals. Still according to our opinion the one day survey in 2010 led to underestimating. As learned from 2017 survey, the difference between two surveys in one year can be 1.5–2 times. In comparison to 2017 (Table 1), the estimate of 2018 is slightly higher but it remains at the level of 95–100 ringed seals in the Russian waters and 13 seals in Finish part of the Gulf of Finland, maximum 113 ringed seals in total. In this way, the comparison with the year 2012 indicates that the population is at a stable low level. Further monitoring is needed to establish the spatial distribution patterns of ringed seals in the Eastern part of the Gulf of Finland.

We suggest in warm winters with lack of snow to make the survey to earlier dates for estimation of population reproduction rates, counting pups on ice are.

The supplementary surveys in Russia, Finland and Estonia show that the core distribution of the ringed seals is in Russian waters of the Gulf of Finland in years of limited ice cover. Observation of 13 seals in Finland and no seals in Estonia is confirming the findings from telemetry studies that seals leave Southern shores to breed on ice on the Northern coasts of the Gulf of Finland where suitable ice forms annually.

Gratitude for participating in the Gulf of Finland ringed seal flights in Estonia: Ivar Jüssi (Pro Mare) in Finland: Antti Halkka (WWF), Maiju Lanki (Metsähallitus) and Petteri Tolvanen (WWF).

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The invasive round goby (*Neogobius melanostomus*) in the eastern Gulf of Finland

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The round goby is considered amongst the most invasive fish species of the Baltic Sea. Expansion of this Ponto-Caspian fish begun in the 1990s, and currently it is numerous and became common in commercial and sport fisheries of some parts of the Baltic Sea. In the eastern Gulf of Finland non-native round goby was firstly documented in 2012 (the Luga Bay, [1]), and currently, the species reach high abundance, becoming an unwanted by-catch in fisheries. These new invasive populations remain mainly unstudied. The aim of the study was to fill in this gap and obtain first data about population structure and morphological characters of the round goby in the eastern Gulf of Finland in the Russian EEZ.

To study the population structure we estimated density and distribution of the round goby, sex ratio, fecundity, fish size, age, and growth rate. Besides, external morphological characters (proportions of body and head, relative position and length of fins, number of fin rays) were studied. Population densities were estimated by means of a beach seine in coastal areas, and gill nets in deeper waters.

Beach seine sampling demonstrated that the round goby is abundant along the southern coast of the Gulf of Finland, in Narva, Luga, and Koporye Bays, but was not found to the east of the Saint Petersburg flood-prevention facility complex (SPb FPFC), inside the Neva Bay, as well as along the northern coast. Juveniles were more common in catches on the coastal shallows than adult fish. Young-of-the-year juveniles comprised 97.2 % of all round gobies caught in the Koporye Bay in 2016. Their length (Sl), weight (Tw) and density were 15 30 mm, 0.07–0.65 g and 10 inds/100 m^2 respectively. Average densities of adults in catches at depths up to 1.5 m in the Koporye and Luga Bays and the SW part of the SPb FPFC were 0.2–0.3 inds/100 m^2. Adults were more common in gill net catches from deeper waters. In the Narva Bay in June 2018 they reached densities 2.6–16.1 ind./100 m^2 and biomasses 62–490 g/100 m^2, being caught at depth range 6–12 m, and dominated in catches. Ranges of length (Sl) and weight (Tw) were 60–155 mm and 16.5–99.2 g for adult pre-spawning individuals and 69 106 mm and 5.6–22.5 g for juveniles respectively.

A sample of 172inds. from the Narva Bay (June 2018) was studied for estimates of length, weight and sex ratio. Females dominated in number, in a ratio of 3.2♀:1♂. On average, males were bigger then females (for adults Sl = 131.7 ± 2.0 vs. 94.7 ± 2.3 mm, and Tl = 55.1 ± 3.2 vs. 21.2 ± 2.0 g). Males had higher ($p < 0.05$) indices (in % SL) of head width and height and height of the pectoral fin basement. The number of fin rays was in the same range as in native and other introduced populations [2].

Specimens from the Gulf of Finland were similar in the sequences of part of the mitochondrial gene encoding cytochrome c oxidase subunit 1 [3] between each other, as well as with other invasive populations of the Baltic and North Seas, and the Great Lakes of North America. This result suggests the spread of the invasive round goby from the same donor region, namely north and/or south-western parts of the Black Sea basin.

During the last decade, we observe successful naturalization of the round goby in the eastern Gulf of Finland. The species is more and more common in new for the species habitats and populations include numerous fry and adults. This fact allows suggesting a further increase of the species abundance and distribution in the studied area.

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SESSION: EVOLUTION OF NATURAL ENVIRONMENT OF THE GULF OF FINLAND. CLIMATE CHANGE AND ANTHROPOGENIC PROCESSES

Cross-Gulf cooperation in the Stone Age study: new results, continuing projects and research perspectives

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The last two decades can be considered as a new stage of the Stone Age research in the Gulf of Finland region. One of the important peculiarities of this stage is a very close cooperation of scientific representatives from all the three Gulf of Finland states: Peter the Great Museum of Anthropology and Ethnography /Kunstkamera/ and the Institute for History of Material Culture of the Russian Academy of Sciences; Helsinki, Turku and Oulu Universities as well as the National Board of Antiquities in Finland; Tartu University in Estonia. Actually, the archaeological studies during this stage are a sequence of international research projects, which have been realizing in general coordination between all parties.

Archaeological studies have been very close integrating with palaeogeographical and palaeoenvironmental researches. This is not a special characteristic of the last period of studies, as palaeogeography and the Stone Age archaeology of the region have been developing for about 150 years in close interaction from the very beginning of the research history. Cooperation of archaeologists and natural scientists gave us a lot for an understanding of natural factors that affected the social and cultural developments of the prehistoric societies. But also archaeological data have been using for many decades as important sources for palaeogeographical reconstructions.

Since the end of 1990th several international archaeological projects were conducted in the region to study the development of subsistent strategy during the Stone Age – Early Metal Epoch and changing of settlement pattern in connection with shorelines displacement and landscape formation [1]. So, generally those studies are not just archaeological, but interdisciplinary archaeological and palaeogeographical studies in both methodological and purpose sense.

Although the archaeological material demonstrates many similarities within the whole region and research contacts were kept through the borders all the time, differences in research schools and scientific approaches produced different archaeological periodizations and typological nomenclature. Intensive cross-border communication during the last two decades has not taken away all the discrepancies but allowed to define them and to build general correlations for national cultural-chronological and typological schemes [2].

Probably the most important achievement for the discussing the research stage is integrating of different methodologies for developing a common methodological approach within a structured research strategy [3]. The last consists of tracing of peculiarities and changes in material culture, settlement structures, subsistence strategy, and communication networks through the millennia in different parts of the region by systematic interdisciplinary studies in certain geographically distinctive areas – so-called micro-regions. The research methodology includes the building of microregional models of shoreline displacement and coastal archaeological sites location at certain chronological periods based on previously known palaeogeographical and archaeological data. The models have been improving during intensive systematical field surveys in the microregions. Small-scale precise excavations have been conducting on series of the found archaeological sites in order to study peculiarities of a cultural layer(s) and under- and overlaid sediments disposition, to obtain diagnostic archaeological material and samples for dating, lithological, geochemical and microfossil analyses. Studying of archaeological sites has been accompanying by analyses of lakes and bogs sediments in the microregion for reconstruction of the local palaeogeographical history and checking for traces of human impact on the ecosystem in the past.

Exchanging of experience in field survey methodology has brought extremely fruitful results. Shoreline displacement models that were developed in Finland for many decades have been adapted (and also improved) for Karelian Isthmus corresponding to the general model of the Fennoscandian isostatic land uplift. It has allowed finding in several years about 150 archaeological sites in several microregions on Karelian Isthmus and in the Northern Ladoga area [4–6].

Intensive surveys in the northern part of Karelian Isthmus revealed several archaeological sites belonged to the Early Mesolithic period, or to the time of the Ancylus Lake stage [7–9]. The early 2000s were indeed a breakthrough in the Early Mesolithic studies of the Eastern Baltic, including Ostrobothnia. Before this time only Pulli in Estonia and Antrea Korpilahti in Karelian Isthmus certainly represented Early Mesolithic contexts in the region. After the turn of millennia, the amount of the confidently dated Early Mesolithic contexts in the region increased rapidly, which distinctively enlarged our knowledge on the time of the initial peopling of these territories [10–12].

Strict following the Russian requirements to archaeological excavations resulted in discovering the multilayer archaeological sites in Karelian Isthmus. Archaeological contexts of different periods of the Stone Age – the Early Metal Epoch are represented on those sites in stratigraphical order and divided or overlaid by archaeologically sterile deposits by Baltic and Ladoga transgressions. Those sites provide a detailed chronology of cultural and environmental changes and can be considered as the reference sites for archaeological and palaeogeographical studies in the region [13–17].

The discoveries of multilayer sites in Karelian Isthmus were totally unexpected and surprising, and distinctively changed and précised the model of shoreline displacement in the area. And even later in the late 2000s, the discovery of the Okhta 1 multilayer site in the center of Saint-Petersburg city became a scientific sensation [18–19]. This site provides archaeological materials that present a full sequence of cultural development of the area since the end of the Lithorina transgression, including submerged Stone Age contexts. After some years of hard scientific battles, it can be considered as one of the most distinguished cases in the modern research history when archaeological discovery has sufficiently transformed the model of the regional geological development.

At the southern coast of the Gulf of Finland in the Narva-Luga Klint Bay, archaeological data, as well as the results of palaeogeographical studies, have been used for building the regional model of Baltic oscillations [20]. Later intensive archaeological surveys combined with palaeogeographical and geological studies revealed the strong association of Stone Age sites of certain chronological periods with ancient coastal forms (palaeospits) of different generations. Developing of the coastal displacement and the Stone Age sites location model for the area enlarged the amount of the known Stone Age – Early Metal sites from 10 before 1990 to 79 in 2017.

The currently obtained data demonstrate a high level of chronological correlation between environmental and socio-cultural changes in the Gulf of Finland region during the Stone Age and the Early Metal Epoch. Some rather rapid cultural changes obviously were coincided with environmental transformations [21]. It is well documented for now that all the coastal Late Mesolithic sites roughly to the south-east from the line between the Viborg Bay and the Riga Bay were inundated during the Lithorina transgression maximum about 7500 cal. BP [22]. Pottery making traditions spread in the region right after the Lithorina maximum. Also the dramatic Saimaa breakthrough about 5900 cal. BP is a pronounced chronological border between the Early Pottery (Narva and Sperrings) traditions and the Typical Combed Ware culture on the discussing territories. The true nature of those correlations needs to be properly investigated in a wider context.

Preliminary results of the Stone Age coastal sites location spatial analysis show that their elevation does not grow gradually along the isostatic land uplift gradient, but display some hinge-lines of probably different age. This well-correspond to the recently obtained geological data about the modern tectonic movements in the region [23–24]; and allows supposing rather a rapid character of not only the Saimaa and the Neva breakthroughs, but also some earlier events like the Lithorina maximum.

Stone Age archaeological studies in the Gulf of Finland region during the last two decades were supported by all the involved Academic Institutions and Universities, by the Russian Foundation for Basic Research, the Russian Science Foundation, the Estonian Research Council and the Academy of Finland. Some of the reference archaeological contexts for different periods of the Stone Age – Early Metal Epoch, including multilayer sites were excavated by the rescue archaeology projects within the Nordstream 1 pipeline construction. Now proper actions for the protection of the Stone Age archaeological heritage realize within the Nordstream 2 project in the Narva-Luga Klint Bay.

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Pottery typology as a tool for relative and absolute dating of Stone Age sites in the eastern Gulf of Finland region

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The purpose of the poster is to present pottery typology as one of the main dating methods for the Stone Age and Early Metal Period sites in the eastern Gulf of Finland region.

Nowadays not less than 500 Stone Age and Early Metal Period archaeological sites are known in the eastern Gulf of Finland region – most of these can be given absolute dating, with varying accuracy. In the absence of radiocarbon dating, pottery typology, alongside with shore displacement dating, is the most commonly applied chronological tool. The basis of the typological scheme was developed by Finnish archaeologists in the beginning of the 20th century [1], and these types have remained in use ever since and moderately supplemented by later additions concerning mostly the absolute datings of the types [4, 6].

Originally, the pottery types were given a relative age based on the shore displacement dating, but the currently varying amount of C14 datings exist for each pottery type [2, 3, 5, 6]. These allow us to define the chronological limits of ceramic traditions even up to some hundreds of years. Slight local variation in the current chronological system can be recognized in smaller micro-regions (like the Karelian Isthmus, the Narva region, the Southern Ladoga region), too.

The Early Neolithic is characterized by two ceramic types – the Narva Ware (5200–3900 BC) on the southern shore of the Gulf of Finland, and the Sperrings Ware (5300–4000 BC) on the northern one. The boundary between them cuts the southern part of the Karelian Isthmus, and the presence of hybrid complexes is yet to be proved. In the Middle Neolithic, the Typical Comb Ware (4000–3400 BC) spread everywhere across the Gulf of Finland area but its local variants remain poorly studied. Towards the Late Neolithic, new ceramic groups appear and partially coexist with the Typical Comb Ware for a certain period of time. These include the varying Asbestos and Organic Wares (around 3600–1900 BC), as well as later the Corded Ware (2800–2000 BC).

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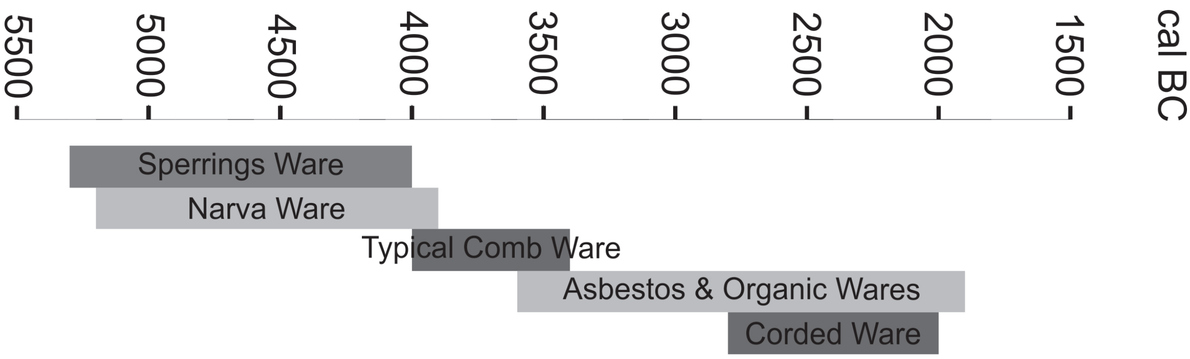

Chronological position of the main Neolithic ceramic types from the eastern Gulf of Finland region

Communication of the population around the Gulf of Finland in the Early Middle Ages. Archaeological evidence

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The initial period of the Middle Ages (V–VIII centuries) was an important historical epoch, which in many respects determined the course of the further historical and cultural development of the significant territories of Europe. This period was studied in the areas around the Gulf of Finland uneven: the antiquities in Estonia and Southern Finland are relatively well known, the Northwest of Russia has been studied much worse. Archaeological sites and chance find of V–VIII centuries are known in the Russian territory mainly on the northern coast of the Gulf of Finland and on its islands and on the Karelian Isthmus. Another important region has emerged in recent years – the downstream of the Luga river and western slopes of the Izhora Plateau. In addition to the archaeological complexes, the spore-pollen spectra and radiocarbon dates are also known from this time.

Coastal areas around the Gulf of Finland should be considered as part of a common East Baltic space, connected by waterways across the Gulf; the huge Peipsi and Ladoga lakes connected with the Gulf of Finland by rivers are adjacent to the same space. The culture of the coastal areas developed in the course of permanent and sustained contacts through water, as evidenced by the geography of sites and the commonality of many phenomena in culture (including funeral rituals). Metal ornaments and weaponry related to the northern European world are most visible in local material culture. The wide dissemination of Scandinavian artifacts in the eastern part of the Baltic was been noted by researchers frequently, this phenomenon is often interpreted as evidence of early Scandinavian expansion. This point of view is generally justified, although one should not forget about the possibility of spreading things that have a high social or semiotic status among neighbors – the Scandinavian things apparently had them.

Archaeological sites located on the islands of the Gulf of Finland most clearly demonstrate the unity of the Eastern Baltic space and the development of navigation. First of all, it is important to name a series of ornaments in the 1st German animal style, found on the island of Bolshoy Tyuters, and the cremation burials of the VI century on the island of Lavansaari (Moshnyi). It is necessary to mention also a very important site at Salme on the island of Saaremaa, which, strictly speaking, is located outside the Gulf of Finland – the recently studied collective burials in boats.

The archaeological sites on the rivers leading from the Gulf of Finland to Lake Ladoga (Neva and Vuoksa) should be considered in the same context as well as the finds on the islands. The cremation grave from VI century was been studied on the island of Riekkala in the northern part of the Ladoga Lake, where both river routes lead. It contained, in particular, blue glass beads, Scandinavian “buttons” (agrafs) and two bracelets with thickened ends. The similar agrafs are common in Northern Estonia, where they are also treated as imports from Scandinavia.

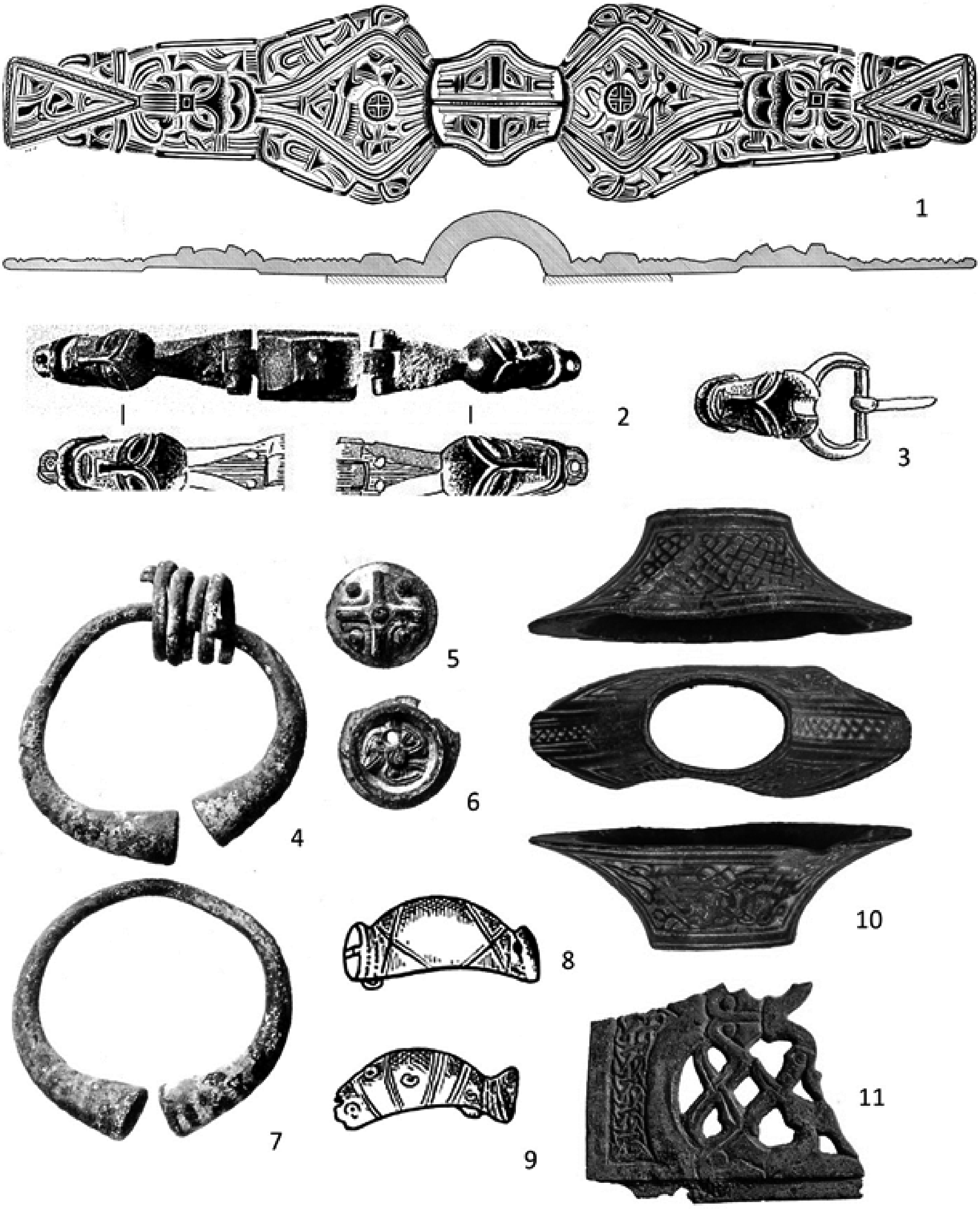
The appearance of the pollen of cultivated cereals (rye) in the spore-pollen spectra around 600 also indicates the population of the islands in the northern part of Ladoga at this time.

The collective burial in the stone-earth mound at Lapinlahti-Naskalimäki (now Olkhovka) is also considered by researchers in the context of links with more western regions. Most authors compare the ornaments and weapons found here, as well as the burial rites, with the sites of South-West Finland.

Several sites of the V–VIII centuries identified in recent years south of the Gulf of Finland on the territory of the Leningrad region, these are the burial grounds of Mally and Kommunar and the single grave of Rosson’ XI. Their burial rite has common features with sites on the territory of Northern Estonia, and many artifacts are similar to those of South-West Finland.

In addition to the complexes studied by archaeologists, there are also finds of separate objects: fire-striking stones, axes, angons etc. The chance finds are more numerous to the north of the Gulf of Finland and on the Karelian Isthmus, thanks to the activities of the Museum Department of Finland, but they are also known on the southern coast of the gulf.

Another cultural world began at a distance of several tens of kilometers south of the Gulf of Finland. Here (in contrast to the coast) archaeologists are known for numerous settlements of the V–VIII centuries, and the cemeteries are represented by barrows or grave-fields. The local archaeological cultures have some common features that distinguish them from sites on the coast and islands: the



Archaeological finds on the islands and coast of the Gulf of Finland and Ladoga Lake (1–3 – Bolshoy Tyuters; 4–7 – Riekkala (Nukuttalahti); 8, 9 – Lapinlahti-Naskalinmäki; 10–11 – Salme)

notable similarity of the ceramic and things, the distinct presence of cultural ties with the territories further to the south and south-west.

The oldest cities in the northwest of the Russian Plain – Staraya Ladoga, Pskov, and Izborsk – appeared in the zone of closest contacts between the "sea" and "forest" cultural worlds. The geographic similarity is very notable: both Ladoga and Pskov are located near the mouth of a large river, flowing from the south into a huge lake, across which one can move further in several directions or enter the Gulf of Finland; both centers are located between the lake and important river rapids. The location of Izborsk, in general, follows the same model, although it is possible to pass a small river Obdekh only to Izborsk itself. In all probability, this is followed by an important historical pattern, which requires further study.

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The population to the South of the Gulf of Finland in the first centuries AD – the sites of Tarand-grave culture in the Leningrad region

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Until recently, the beginning of the constant settlement of the Izhora Upland was attributed to the Middle Ages. In the last ten years, a new group of sites of 1–7 centuries AD has been discovered [1]. They are concentrated in the north-west of the Izhora Upland. These are cemeteries and stray finds of Tarand-grave culture (1–4/5th centuries AD) and of the subsequent period (about 6–7 centuries AD). Two cemeteries were investigated by excavations in 2008–2016. They are located in the district of the village Kerstovo - burial grounds Kerstovo and Mally. Here, funerary structures were discovered in the form of stone fences. Numerous cremation burials and a rich collection of funeral implements were found. Both cemeteries were built in the 1–2 centuries AD. In Malli also made burials in the 6th-7th centuries. The population who left these burial grounds most likely spoke in the Baltic-Finnic languages and was ancestors of the local Baltic-Finnish population, known by medieval historical sources.

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Dangerous sea level rises in the Gulf of Finland in a changing climate

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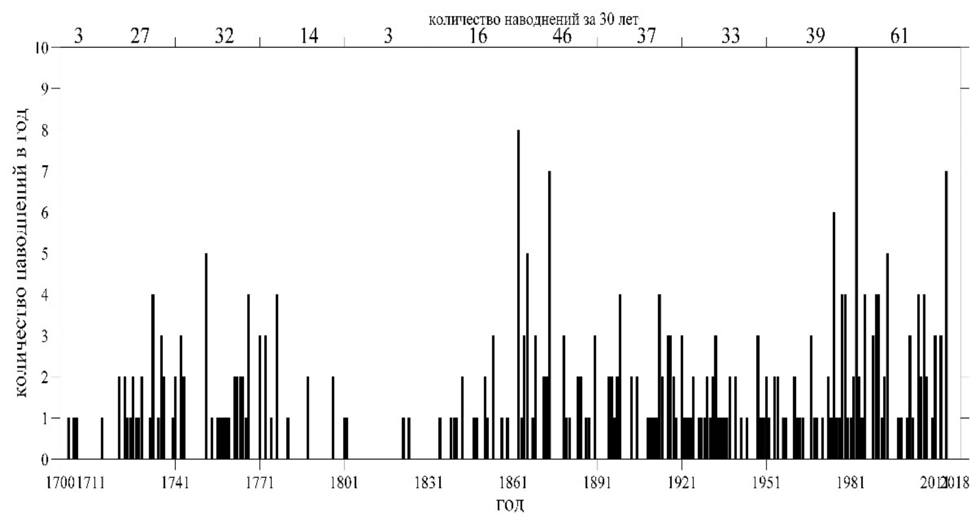
To dangerous sea level rises in the east of the Gulf of Finland it is customary to refer elevations above 160 cm relative to the zero of the Kronstadt footwell, for which the average long-term position of the water surface of the Baltic Sea is taken at the Hydrometeorological Post of Kronstadt (Kotlin Island). Accumulated historical data show that from 1703 to 2016, 322 flood cases were recorded in St. Petersburg, and statistics show that dangerous sea level rises in the East of the Gulf of Finland occur at any time of the day and season of the year under the most diverse weather conditions in this region.

According to current views based on empirical and theoretical research, Neva flooding is a complex multifactorial process. It is believed that the dominant contribution to the formation of the Neva River floods make mesoscale sea level fluctuations with typical periods of 24–30 hours caused by atmopsheric forces of deep cyclones, moving on the area of the Baltic Sea. The mechanism of catastrophic level rises in the estuary of the Neva River is described as follows. When a deep cyclone going over the open Baltic Sea mainly from west to east on the northern periphery level perturbation is formed, which at the termination of the disturbing forces spread to east of the gulf of Finland in the form of free long gravitational waves [1, 2, 3]. Moving to the top of the Gulf of Finland, the long gravity wave is constantly increasing due to the reduction in the height of cross-sectional areas of the bay. If speed of atmospheric cyclones coincidence with speed of free gravitational wave occurs resonance phenomenon, which leads to a particularly strong increase in amplitude. It is believed that another major contributing factor in the formation of highly dangerous and catastrophic level rise is blowing in the rear of cyclones over the Gulf of Finland, a strong west or southwest wind, which creates a significant surge, combining with the crest of the length of the gravitational wave [3].

Historical data about dangerous sea level rises that occurred in the east of the Gulf of Finland indicate that their number in the late 20th and early 21st centuries increased noticeably. The results shown in Fig. 1, show that over the last three decades the total number of floods over the previous thirty-year period increased by half. The mechanism of interannual variability of the frequency of dangerous sea level rise in the east of the Gulf of Finland remains still incomprehensible.

One of the hypotheses of increasing the frequency of floods in recent decades may be associated with long-term changes in the characteristics of atmospheric cyclones. Indeed, our knowledge of the mechanisms of flooding in the Neva River gives good reasons to assume that the interannual variability of anemobaric forces in cyclones, their numbers, trajectories and speed of movement should, apparently, influence the changes in the frequency of dangerous sea level rise in the East of the Gulf



Distribution of cases of Neva floods by years

of Finland. The second hypothesis of increasing the frequency of dangerous sea level rise in the East of the Gulf of Finland may be associated with the theoretical identification of waves of the Neva floods as baroclinic topographic waves [4, 5]. Such identification does not exclude the hypothesis of the effect of interannual changes in baroclinic conditions of the Baltic Sea on the frequency of generation of dangerous level rises in the East of the Gulf of Finland.

To assess the characteristics of atmospheric cyclones (horizontal gradient of atmospheric pressure, trajectory, number of cyclones, their depth and speed of movement, wind speed), different meteorological information was used. Based on the obtained data, the interannual variability of these characteristics and their effect on the frequency of dangerous level increases are investigated. The carried out cross-correlation analysis between the number of floods and various characteristics of atmospheric cyclones did not reveal significant connections between these processes (the largest correlation coefficient is 0.39).

It was shown in [4] that in some cases the waves of the Neva floods are identified as baroclinic topographic waves. However, baroclinic wave modes can be generated and propagated only in a stratified ocean. Neva floods occur in 90 percent of cases in the autumn-winter period, in storm winds, in autumn-winter convection, and in strong wind-wave mixing. Evidence is required to maintain a stable stratification during dangerous level rises. To study the variability of hydrological conditions during floods, we analyzed data from instrumental measurements using ADCP vertical flow profiles, and data of vertical distribution of temperature and salinity.

The results of the analysis of vertical temperature and salinity profiles obtained from international databases show that, despite the stormy wind, autumn-winter convection and intense wind-wave mixing in the Gulf of Finland during dangerous sea level rises, a pronounced stratification is maintained. Apparently, under such conditions, with the intensification of the processes of turbulent viscosity and the diffusion of the substance, there is a significant increase in the advection of heat and salt to the Gulf of Finland from the open Baltic, which helps maintain a stable stratification.

To assess the vertical structure of the currents, we used data from instrumental observations performed with the help of Doppler profilographs of currents in various parts of the Gulf of Finland during the passage of a flood wave along it. A study of the structure of vertical flow profiles in the Gulf of Finland showed that as the depth increases, no turn is registered of the mean current vector along the Ekman spiral, that indicates an insignificant contribution of the purely drift component to the background transport evidently formed under the influence of the gradient current. In this case, during the propagation of flood waves on the bins, rotation of the vectors of total currents with time, which is characteristic of the wave process, is noted. In addition, when assessing the baroclinic and barotropic components of the current, it was revealed that during the dangerous sea-level rise there is no reinforcement of barotropic component; on the contrary, during this period, the amplitude of their baroclinic component increases. The vertical structure of baroclinic flows is the same as that of the internal waves of the 1 st vertical mode: maximum currents are observed in the surface and near-bottom layers, and in the deep layer one minimum (the wave node); with the depth of the current change their direction to reverse. These results confirm the hypothesis stated earlier in [4, 5] that in some cases the waves of the Neva floods are identified as baroclinic topographic waves.

To verify the assumption of the effect of interannual changes in the baroclinic conditions of the Baltic Sea on the frequency of generation of dangerous level rises, the data of the reanalysis of the hydrophysical fields of the Baltic Sea, obtained in the framework of the MyOcean Products project (http://www.myocean.eu) are used. The results of a cross-correlation analysis between the number of floods in the Neva estuary and the changes in the baroclinic conditions of the Baltic Sea show that in the northeast of the open Baltic, at the entrance to the Gulf of Finland, an area is identified where the correlation coefficients approach 0.60, indicating that the increase in the number of Neva floods is connected with the intensification of stratification. For several local areas of the Baltic Sea, there are high correlation coefficients between the number of Neva floods and the horizontal density gradient, reaching 0.66-0.73.

Thus, the results of statistical analysis of various hydrometeorological information obtained on the basis of the methodological approaches used by us do not support the hypothesis of the effect of the interannual variability of various characteristics of atmospheric cyclones on the increase in the frequency of floods in the Neva estuary in recent decades. In contrast to this for a several areas of the Baltic Sea, there is a high correlation between the number of dangerous rise in the level in the east of the Gulf of Finland and changes in the baroclinic conditions of the sea.

The forces of the wind stress and the horizontal gradient of atmospheric pressure in a deep cyclone discharge the thermodynamic system of the Baltic Sea from the equilibrium state at the frequency of its natural oscillations, forming a sea level disturbance, the relaxation of which in the low-frequency frequency range occurs in the form of baroclinic topographic waves propagating eastward to the Gulf of Finland. However, for the anomalous growth of their amplitude, which ultimately affects the dangerous sea rise in the Neva Bay, favorable baroclinic conditions of the basin are needed.

It can be assumed that the increase in the temperature of the Baltic Sea in recent decades as a result of global warming also affects the baroclinic conditions of the basin, which are apparently more favorable for the generation of baroclinic topographic waves that form floods in the east of the Gulf of Finland.

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Geological hazards of the Eastern Gulf of Finland coastal zone

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Traditionally the coastal zone of the easternmost (Russian) part of the Gulf of Finland has not been considered as an area of active litho- and morphodynamics, but a recent study in frame of projects "State Monitoring of geological environment of the near-shore zone of Russian Baltic Sea" (funded by "Rosnedra Agency"), "Geological and geophysical research aiming development of St. Petersburg Coast Protection Program" (funded by Committee on Natural Use, Environmental Protection and Ecological Safety of St. Petersburg) and of project № 17-77-20041 of Russian Science Foundation has shown that the easternmost part of the coastal zone suffers from erosion. Within some coastal segments the shoreline recession rate reaches 2–2.5 m/year.

There are several natural and anthropogenic reasons of this process. The geometry of the Gulf of Finland and Neva Bay is such that only storms from a narrow range of directions may cause high wave loads and storm surges in this area. The specific feature of the coasts in question is that they are jointly impacted by several geological, geomorphic, hydrometeorological and anthropogenic factors, the magnitude of which may vary in a wide range depending on a particular event and region. The geological and geomorphic factors determine the long-term coastal zone development. The most important prerequisite of relatively rapid coastal erosion in the area in question is the composition and properties of coastal deposit. The coasts mostly consist of easily erodible Quaternary deposits (clays and sands). They evolve under overall sediment deficit which is partially augmented by numerous boulder belts formed as a result of glacial till erosion. Moreover, some specific, small-scale features of the near-shore bottom (such as submarine terrace erosion, erosion runnels and other points of sediment loss) play a very important role in the entire erosion process [1].

The most extreme erosion events are controlled by a specific combination of hydrometeorological factors. Such events occur when three unfavorable conditions take place simultaneously:

– long-lasting western or south-western storms that bring high waves to the area in question;

– high water level (more than 2 m above the mean level as measured by the Gorny Institute water level measurement post;

– absence of stable sea ice during such events [1].

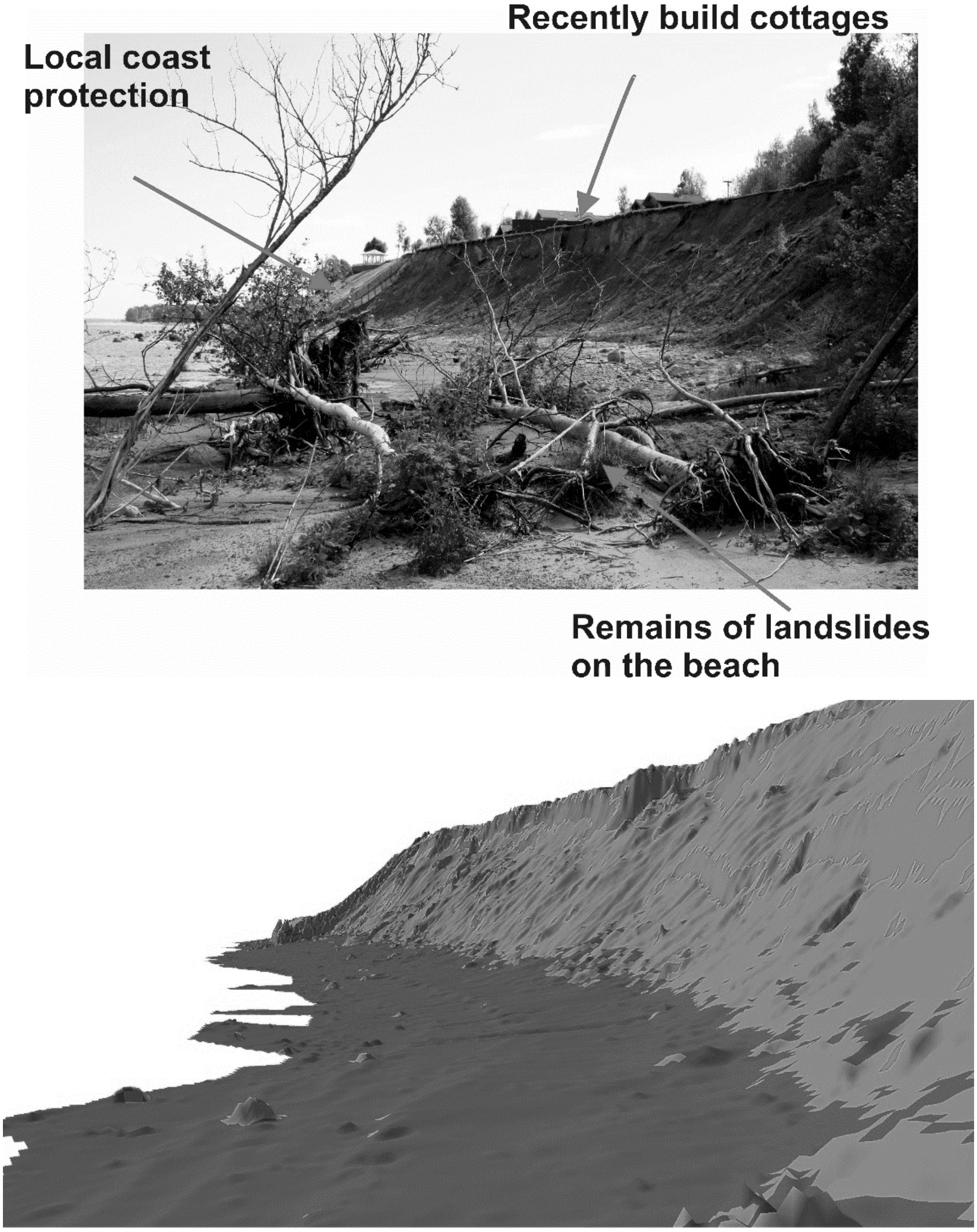
Among the most important anthropogenic processes effected coastal erosion should be mentioned: 1) St. Petersburg Flood Protection Facility; 2) extraction of raw material (sand, gravel) from the submarine terraces of the Eastern Gulf of Finland and (locally) from the beaches; 3) absence of effective coast protection strategy.

Flood Protection Facility (FPF) is completed in 2011. Since completing FPF the coasts within Neva Bay are well protected from coastal erosion. On contrary, coastal erosion processes outside the FPF becomes recently much more risky due to higher extreme storm events frequency and increasing of water level as a result of Flood Protection Facility impact. Modern effective coast protection measures are urgently needed here.

Observations of the coastal processes of the Eastern Gulf of Finland shore have shown its recent drastic intensification. According to observations, since 2004 the frequency of occurrence of such unfortunate combinations apparently has increased and observed three times (during autumn and winter storms and floods of 2006–2007, 2011, 2013, and 2015). Each time extreme coastal erosion events took place during relatively warm winters.

Analyses of terrestrial laser scanning results [2] results permitted to establish mechanism of beach morphodynamic response due to extreme storms. Comparison of relief surfaces over the years made it possible to identify the most dynamic zones of the backshore of the coastal zone. In the stormy years, a sharp degradation of the foredune and coastal escarpment is observed that is accompanied by sharp reduction in the thickness of sand deposits by 0.6–1.2 m in a narrow strip of the backshore. The surface of the beach in turn undergoes less noticeable transformations, mainly with a sediment thickness decreasing in the upper and lower parts of the beach to 0.3 m, and increasing of sand thickness to 0.3–0.6 m in the central and beachface zones in the form of a discontinuous bar. Separately in the scanning area, it is possible to distinguish the migration zones of the stream mouths, shifting by 60 m in different directions along the coast, with a predominant eastward direction.

Analyses of natural factors controlled coastal erosion has shown that for some of them are not



A

B

Coastal escarpment with active landslides (Lebyazhye village). A – photo after intence storm (2013); B – 3D model of slope based on results of terrestrial laser scanning

possible to develop more or less adequate prognoses using available scenarios. It is possible to predict changing of ice-coverage time and an average sea-level rise. On the other hand prognosis of storminess and extreme increase of water level is practically impossible by now. That is why the next stage of predictive coastal erosion map was mathematical modeling of erosion rates in case of different climate change scenarios [3].

Rather smooth relief with low coasts and shallow nearshore characterizes most part of the Eastern Gulf of Finland coastal zone. That is why coastal escarpments higher than 10 m are observed just locally. Nevertheless within areas of high escarpments development landslides are can be very active, reaching hazardous level. It is noteworthy that exogenous hazards are closely links with each other. Coastal erosion trigger the landslides, as extreme storms resulted in removing of sediment material from the backshore. This processes leads to breaking of slope equilibrium and started activation of landslides (Figure). Among the other reasons of landslides activation is high rainfall amount, provoking both surface slope erosion and increase of groundwater discharge.

On the other hand active landslides along with intense river erosion, triggered by high rainfall amount, can temporally decrease intensity of coastal erosion filling the deficit of sediment material in coastal zone. One of the main tasks of hazardous processes monitoring is quantitative assessment of sediment volume remove and loss, as well as modeling and prognosis of the coastal zone development.

Hazardous coastal exogenous geological processes can be definitely classified as a „climate dependent" geological hazard, proper understanding of possible future development of such climatic factors as annual time of ice coverage, sea-level change and storminess is very important for prediction and mitigation of future damage of coastal infrastructure and choosing of adaptation strategy. One of the first step in this direction should be an implementation of "St. Petersburg Coast Protection Program", initiated by Committee on Natural Use, Environmental Protection and Ecological Safety of St. Petersburg and developed by team of scientists and engineers in 2015–2016. The main idea of developed strategy is sand nourishment and creation of artificial beached within most valuable and vulnerable segments of the Eastern Gulf of Finland coastal zone.

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Stone battle axes in the North-West Russia and Finland: similarities and differences

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There are a lot of stone battle axes in the territory of the North-West Russia and Finland. Most of them are stray finds (80 %). The main purpose of this project is to classify stone battle axes, to identify their common and regional features and chronology. Mostly, these artifacts dated to the III mil. BC and relate to the spread of Corded Ware culture. These archaeological cultures most of the researchers identify with the Indo-Europeans. In XX century was created a hypothesis about migration inhabitants of the Fatyanovo (forest part of Russia) Culture to Estonia, which was based on the battle axes typology. Nowadays this theory is not proved. Also, we should note, that there are a lot of classifications of the stone battle axes in the different regions, including Finland and Russia. In this topic, each of the classifications will be examined and will be offered an explanation of the cultural and historical processes that have taken place in North-Western Russia and Finland.

Cyanotoxins Occurrence in Gulfs of Baltic Sea

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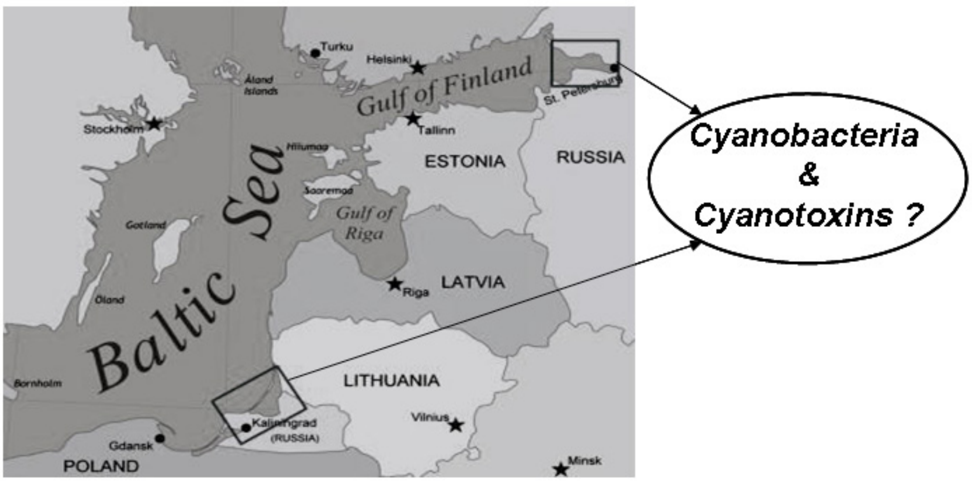
Since the 2000s, Harmful Algal Blooms (HAB) have been observed in the Baltic Sea from the Southern to the Easternmost part annually. One of the consequences of HAB is the occurrence of highly toxic secondary cyanometabolites (cyanotoxins) appearing dangerous to aquatic organisms, mammals, and human. Even low levels of cyanotoxins concentration may pose a significant health risk during the recreational and water supply use of water bodies.

The Curonian Lagoon situated in the South-Eastern part of Baltic Sea is a hypertrophic, mostly freshwater water body, with well-developed commercial fishery and recreational activity. This shallow lagoon has limited water exchange with the sea. All this provides the most favorable conditions for high production of cyanobacteria for 8 months in a year. Since the late 1990s, the increase of frequency and duration of HAB have been observed. It was noticed that phytoplankton biomass reached 1000 mg L–1 in the spots of hyper-bloom. Since 2008 in spring and late autumn, bloom incidents have been often accompanied by mass mortality of fish, invertebrates, and birds.

In our study (during the 2012–2015 period) in Curonian Lagoon, HAB events occurred annually with the domination of cyanobacteria of 20–98 % in abundance. Domination of toxic species, such as *Aphanizomenon flos-aquae, Microcystis spp., Woronichinia compacta, Planktothrix agardii* was recorded. During all the season the presence of cyanobacterial hepatotoxic microcystins (MC) in a high amount was revealed by mass-spectrometry method (HPLC-HR-MS/MS). Generally, 7 microcystin congeners were detected; they are MC-LR, dmMC-LR, MC-RR, dmMC-RR, MC-YR, dmMC-YR, MC-FR. The total concentration of the dissolved (extracellular) fraction of MCs were in the range of 0.1 – 290 mkg L^{-1}. The content of the intracellular fraction were 0.4 – 4719 mkg g^{-1}.

The Easternmost part of the Baltic Sea, in particular the Russian part of the Gulf of Finland, was less prone to HABs. The blooms usually spread only to Gotland Island. In the Gulf of Finland cyanobacterial blooms were recorded mainly in the Vyborg Bay and near the Primorsk. In our study, 7 cruises, which covered Eastern parts of the Gulf of Finland, including Vyborg Bay, Cu-



rort Area, Neva Bay, were undertaken during 2012–2014. In 2012–2015, HAB events were not observed and other algae species were dominant (including diatoms and green algae) in the phytoplankton. In the studied period the cyanobacterial biomass in the samples varied from 0.04 mg L–1 (cruises in 2012–2013) to 25.2 mg L–1 during bloom events. 25 % of the collected samples contained a trace amount of extracellular microsystins (0.01–0.10 µg L–1). MCs concentration in a range of 0.11–20.00 µg L–1 was detected in 8 % of the samples. At the species level, the most frequently occurring cyanobacteria were *Aphanizomenon flos-aquae* and *Planktothrix agardhii*. Generally, cyanotoxins were detected in the lateral zone. The level of detected toxins was in accordance with Satellite MODIS data (set on space satellites Terra and Aqua, resolution 250 m), which estimated the cyanobacterial blooms in the Baltic Sea in a range from weak to average.

However, in the autumn of 2015 and 2017, HABs were recorded in coastal waters of Saint-Petersburg (near Komarovo and Zelenogorsk). The water samples were collected in the coastal area and in open waters next day. The samples taken in zone of open water area did not contain or contained trace amounts of toxins. The contribution of cyanobacteria in the coastal water samples exceeded 90% of the total biomass. *Dolichospermum* spp., *Planktothrix agardhii, Aphanizomenon flos-aquae, Microcystis aeruginosa* were dominant species. LC-MS/MS analysis revealed the presence of 9 congeners of hepatotoxic microcystins, and neurotoxic anatoxin-a. The maximum total MC concentration in coastal waters (49 µg L^{-1}) near Zelenogorsk was higher than the WHO guideline value for recreation water. In the biomass, 12 variants of intracellular MCs were detected.

Conclusion:

– The hydrological (wind mixing, a limited water exchanges with the sea and shallow) and ecological difference (trophic state) between the two regions – the Easternmost (Gulf of Finland) and the South-eastern part of the Baltic Sea (Curonian Lagoon), explains the significant difference in the cyanotoxin content and the dynamics of HABs.

– Phytoplankton biomass varied in several times and phytoplankton composition differed between studied parts of Baltic Sea.

– In Curonian Lagoon, the microcystins concentrations constantly transcend (more than once) the guideline concentration annually. In the eastern part of the Gulf of Finland, the maximum total microcystin concentration in water of coastal zone only once sporadically exceeded the guideline value for recreation water stated by the World Health Organization.

– In spite of the similar composition of toxigenic cyanobacterial species in both studied parts of the Baltic Sea, the presence of neurotoxic anatoxin-a was detected only in the eastern part of the Gulf of Finland.

Due to the presence of potentially toxic cyanobacterial species, further monitoring investigations should be conducted for better assessment of potential risk for water users.

Marine litter study in the estuary of the River Neva: results of monitoring and mathematical modelling

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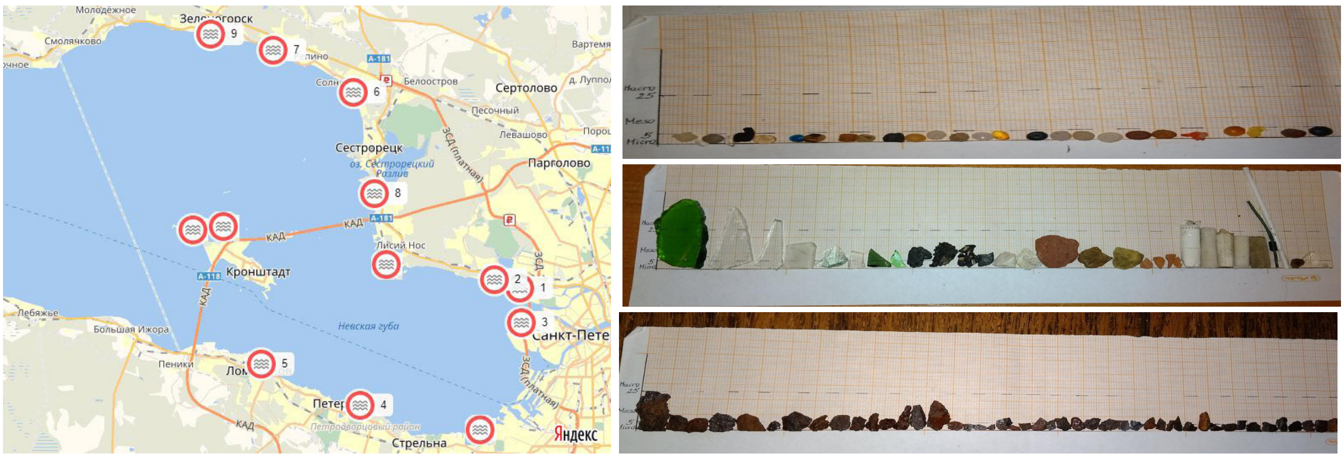
Marine litter pollution is now becoming a growing issue for the coastal regions, in particular for enclosed and highly populated water bodies, like the Gulf of Finland. Ecosystems of enclosed seas with the high anthropogenic load can be especially vulnerable to accumulations of plastic particles along the coast, in lagoons and estuaries. The sources of marine litter are mainly land-based and are associated with poor waste management including littering, wastewater and rain drainage management [2].

The metropolitan area of St.Petersburg together with the Leningrad Oblast produces annually about 112 000 tons of plastic wastes [4]. Due to no centralized system of plastic litter separation and treatment, all wastes are stored in landfills, with much of it eventually finding its way to the adjacent waters (rivers, lakes and the sea) and migrating through the borders. A great amount of litter is accumulated on the beaches of the Gulf of Finland and the Neva Bay. The enclosed lagoon-type bay of the Neva Estuary can serve as an accumulation zone for some types of litter.

The plastic litter problem has never been investigated for the Russian sector of the Gulf of Finland and the Neva River estuary, thus, in the summer of 2018 for the first time the field study was carried out in this area to assess the marine litter accumulation in the aquatic environment. The results of monitoring will serve the basis of a mathematical model of litter distribution in the Neva estuary.

Beach litter accumulation is now the most studied in the Baltic Sea region as compared to plastics distribution in water and at the seafloor, however, the methods for an adequate and harmonized assessment of the distribution and sources of marine litter are still under development. Various international methods for marine litter monitoring were used in summer 2018 in order to estimate litter distribution on the northern and southern coasts of the Neva Bay in urban and rural areas with different recreational loads.

The coastline of the Russian part of the Gulf of Finland and the Neva Bay in particular is very diverse and was formed by subaerial and tectonic processes (Skerries), non-marine processes (alluvial plains), by waves (marine erosion, accretion, abrasion coasts) as well as technogenic processes (embankments, hydrotechnical constructions, etc.) [1]. The most widespread coast type on the northern and southern coasts is erosion coasts with bays and sand accretion areas with wide (50–150 m) stable sandy beaches. The easternmost part of the coastline within the Neva River mouth is completely transformed by the technogenic processes [1]. In terms of the recreation potential, the most visited



Stations of beach litter monitoring in the Neva Bay in summer 2018 and some samples of micro- and meso-litter (plastic pellets, glass fragments, cigarette butts, metal pieces)

sandy beaches are located in the Kurortny District (northern coast) and near Peterhof and Lomonosov area (southern coast). Kurortny District hosts 12 the most popular and visited public beaches that are regularly cleaned by the municipal services, however, there are a lot of so-called "wild" beaches in between, that are cleaned randomly throughout the season. Thus, several spots were selected for beach litter monitoring on both sides of the Neva Bay (see Figure) in terms of cost-effectiveness and accessibility by the main roads.

The Neva river estuary is separated from the open area of the Gulf of Finland by the Flood Protection Barrier (FPB or a Dam), i.e. is an almost enclosed water body receiving the Neva river waters. At the same time, the coasts outside the dam were also monitored (coasts of Kronshtadt, northern and southern coasts of the Gulf), that allowed the comparison of the marine litter pollution levels inside and outside the Neva Bay.

In summer 2018 two beach litter monitoring methods were used, developed at the Leibniz Institute for Baltic Sea Research (Leibniz-Institut für Ostseeforschung Warnemünde, IOW) [3] – the Sand Rake method and the Frame-method – that focus on large-micro (2–5 mm) and meso-litter (5–25 mm) in the 30–50 mm upper sediment layer. Rake-method is used to cover at least 50 m^2 of the sandy beach between the water line and the vegetation line along the whole width of the beach, while Frame-method is applied locally in the lagoon-type bays along the wave wreck-line of the beach. Both methods are suitable for sandy beaches, even if they are regularly cleaned, and to assess pollution hot-spots.

The structure of litter on the beach and deeper in the water (near coast seafloor) can be very different. This is mostly due to the different origin of the litter but also due to the different physical properties of the litter. Most of the floating litter is washed ashore (mostly plastic, paper etc.) and heavier items sink to the bottom in locations they enter the marine environment. The areas with heavy human impact, like harbours, tend to accumulate the different types of litter. Also, in the Neva Bay, tourism/beach visitors always plays the main role in seasonal litter pollution.

The preliminary results of beach monitoring in summer 2018 showed that:

– the northern and the southern coasts of the Neva Bay and the Gulf of Finland (Kurortny District) differ dramatically in terms of litter composition (particle size, material, amount, etc.)

– the largest litter accumulation in the Neva Bay was registered at the city beach near metro Primorskaya (north side of the Port), at the city beach Zhemchuzhny (southern side of the Port), at the Park Aleksandria (Peterhof) and at the Lomonosov city beach. However, the composition and the particle size were very different.

– The cleanest city beach, in general, was at the Park of 300-year Anniversary of St.Petersburg (the park is cleaned every day).

– Plastic was the dominant type of litter in all fractions (50–60 %) on the northern coast of both the Neva Bay and the Kurortny District beaches, however, it was much less found at the regularly cleaned public beaches like Lakhta or Zelenogorsk than at "wild" beaches.

– Beaches on the southern coast of the Neva Bay were mostly covered by broken bottle glass, pieces of corroded metal (from boats) and plaster (gypsum cement) – a very light and crumbly construction material. Plastic made only up to 10–12 % of the total amount of litter.

– Beaches of Kronshtadt (outside the Dam) contained mostly corroded metal and broken glass pieces.

– The largest amount of meso- and macro-litter was found inside the Neva Bay as compared to the area outside of the Dam (Kurortny District), where the dominant fraction of litter was micro-particles (2–5 mm).This can be explained by the irregular beach cleanings in the city and large amount of tourists in this area.

The results of beach monitoring will be used in the modeling of the process of litter distribution in the easternmost Gulf of Finland, including the Neva Bay. Modeling will be based on a 3D model of transport and resuspension of bottom sediment particles in the indicated region, considering the transport of particles by currents and wind waves [5]. This model has a high resolution (from 40 m at the mouth of the Neva to several hundred meters near the FPB), which will allow reproducing details of the distribution of marine litter coming with the waters of the Neva, within the Neva Bay. At the first stage of the study, the two specified litter fractions will be considered separately, as passive (with respect to hydrodynamics and biogeochemistry) tracers with individual rates of gravitational sinking. The calculations will use near-real wind speed fields, which are planned to be determined using both reanalysis products and short-term data from meteorological stations. It is assumed that the release of litter ashore will be proportional to the intensity of the waves (significant wave height) in the surf zone. The obtained estimates of potential litter accumulation sites on the shore will be matched with the above monitoring results.

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Geochemical structure of the Fe-Mn concretions of the eastern Gulf of Finland: natural processes and anthropogenic impact

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Shelf ferromanganese concretion formation is a widely consolidated process of modern subaquatic ore genesis. Ferromanganese concretions are widespread in the different shallow-water areas of the European seas, including the Baltic Sea White Sea and the Barents and Black seas. Its intensity and variety of consolidation forms in the Gulf of Finland of the Baltic Sea reach extreme values in comparison with other marine basins, which predetermines an increased interest to this object. In the eastern Gulf of Finland, the abundance of spheroidal concretions locally reaches 50–60 kg/m^2 (wet weight).

Nowadays geo-ecological aspects of ferromanganese concretion studying of the Gulf of Finland have acquired particular significance, because the Gulf of Finland is badly stressed by the population of almost 16 million people in its catchment area, with the largest city being St. Petersburg with more than 5 million inhabitants [3]. Experimental-industrial mining of ferromanganese concretions was carried out in the Vyborg Bay in 2006–2008. A unique natural experimental landfill was formed where it has become possible to study modern sedimentary and geochemical processes disturbed by technogenic interference.

The purpose of this study is to examine the impact of the extraction of ferromanganese concretions on the marine benthic geological environment and to study the possibility of ferromanganese concretion field natural regeneration after extraction.

The distribution and composition of the various morphological types of concretions in the Gulf of Finland are related to the bottom relief and character of the sediment, but the ones mostly enriched by manganese has a spherical shape. As a rule, the sediments underlying the layers containing spheroidal concretions are represented by early Holocene Ancylus lacustrine clays or the upper parts of glaciolacustrine clays. The concretion layer is rarely found covering Middle Holocene Littorina Sea sediments or recent marine muds but occurs within a limited range of water depth at the margins of mud zones. Mn, Fe and related elements are remobilized from anoxic muds and migrate into the bottom waters [1]. The constant (or seasonal) lateral migration of these elements from the mud zones to the periphery provides the spheroidal nodules with a source of metals. The deposition of Mn and Fe at the borders of mud zones may, therefore, be considered to be the result of sorption of the metals on the active surfaces of clastic particles and iron-manganese oxyhydroxides.

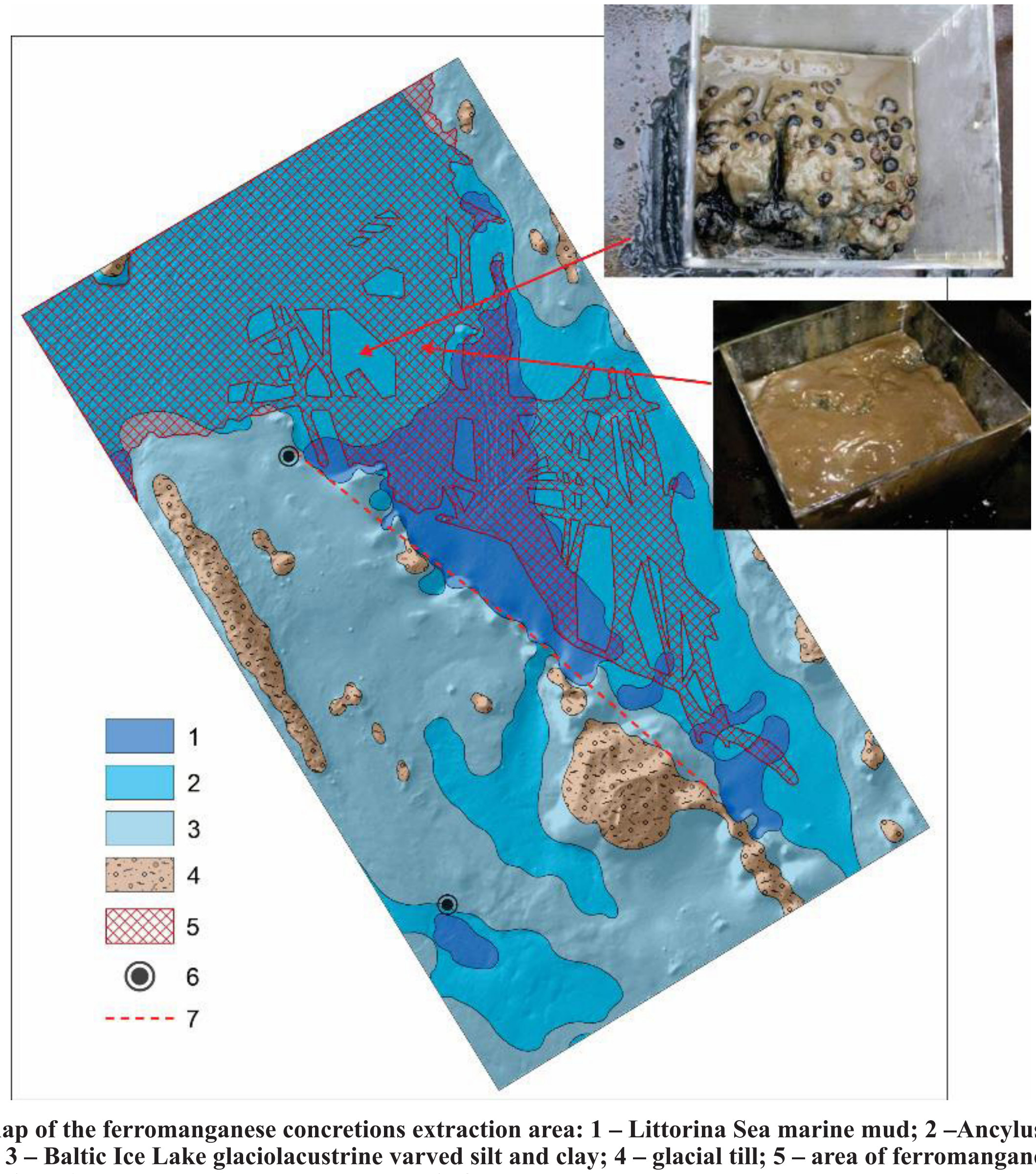
The dating of concretions from the eastern Gulf of Finland is important for revealing the formation time of ore lodes, establishing the rates of the recent ore deposition, and assessing its influence on the environmental parameters. According to our data based on the equilibrium 210Pb isotope, the age and average growth rates of spheroidal concretions (2 cm in size) from the Gulf of Finland are estimated to be 670–850 years and 0,014 mm/year, respectively.

Ferromanganese concretions of the eastern Gulf of Finland accumulated Mn metal via riverine input to the gulf for 1350 to 2700 years. The average concentrations of P_2O_5, one of the main pollutants in the Gulf of Finland, in ferromanganese concretions are 10 times higher than those of the bottom sediments [2]. Under natural conditions, the contents of most minor heavy metals in the ferromanganese concretions just slightly exceed the level of regional background concentrations in the bottom sediments. However, because of the increasing input of anthropogenically derived toxic metals (e.g., Pb, Zn, and Cu) to the Gulf of Finland in the 20th century, the content levels of these elements at surface micro-layers of growing flat concretions and in the smaller or younger concretions have increased by 3–5 times. In addition, concretions sampled in the northeastern part of the Gulf of Finland are characterized by high concentrations of As. The median value of As concentration is 185 ppm. This value is approximately 20 times higher than the background As concentration (8 ppm) in silty-clayey sediments of this area [2]. Ferromanganese concretions are also enriched in some radioactive elements.

Thus, we can consider shallow-water concretions as natural metal ionic traps «cleaning» near bottom waters of some toxic elements. It is also possible to assume that abundant concretion fields situated in the border area between oxidized and reduced conditions in the sediments can play an important role as a buffer system, partially smoothing changes of redox conditions in near-bottom and pore waters.

In 2006–2008, Petrotrans Ltd. extracted concretions using the dredge pump vessel Lauwer in the Vihrevoey economic deposit area in the Vyborg Bay at the water depth 25–28,5 m. In total, approximately 56.000 t of spheroidal concretions were extracted from the bottom of the sea and partly processed into manganese concentrate at a factory in Kingisepp, Russia. This was the first experimental-industrial extraction and processing operation of marine shallow-water ferromanganese concretions in the world.

The whole Vihrevoey economic deposit area was characterized by slow or almost no sedimentation prior to concretion extraction operations. The spheroidal concretions are exposed at the seafloor or covered by a 10–20 mm layer of flowing mud. The thickness of the concretion layer achieves 50–150 mm. At a depth of approximately 50 mm, iron oxyhydroxide cementation of the concretions is often found. Spheroidal concretions 2–30 mm in diameter and with a granular surface texture are typical for undisturbed seafloor areas. The conditions of sedimentation changed markedly in the trenches (up to 1 m depth) left by the dredging vessel Lauwer (figure). Spheroidal concretions (up to 1 cm in diameter) and their debris are rare and mainly found buried at a depth of 50–100 mm in the sediments. The thickness of brownish-gray silty-clayey mud surface layer covering concretions suggests a significant increase (up to 1–1,5 cm/year) in sedimentation rate, supposing that sediment evenly accumulated after dredging in 2006–2008 (figure). In that case, slow or almost non-sedimentation was replaced within the trenches by mud accumulation. Conversely, it is possible that accumulation occurred as a result of re-deposition of dred-



Sea-bed map of the ferromanganese concretions extraction area: 1 – Littorina Sea marine mud; 2 –Ancylus lacustrine clay; 3 – Baltic Ice Lake glaciolacustrine varved silt and clay; 4 – glacial till; 5 – area of ferromanganese concretion extraction; 6 – pockmark; 7 – supposed tectonic fault

ging caused suspension. In either case, within the trenches, the redox potential in the bottom water was recorded over a range of 0 to 63 mV, and only at two sites was it positive (+20 and +27 mV). The samples of buried spheroidal concretions that were gathered within the trenches are characterized by an absence of microconcretions or young concretions. The surface of the sampled concretions is not granular but smoothed [4].

It is possible to suppose that concretions that are buried in the trenches conserve or, more likely, dissolve. The geochemical characteristics of spheroidal ferromanganese concretions, sampled from the area of extraction, differ significantly from concretions of similar morphology that were collected from the undisturbed areas.

Factor analysis of chemical composition of combined sample group of concretions collected in the area of under-water extraction and concretions collected in the undisturbed areas showed essential difference between them. It can be assumed that concretions sampled within the area of under-water extraction essentially differ in chemical composition and geochemical structure from concretions sampled within the undisturbed areas. In general, the Mn/Fe ratio in concretions as well as content of terrigenous elements, which are mechanically involved by growing concretions, depend on several natural factors, among them the location and water depth of concretion field occurrence. But these natural factors cannot provide such a high difference in contents of major elements in the concretions, and certainly not able to violate geochemical associations in the concretions. Most likely the reason for such significant changes in the chemical composition of the concretions is the selective removal of elements from dissolving concretions.

Thus, the concretions remaining after underwater extraction as a result of changing sedimentation conditions, mud accumulation and concretion burial, become a secondary source of contamination for seabed sediments. It is possible to predict further dissolution of concretions buried in the sediment and their subsequent formation on the periphery of the areas of modern mud accumulation after sediments will fill the trenches left by the dredger, and sedimentation equilibrium will be restored to how it was before concretions extraction.

The processes of ferromanganese formation can influence on the ecological state of the Gulf of Finland Ferromanganese concretions are in a state of stable dynamic equilibrium if oxidative conditions exist at the bottom-water boundary [3]. At the same time, during the last decades there has been a periodic expansion of hypoxia zones [3]. The lack of oxygen in the bottom waters of the Gulf of Finland can lead to the dissolution concretions and the release of a large amount of phosphorus and heavy metals from them. Thus, it is possible to allocate a close connection between the processes of eutrophication and ferromanganese formation. Eutrophication leads to the disappearance of oxygen in the bottom waters, which can affect the dissolution of the located on the bottom ferromanganese concretions, and vice versa, concretions in periodically occurring anoxic conditions can serve as a source of phosphorus, which enhances the eutrophication processes.

It has been estimated that the concretion fields of the eastern Gulf of Finland contain more than 330.000 tons of P_2O_5 which is equal to some 175.000 tons of elementary phosphorus. During our simulation ferromanganese concretions dissolution experiments, it was found that when the natural conditions in bottom sediments change, selective removal of elements from the concretions occurs with secondary water contamination by metals. The experiment on desorption of chemical elements from concretions showed that Mn is the most mobile, it is desorbed even with a small pH change, the behavior of Ni is similar to Mn.

The behavior of Fe and As is fundamentally different, desorption of these elements requires a more acidic environment, the desorption occurs explosively. Based on the results of the experiment on the desorption modeling in oxygen deficiency conditions, it was found that the dissolution and selective removal of not only the ore components but also the terrigenous component occurs. With a slight En decrease toward the reductive medium, a significant transition is observed precisely of the sorbed Ni and As.

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Input of nutrients to the Gulf of Finland from Russian and transboundary rivers

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BSAP provides for pollutant reduction of nitrogen and phosphorus compounds into the Baltic Sea to 135,000 t and 15,250 t respectively to the year 2016 (Helcom, 2007). This dataset has then been used for calculating the revised nutrient reduction scheme which was adopted by the 2013 HELCOM Copenhagen Ministerial Meeting (HELCOM 2013a) (table 1).

Table 1

Allowable inputs of nutrients to the Gulf of Finland, tons

Maximum allowable inputs	
Total nitrogen (TN)	Total phosphorus (TP)
101,800	3,600

Nitrogen and phosphorus are the main growth-limiting nutrients - high nutrient concentrations in the aquatic environment stimulate the growth of algae, which leads to an imbalanced functioning of the ecosystem. The aim of this research was to assess dynamic of input of nutrients to the Gulf of Finland from some Russian (the Neva River, the Luga River) and transboundary rivers (the Narva River, the Seleznevka River). Primary data were taken from the materials yearbooks of the North-West Administration for Hydrometeorology and Environmental Monitoring. Fluxes of total phosphorus and total nitrogen are calculated on annual basis concentrations by multiplying annual mean discharge:

$$Q = 0.031536 \cdot C_i \cdot R_i,$$

where Q is input of TN or TP, tons; Ci is average annual concentration, $\mu g \cdot L^{-1}$; Ri is annual mean discharge of water, $m^3 \cdot s^{-1}$. Results of calculations are given in table 2.

Table 2

Mid-annual input of nutrients to the Gulf of Finland, tons

River	Period covered	Average input	
		Q(TN)	Q(TP)
The Neva River and its branches	2004–2017	56,162	2,535
The Narva River	2004–2017	13,120	407
The Luga River	2004–2017	5,341	586
The Seleznevka River	2011–2017	481	15
	Total	75,104	3,543

The results show that the input of TP and TN to the Gulf of Finland is less than the maximum allowable input.

Satellite mapping of threats of ecological safety in the coastal zone of Gulf of Finland

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Ecosystems of the coastal zone of the Gulf of Finland are suffering from urbanization and global warming. The main goal of our researches was to develop satellite technology to map a risk of mortality of Saint-Petersburg population, caused by a global warming, as well as an accumulated ecological economical loss of forest ecosystems under anthropogenic loading.

The 30-year time series of land surface temperature (LST) of Saint-Petersburg, retrieved from infrared thermal images of NOAA, Terra, Aqua satellite was analysed. As a result, additional +3 heating of LST was forecasted for daytime of July 2024 [1]. We mapped following thermal properties of Saint-Petersburg surface by using multiple satellite infrared thermal images: the surface albedo, the anthropogenic heat flux, the thermal inertia, the emissivity, the evaporation rate[2]. These maps gave possibility to forecast LST for the any given meteorological condition. As a result, maps of daily maxima UST of Saint-Petersburg for the July of 2024 was compiled. It was exhibited that in July 2024 more than 38 % of Saint-Petersburg area will have LST higher than +30 in spite of 2 % in July of 2014. Such LST rising can cause additional heating of air temperature and the mortality of population rise. Therefore, we developed the method for mapping the risk of population mortality mapping. However, we had no possibility to get the statistical data of real daily mortality in Saint-Petersburg. That is why we suggested that the dependence of mortality on air temperature in Helsinki [3] could be used for Saint-Petersburg, too. Finally, the map of mortality risk was compiled. Additional mortality in Saint-Petersburg due to environment overheating was estimated as 223 deaths. The economic losses of these deaths were estimated at 500 million rubles.

The next our development is the satellite method of mapping of accumulated ecological economic losses of forest ecosystems. It based on the evaporation rate mapping of investigating territory. However, the accurate knowledge of sensible heat flux is quite necessary. The most accurate measurements of this parameter of the atmosphere state can be obtained at special flux towers. However, there are no flux towers in Russia nearby Saint-Petersburg. That is why we have used data from Finnish flux towers (figure).

As a result, we compiled the map of the evaporation rate for the territory, shown above. We noticed that the state border between Russia and Finland, as well as between Russia and Estonia separates area with different evaporation rate. The hypothesis that it is the result of different forestry systems indicates by the evaporation rate. After that, we developed the method of accumulated ecological economic losses mapping by using maps of evaporation rate, maps of ecosystems and the costs of each ecosystem type. This technique provides

Location of Finnish flux towers

the possibility for us to compare different regions of Leningrad Oblast' according to the accumulated ecological losses.

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Geochemistry of Late Pleistocene – Holocene deposits of the eastern Gulf of Finland

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During 2014–2017 years in frame of geological surveys, carried out by A.P. Karpinsky Russian Geological Research Institute "VSEGEI" within the various research projects, bottom sediment cores (1.5 to 2.5 m long) were collected from sedimentation basins of the Eastern Gulf of Finland (EGoF). Deposits of these cores are characterizing the processes of post-glacial sedimentation. Besides, annual sampling of the bottom surface sediments was undertaken within some key areas, which allowed to study the contemporary sedimentation processes.

Late Pleistocene sequence is represented mainly by varved, laminated and homogenous clays of the Baltic Ice Lake (BIL). According to modern concept, the ice lakes were developed within the Baltic Sea Basin between 17 and 11.7 ka BP (Houmark-Nielsen, Kjaer 2003; Andren et al. 2011). Inflows of the saline water during the Yoldia Sea stage (11.7–10.7 ka BP) have never been detected in the sediments cores of the EGoF. Freshwater of Ancylus Lake (10.7–9.8ka BP) sediments are characterized by the presence of distinct, black hydrotroilite inclusions (Spiridonov et al. 2007). In the western part of the Russian Gulf of Finland during this stage (attributed in some publication as Mastogloia Sea, 9.8–8.5 ka BP) the "blue clays layer" were formed, differs from both Ancylus and Littorina sediments by lithology and authigenic minerals (Virtasalo et al. 2012). In brackish-water environment of Littorina and postLittorina seas (since 8.5 ka BP (Andren et al. 2011; Harff et al. 2011)) olive-grey silty clayey mud with a high content of black dispersed organic material was deposited.

For all studied sediment cores a complex of high-resolution sedimentological studies was performed, including grain-size analysis (subsampling every 1 cm, for laminated deposits – each layer) and chemical analysis (including determination of Br as an indicator of paleosalinity) (subsampling every 3 cm). Dating of one of the columns by radiocarbon method was performed, however, it did not give satisfactory results. The samples of bottom surface sediments were investigated by analytical methods include determination of heavy metals concentrations.

Varved clays of initial stage of Baltic Ice Lake (BIL). The sedimentation rate of glacial lacustrine deposits (varved clays) and its change during glacier retreat and increase of basin depth was determined by grain-size analysis. Assuming a "one-year" character of rhythm formation, sedimentation rate can be estimated as a very high (from 20 to 100 mm/year). Distribution of chemical elements in each lamina of clays was studied: two stable groups of chemical elements were identified by factor analysis. The first one is associated with lithological composition and sedimentation conditions (MnO, TiO_2, Fe_2O_3, Co, Zn, Ni, V, Cr). Another one is nearly independent of the grain-size composition and sedimentation conditions (As, Pb, Br, Cu).

Baltic Ice Lake (BIL). Comparison of chemical content between very homogenous clays of Baltic Ice Lake with varved clays revealed a drastic decrease of sparingly soluble mineral forms value, especially of chalcophile and siderophile elements. Withal the concentrations of oxides and hydroxides of Cr, Mn, Fe, Co, Ni, Cu, Zn and As have a sharply increase. These features probably indicate the intensive formation of authigenic sedimentary minerals. Another characteristic of Baltic Ice Lake sediments is an elevated level of humus forms, mainly for chalcophile elements, while the value of carbonate forms decreased. Final difference between sediments of Baltic Ice Lake and sediments of varved clays is noticeable decrease of water-soluble forms concentrations. Sorbed forms and forms associated with bituminous organic constituents have extremely limited distribution both in the Baltic Ice Lake sediments and sediments of varved clays.

Ancylus Lake. Holocene sediments of Ancylus Lake do not show much difference in grain size from Baltic Ice Lake sediments – that is a clay fraction, only containing amorphous iron sulphides. Usually there is a sandy erosion horizon between Baltic Ice Lake and Ancylus Lake sediments, but one of the cores represented the gradual replacing. According to results of statistical analyses of sediment cores geochemistry, some characteristics of sequential sediments were received. Ancylus Lake sediments and Littorina Sea sediments from core 14-T3 show perceptible distinctions in average content, including a wide range of elements: Ancylus Lake sediments represent the higher concentrations of Zn, Ni, Co, Fe_2O_3, Cr, V, TiO_2, then Littorina Sea sediments.

Distribution of the forms of chemical elements (Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Sr and Pb) have specific features in comparison with underlying Baltic Ice Lake sediments. A certain decrease of oxide and hydroxide forms value in Ancylus Lake sediments was revealed, especially for chalcophile elements. Nevertheless, the forms of chalcophile elements associated with the humus organic component increase noticeably. A slight increase of water-soluble forms concentrations was fixed, especially for As, Cu and Mn. The study of bromine vertical distribution allowed to calculate changes of bottom sediments salinity, due to paleogeographic conditions in the basin development of the EGoF. This boundary is characterized by slightly increase of salinity, demonstrates an influence of salty water of Yoldia Sea stage, when the Baltic Sea had a connection with the ocean.

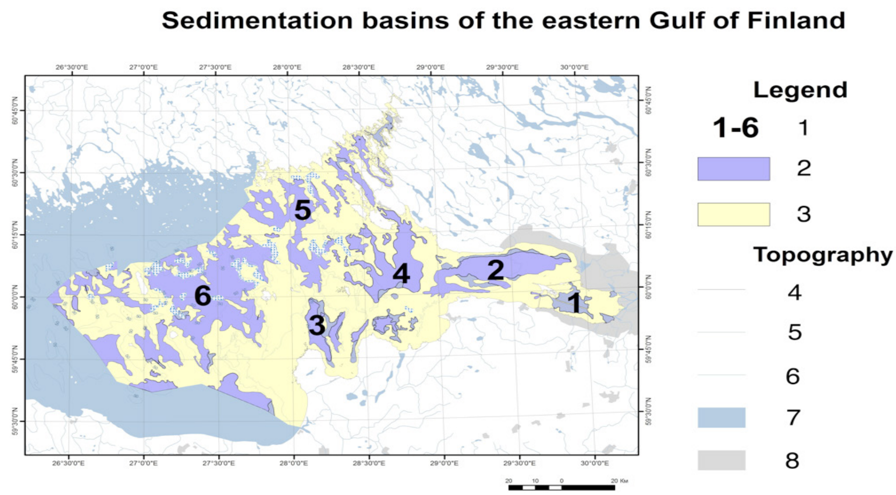
The top of Ancylus Lake sediments in some cores represented by a layer of light blue clay a few centimeters thick. Grain size composition of it differs both from the underlying and overlying sediments by slightly coarser sediments. A layer of “blue clay” was found only in deposits of sedimentary basins, located to the west of the cape Kurgalsky and Maly Island. Probably there were no proper conditions for the basin sedimentation at this time. The vertical distribution of bromine content (and the calculated salinity) in the core 16-G-30-2 shows a drastic change of sedimentation conditions from freshwater (Baltic Ice Lake and Ancylus Lake) to brackish water, fixed in that transition horizon of the “blue clay”. Similar results were obtained for column 09-BI-3.

A thin sandy layer directly above the “blue clays” fixed erosion time of pre-Littorina Sea regression. Grain-size analysis identified the composition of this layer as a silty sand or sandy silt (sandy content is about 20–50 %, according to different cores samples). In the core 16-Г-30-2 this transition zone between Ancylic and Littorina sediments was not marked by an erosion horizon.

Littorina Sea. Grain size composition of the Littorina Sea sediments differ from underlying Ancylus Lake sediments by considerable increase of silty fractions and appearance of sandy admixture (cores 14-T3, 09-BI-3-T-2 and 16-Г-30-2). Near the top of this layer sediments became even more sandy, which indicates an intensification of the near-bottom hydrodynamic activity. A distinct thin lamination was observed only on a short interval in the core 09-BI-3-T-2. Some of samples of homogeneous clays contain organic inclusions.

Concerning the distribution of Br, the Littorina Sea sediments are characterized by two well-marked peaks of salinity maxima, probably due to increasing of water exchange with the ocean, which associated the marine transgression processes. The estimated paleosalinity reaches 10 ‰. It should be noted that the upper part of the core 09-BI-3 was broken when delivered, therefore, in contrast to the results obtained for core 09-BI-3-T-2, the calculated salinity of the upper horizon is slightly higher than the current one.

Sediments of the Littorina Sea show a trend to a certain decrease in the value of oxide and hydroxide forms of chemical elements (Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Pb). The content of sparingly soluble mineral forms has a decline in concentrations, especially for siderophile and chalcophile elements. Abundance of water-soluble forms (except V) is extremely low. Values of the forms associated with the humus organic component, compared with Ancylus Lake sediments, is noticeably lower, however these forms of V and Mn have an enhanced level.



Sedimentation basins of the Eastern Gulf of Finland: 1 – sedimentation basins (*1 – Neva Bay, 2 – Kyrortny basin, 3 – Koporsky and Luzhsky basin, 4 – Berezovy basin, 5 – Vyborg basin, 6 – Deepwater basin*), 2 – silty clay sediments, 3 – other sediments, 4 – coast line, 5 – isobaths, 6 – rivers, 7 – water areas, 8 – urban areas

The modern sedimentary basins of the eastern part of the Gulf of Finland are located in relief depressions (4–5 m depths in the Neva Bay and 50–60 m depth near the Gogland island). These basins are separated by elevated bottom areas where erosion processes, transit and lack of sedimentation prevailed and accompanied by formation of coarse grained sediments, sands and mixed sediments. The research area was divided into six sedimentation basins (including Neva Bay sedimentation basin) due to their distinctions in bathymetry, source of supplying sediments and the hydrochemical regime specifics (Figure).

Using results of geochemical investigations of the cores of bottom sediments undertaken by specialists of Geological Survey of Finland (Vallius, 1999) and VSEGEI, pre-industrial concentrations of elements were calculated for each sedimentation basin (except "Kurortny" basin), fixed at intervals from 25–30 cm to 40–60 cm, depending on the rates of sedimentation. The 'natural' concentrations of elements (assumed to be unaffected by human activities) differ in sedimentary basins: there is an increase of most of the elements in the northwestern sedimentary basins. The highest concentrations of Zn, Cu, As were determined for the bottom sediments of Vyborg basin, the increase of Cu in Berezovy basin. Probably it is caused by geological structure: the northern part of the Gulf of Finland are associated with the crystalline basement of the Baltic Shield, supplying basins with a wide range of chemical elements, transported through eroded material from the rocks of the shield. The lowest concentrations of heavy metals characterized the sediments of Koporsky and Luzhsky basins, which sources of material are located in sedimentary platform area, depleted in ore elements.

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Environmental impacts of seabed mineral extraction – Towards a comprehensive risk assessment

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Mineral extraction from the seabed has experienced a rapid surge of commercial and scientific interest. While the improved methods of geological investigation enable mapping new seafloor mineral reserves, the ecological impacts of mineral extraction in both coastal seas and the deep sea are still poorly known. Baseline data on species and habitat characteristic associated with seafloor mineral deposits are severely lacking and consequently, the integrity of environmental impact assessments could be compromised by this lack of data. While FeMn concretions in the Gulf of Finland have been subject to numerous geological investigations, little information on their distribution and ecological role in habitat formation is available.

In this work, we examine the ecological role of FeMn concretions in the Baltic Sea and the potential impacts of their extraction. In the first part, we have applied a problem-structuring framework to review the environmental impacts of concretion extraction and requirements for environmental risk assessment. In the next phase, we will further study the drivers of FeMn concretion distribution and develop maps for concretion in Finnish coastal sea areas. The obtained results will provide insight into the spatial coverage of concretion fields in the Northern Baltic Sea. After this, we will examine the ecological role of concretions by combining available species community data together with complimentary sampling to assess the habitat role of FeMn concretions. The obtained information may be used in building a basis for causal chain based risk assessment to estimate the ecological impacts of seabed mineral extraction. The work is conducted as collaborative work within the SmartSea consortium.

Structure and sorption properties of the in-shore zone bottom sediments of the Western part of the Gulf of Finland

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In the recent years, the ecological problems of waters of the Western part of the Gulf of Finland increased significantly. The insertion of pollutants with effluents of flowing rivers, the construction of alluvial territories and oil terminals are among the main problems causing Baltic sea pollution. That leads to the ecological disequilibrium of the environment and, thus, the death of the aqueous biota. Here the bottom sediments play the main role in the formation of the chemical composition in the water systems. In this way the investigation of bottom sediments in this water system being the indicators of the technologic pollution as a promising way for the efficient ecological monitoring of the Baltic seashore. According to [1] these sediments are layered particles of sands. Herein the alternation of organic (including humic) and inorganic layers consisting of both charged metal cations and uncharged inorganic substances are predetermined by the composition of water medium, where they are placed. Generally, the evaluation of the capacity of these multilayered particles to ecotoxicants accumulation is carried out via the systematic investigation of physical, chemical and biological factors affecting the formation of bottom sediments microstructure. So the goal of present work was the investigation of the effect of the phase composition, particle size distribution and chemical composition of the in-shore bottom sediments of the Western part of the Gulf of Finland on their tendency to the heavy metal sorption (Cu^{2+} and Zn^{2+}).

The upper layers (0–10 cm) of in-shore bottom sediments of the Western part of the Gulf of Finland (the depth is 0.5 m) were chosen for the present study. In order to track the changes in dispersity and microstructure of bottom sediments and Cu^{2+} and Zn^{2+} content in the probes the following control points in the inshore zone of the Western part of Gulf of Finland of Baltic sea were chosen for the observation: Grafskaya bay, Repino, Lomonosov, Sisto-Palkino, Sestroretsk, Luzhskaya Guba, Primorsk, Martishkino, Olgino, Ushkovo, Bolshaya Izora and Cape Flotsky. The bottom sediments i.e. sands were investigated via X-Ray phase analysis (XRD SHIMADZU XRD-6000), particle size distribution (PSD analysis, Horiba LA-950), scanning electron microscopy (Hitachi S-3400N with the equipment for energy dispersive X-Ray spectroscopy EDX analysis). In order to obtain sorption curves for heavy metal ions from the model solutions, the sands were preliminary washed from organic and inorganic impurities adsorbed on their surface. As a result, the dependence of the electric conductivity of the washing waters on the exposure time was plotted. Six peaks related to the dissolution of organic and inorganic layers were observed indicating the multilayered nature of samples. In order to obtain the data on copper and zinc ions sorption 0.02N $CuSO_4$ and $(Zn(NO_3)_2$ model solutions were prepared. Each probe of bottom sediment (5 g) was placed in 50 ml of the model solution. Then the system was left for one week in order to reach equilibrium and the equivalent amount of absorbed ions was determined by complexometric titration. 0.05N Trilon B was used as a standard solution. After that, the probes were left in the solution for one week more. No sorption was detected i.e. the equilibrium was reached in one week.

The data on the microstructure and dispersity of bottom sediments were obtained via SEM and PSD analysis. Size and volume distributions of particles in sands were obtained. Mean particle size was calculated using the data of distributions. Mean particle size in the probes varies significantly depending on the chosen control point of the observation. Overall, for the probes collected in Grafskaya bay, Sisto-Palkino, Primorsk, Bolshaya Izora, and Cape Flotsky ultrasound impact results in mean particle size decrease in 2–8 times from 13,32–72,51 to 5.57–8.84 mkm, i.e. the dispersity increases significantly. In case of probes collected in Lomonosov, Sestroretsk and Luzskaya Guba ultrasound does not affect significantly on the mean particle size and it lies in range 106.14–221.8 mkm. So one can suggest low heavy metal ion sorption of latter probes. Bottom sediments collected in Sisto-Paltino in 2016 and Luzskaya Guba in 2017 contain algae. Taking into account the fact that these algae were absent in the probes in 2014, it is, most likely, because of the pollution level increase. According to X-Ray patterns, SiO_2 is the main phase present in all bottom sediment probes. Depending on the control point of observation small contents of following phases were found: $Fe_2S_2O_9$*xH_2O and (Na, K)

$(Si_3Al)O_8$ were detected in almost all samples; then $NaHSi_2O_5$ – in probes collected in Primorsk, Luzhskaya Guba, Martiskino, Na6Si8O19 – in Primorsk, Bolshaya Izhora, Luzhskaya Guba. $Fe_2Al_2(SiO_4)_3$ appeared to be characteristic just for Luzhskaya Guba in-shore territory. The EDX data for chemical composition obtained is in accordance with XRD results. Thus the following factors are contributing mostly in the Cu^{2+} and Zn^{2+} sorption capacity of the bottom sediments i.e. dispersity, phase composition and the presence of algae.

Summarizing the results of the present work following conclusions were made: using the probes collected in Grafskaya bay it was shown that mean particle size decrease from 24.46 to 2.58 mkm results in five times full Cu^{2+} exchange capacity increase; using the probes collected in Sestroretsk it was proved that multilayered structure of bottom sediments as well as the presence of phases, able for the microelements accumulation i.e., for example, $Fe_2S_2O_9*xH_2O$, enhances their sorption ability considerably. For the bottom sediments collected in Luzhskaya Guba and Grafskaya Bay, it was established that the presence of algae significantly enhances Cu^{2+} sorption i.e. from 0 to 0.08 mg-ecv./g and from 0.01 to 0.085 for bottom sediments collected in Luzhskaya Guba and Grafskaya bay, respectively. Ion forms of zinc and copper are bioaccessible i.e. they can undergo desorption from bottom sediments upon pH value change. That can affect the ecological balance of the water system.

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Geophysical exploration of geological hazards in the Eastern Gulf of Finland

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The harbors infrastructure of the Eastern Gulf of Finland is being actively developed. In addition to the existing harbors of Vyborg, Vysotsk and the Big Port of St. Petersburg, the General Scheme of the Russian harbors complex in the Eastern Gulf of Finland includes several new ports such as Primorsk and Ust-Luga. Reconstruction of existing and construction of new harbor facilities require reliable site surveys results that will provide a comprehensive study of the engineering and geological conditions of the construction area. Nobody doubts the utility of seismoacoustic exploration during engineering geological offshore site investigations. Though, the quality of data obtained by different seismoacoustic techniques may be poor and have fail resolution and low penetration depth which depend on seismo-geological conditions. The article demonstrates the combined application of very high and ultra high resolution seismic which were useful for geophysical exploration of geological hazards in the seismo-geological conditions of the Eastern Gulf of Finland. There are widespread thixotropic muds and clays, dissected roof of the bedrock, landslide faults and shallow gas charged intervals. The main goal of this article is to present new high-resolution geophysical data from that area of the Gulf of Finland which had previously lacked good data for understanding the marine geology and geological hazards mapping.

The study area is located around the harbor structures near the coastline of The Eastern Gulf of Finland. Regional geophysical research in The Eastern Gulf of Finland for many years has been carried out by the «National Geological Research Institute named after A.P. Karpinsky» (VSEGEI). The results of these research, based on data from many thousands of kilometers of seismoacoustic exploration, were summarized in the Atlas of geological and ecological-geological maps of the Russian sector of the Baltic Sea [1]. According to the geological hazards map, the coastal part of The Eastern Gulf of Finland is mostly concerned to a high level of geological risks [2]. There are endogenous and exogenous hazards. The first includes the latest and modern tectonic movements, active faults and gas seeps. The second include erosion, accumulation, and transit of bottom sediments, which can lead to landslides, slumps, screes, underflooding, dangerous changes in the depths of the water area. Representative seismoacoustic data obtained at one of the sites in the Vyborg region (a joint cruise of VSEGEI and the Institute of Oceanology of the Russian Academy of Sciences in 2017) characterize the geological structure of The Eastern Gulf of Finland. The sequence of beds is composed of several seismostratigraphic complexes, which include rocks of the Proterozoic basement, till (Morain), questionably glaciofluvial sandy deposit, Late Pleistocene glacio-lacustrine clays, Holocene lacustrine and marine silty-clayey muds [3].

The following geophysical exploration included very high and ultra-high resolution seismic (VHRS and UHRS) survey. The figure shows a complex (VHRS and UHRS) seismoacoustic cross-section along one of the geophysical survey lines. The geological interpretation is based on drilling data considering information about the geological structure of the area.

The shallow geology is described by three seismoacustic units exhibited on the cross-section. The roof of Unit 1 corresponds to the acoustic basement on VHRS data. According to the drilling data, Unit 1 is represented by Proterozoic rock basement. Upper on the cross section there is Unit 2 which roof corresponds to the acoustic basement on UHRS data. Unit 2 is complicated by compact state sand of different grain sizes with gravel, rubble, and boulders and interbeds of sandy loam and loam. In its genesis, Unit 2 refers to till (Moraine) deposits. The uppermost layer of the shallow geology is Unit 3 which roof corresponds to the bottom surface. According to the drilling data, Unit 3 is composed of liquid silt with interbeds of dusty sand.

The values of velocities 1457 m/s for the water column (based on sound velocity measurements in water), 1200 m/s for Unit 3 (silt) and 2100 m/s for Unit 2 (till) (based on correlation of seismoacoustic horizons with drilling data) were used for conversion seismoacoustic cross sections from the vertical timescale to the depth. These velocities are in good agreement with the meanings which were calculated based on the velocity analysis of multichannel seismoacoustic data for similar geological formations in the Baltic Sea [4].

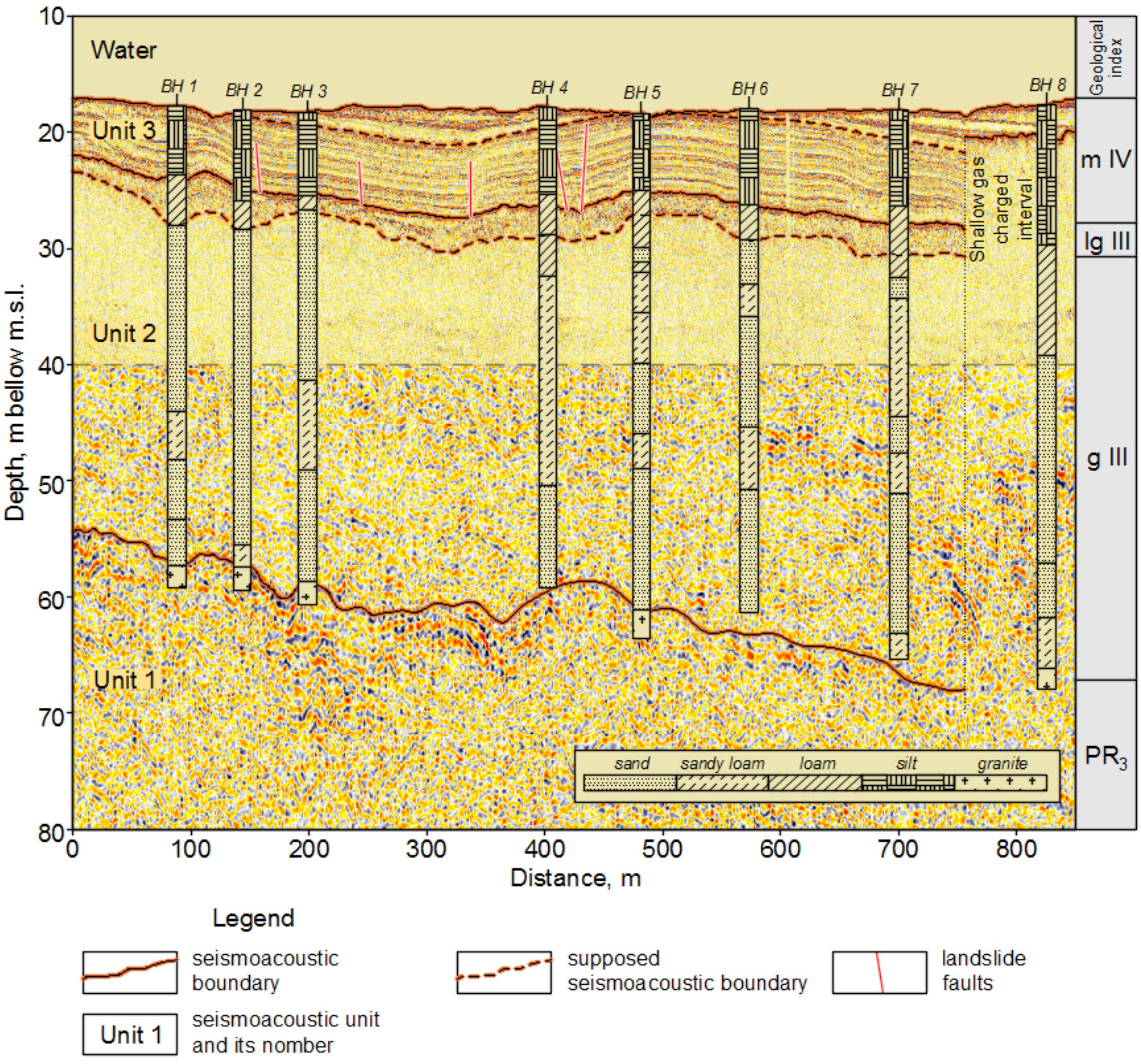
The site survey area refers to the depression of the bedrock. The depth of the bedrock roof is more than 50 m, which is confirmed by the drilling data. There are several geological hazards identified during site survey: shallow gas charged intervals, the areas covered with thixotropic muds and clays layer with thickness more than 10 m, the areas of supposed subsiding in thixotropic muds and clays, the areas of the bedrock roof with slopes more than 15°, landslide faults.

Analysis of the geological hazards map has shown that the most objective approach to regionalization the survey site by the level of geological risk is zoning by the total number of hazards per unit area. The areas covered with thixotropic muds and clays layer, due to its ubiquitous distribution, is conditionally assigned to a low level of geological risk.

Steep and very steep slopes of the bedrock roof or shallow gas charged intervals would be caused the landslides or subsidence in the thixotropic muds and clays upper layer. Therefore, when this features combined together in any area, it assigns as an area with a medium level of geological risk. The medium level of geological risk is also assigned to the areas covered with thixotropic muds and clays layer with thickness of more than 10 m. A high level of geological risk is assigned to the areas where the geological hazards have already appeared in a form of subsidings or landslide faults.

The approach to area regionalization according to the cumulative number of hazards per unit area is based on the analysis of the cause-effect relationships between various geological hazards and their manifestations. The advantage of this approach is the absence of the subjective expert assessments, meanwhile qualitative geophysical data with a sure geological interpretation are necessary for its implementation.

A representation of the geological structure and engineering-geological conditions of the soil massif adjacent to the hydraulic structures was obtained and a number of geological hazards were identified based on the geophysical site survey. Seismoacoustic methods provided a sufficient penetration depth of research and allowed to map the roof of the Proterozoic rock basement, which spatial position is confirmed by the drilling data. Widespread thixotropic muds and clays layer with significant thickness covering the survey site are shown based



Seismoacoustic cross section with geological interpretation

on Geophysical data analysis. The designing of naval gravitational type structures and anchors installing should take into account the low strength properties of the thixotropic muds and clays layer and its possibility to convert into the liquefaction state under the action of wave loads. The shallow gas charged intervals are mapped. These intervals are spatially correlated to areas with a maximum thickness of the thixotropic muds and clays layer. The shallow gas can change the physical and mechanical properties of sediments and increase the instability of slopes, thus being an indirect source of danger of landslide processes. Several local negative forms of relief are observed, similar to the subsidence of the territory, which are probably associated with a decrease in the strength of the ground caused by shallow gas accumulations. The presence of landslide processes is confirmed by a number of landslide faults identified in the muds and clays layer.

The VHRS and UHRS site survey demonstrated the high efficiency of geophysical exploration for geological hazards mapping in the Eastern Gulf of Finland. Meanwhile, the complicated seismo-geological conditions due to the shallow gas propagation cased seismoacoustic signal attenuation. So, there are several limitations on seismic acoustic methods which require the use of low-frequency sources up to 200 Hz or the use of additional geophysics methods, for example, electrical prospecting. Further development of seismoacoustic exploration in the Eastern Gulf of Finland is associated with the use of multichannel recording systems, allowing to produce a velocity analysis with quantitative data interpretation.

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Impact of the Major Baltic Inflows to the Gulf of Finland

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Gulf of Finland receives its deep layer water from the Northern Baltic Proper. Despite high wind-driven variability of the salt-wedge, salinity in long-term is correlated to the Major Baltic Inflows (MBI). Exact mechanisms of lateral signal propagation from the Eastern Gotland Basin to the Gulf of Finland, are not clear. We merged Estonian-Swedish-German-Finnish oceanographic data from January 2014 to March 2017 to investigate the impact of recent MBIs from Gotland Deep towards Gulf of Finland [1].

The first impact of the 2014 December MBI occurred in the Gulf of Finland in nine months as the arrival of forward pushed former Northern Baltic Proper deep layer water. The warmer and saltier MBI water arrived in the Gulf of Finland 14–15 months after occurrence of the December 2014 MBI. Salinity peaked in the Gulf of Finland at 10.77 g kg^{-1} in October 2016, which is the highest value in this area since mid 1970s. The warmer and saltier deep layer water originated from the sub-halocline layer (110–120 m) of the Eastern Gotland Basin. The pre-condition for such mid-layer advection was a denser deep layer in the Gotland and Fårö Deep. MBIs did not improve the oxygen conditions in the area north of the Gotland Deep and oxygen conditions rather worsened in the Northern Baltic Proper and the Gulf of Finland.

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Organotin compounds in surface sediments from the deep water part of the Eastern Gulf of Finland (Russia)

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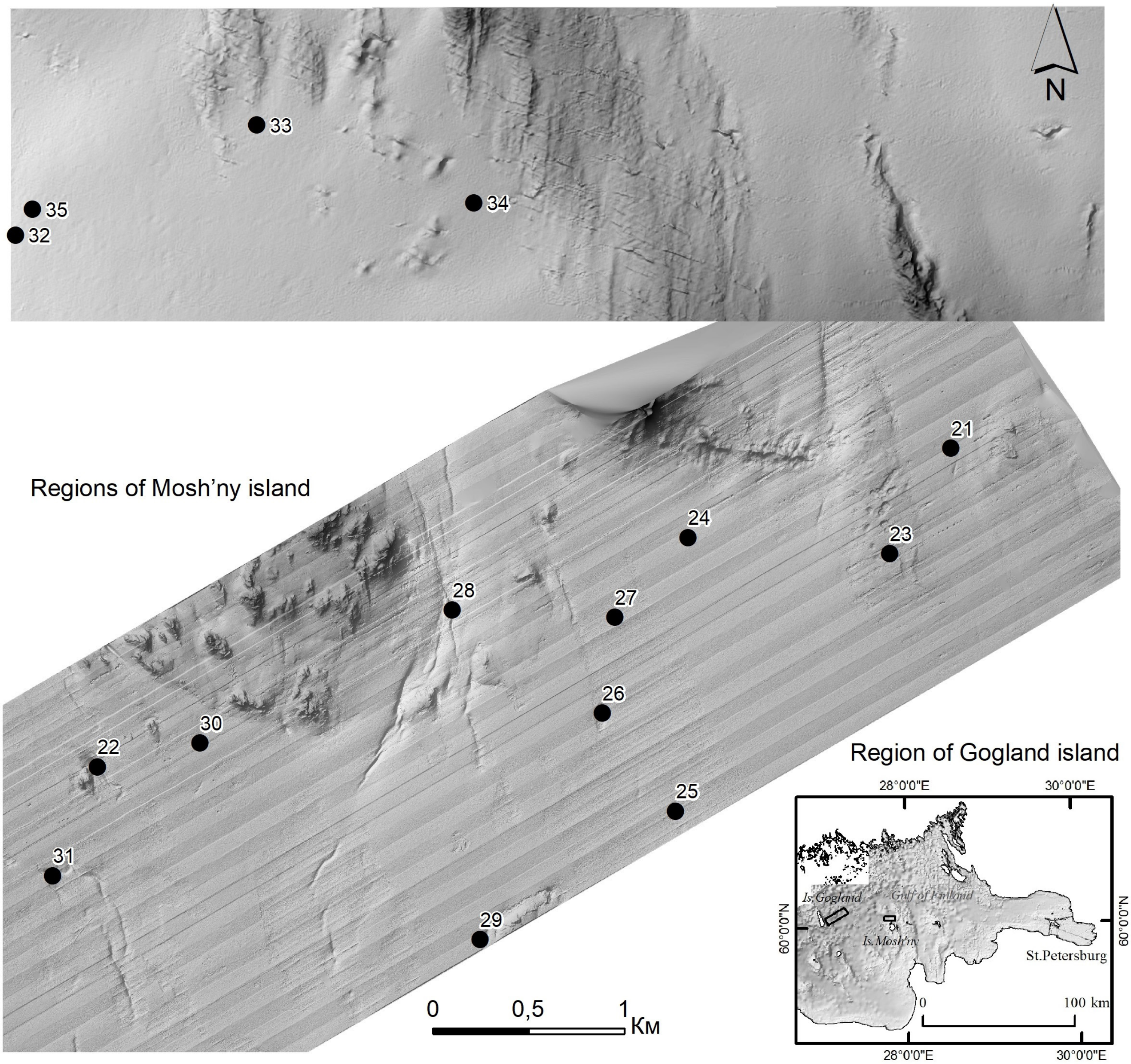
Organotin compounds (OTs) are widely used worldwide as stabilizers for polyvinyl chloride, in the manufacturing of polyurethanes, silicon, paints, and pesticides. Especially ubiquitous are compounds of tributyltin (TBT) used as biocide components of antifouling paints for ships. Presently, high concentrations of TBT and their degradation products dibutyltin (DBT) and monobutyltin (MBT) are found in coastal waters almost all over the world. The widespread use of TBT in antifouling paints has resulted in adverse biological effects on non-target water organisms. Therefore the antifouling use of all OTs on all vessels has banned in 2003 in European countries. TBTs have been identified as priority hazardous substances specified in HELCOM BSAP. Several countries have strict recommended values for TBT concentrations in water, sediments, and biota.

The first key study area is located to the east of Gogland Island, within the relatively large sedimentary basin. Locally, Late Pleistocene till surface is outcropping. Water depth varies from 55 to 75 m. The thickness of Holocene marine mud according to sub-bottom profiling data reaches 8–10 m. One of the typical features of the Holocene mud is a wide spreading of gas-saturated methane-rich silty-clayey sediments. Elongated bottom depressions and pockmarks are the special features of the bottom relief of gas-saturated sediments' surface. The key study area to the north off Mosh'ny Island is located in the area of recent non-sedimentation or submarine erosion. Water depth varies from 20 to 60 m. Within most parts of the bottom outcrops of Late Pleistocene lacustrine glacial clays are covered by sands, mixed sediments, and Fe-Mn concretion. Recent mud accumulations occur in local sedimentary basins in northern and western part of study key area, the maximal thickness of marine Holocene sediments is 5–7 m.

In 2017 geochemical study of the bottom sediments within both key areas were undertaken by VSEGEI in the frame of the project "State monitoring of geological environment of the near-shore bottom of Russian Baltic White and Barents Seas". 37 samples were in the morphologically and sedimentologically different areas (gas-saturated Holocene marine mud, pockmarks, linear depressions in Holocene mud, glacial and lacustrine-glacial deposits' outcrops). The samples are analyzed for grain-size and semiquantitatively for compositional properties using optical emission spectral analysis (44 elements, including Co, Ni, Cu, Pb, Zn, Cr, and V). From an environmental point of view, the most important result of surface sediment geochemical study is relatively low concentrations of hazardous heavy metals. The average concentration of Cr, Pb, and Zn did not exceed the "little or none" (Class 1) contaminant level of the Swedish EPA [1], an average concentration of Co, Ni, and Cu gave concentrations classified as slightly contaminated (Class 2). Maximal concentration reaches "significant" contamination level just for 4 samples for Co; 7 samples for Ni and 5 samples for Cu. Neither average nor maximal concentration did not reach "probable effect level" (PEL, upper threshold) according to Canadian sediment quality guidelines (CCME 2002 [2]).

In this study, 15 surface sediment samples were collected from the deepwater part of the Eastern Gulf of Finland (regions of Gogland and Mosh'ny Islands) during a joint 35th scientific cruise on board of R/V Academic Nikolaj Strakhov in summer of 2017 (figure). Both study key areas were covered by the full coverage multibeam survey, allowed to compile detailed bottom relief and surface sediment types' schemes. Six species of OTs including tetrabutyltin (TTBT), TBT, DBT, MBT, triphenyltin (TPhT) and tricyclohexyltin (TCyT) were quantified using GC-MS. The grain size characteristics of the sediments were also determined. The concentrations of total OTs in sediments were in the range of 7.6 – 123 ng Sn g^{-1} d.w. and TBT was the dominant component in the most samples. The average TBT concentrations were 30 and 6.3 ng Sn g^{-1} d.w. for Gogland and Mosh'ny Islands respectively. Based on the OSPAR quality sediment guidelines the most samples studied can be classified as lowly contaminated by TBT [3, 4]. To evaluate of TBT transformation degree in sediments the BDI (Butyltin Degradation Index)



Location of the sites sampled for organotin compounds studies on the shaped relief map of study key areas

is used – ratio of [MBT+DBT]/[TBT]. This coefficient when its value is <1 point to slow degradation of TBT and there is a constant source of pollution. The data obtained indicates that all studied samples showed values <1. Additionally, sediments from the area of Gogland Island mostly showed BDI value of no more than 0.5, which is typical for waters with a lot of shipping activity. TPhT concentrations were distinctly lower and ranged from <0.5 to 13 ng Sn g^{-1} d.w. Presence of TBT and their metablolites DBT and MBT in sediments and also TPhT is usually connected with the use of antifouling paints. TCyT has a different source from which it pervades the environment since it is usually used in farming and manufacturing as a pesticide. TCyT was not detected in all sediment samples (<0.5 ng Sn g^{-1} d.w.) which indicates that this compound is not typical for the studied region.

TTBT is used in the manufacturing process for MBT, DBT, and TBT. Limited direct usage of TTBT and its assumed low emission into the environment explains why is TTBT monitoring is a much lower priority than other OTs. In the past few years however significant amounts of TTBT are being found in sediments all around the globe. In this study, TTBT is registered in most samples and in significant concentrations (up to 100 ng Sn g^{-1} d.w.) which points to the wide usage and spread of this compound. One possible source of TTBT being emitted into the ecosystem of the Gulf of Finland is its possible usage in antifouling paints in place of TBT, which was prohibited from use in Russia in 2013. TTBT transformation in water environment happens with the gradual removal of alkyl groups, and as such TTBT is both a precursor and a source of its most toxic and standardized homologue – TBT. For this reason, TTBT should be controlled in water, sediments and living organisms, same as TBT.

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New data about pockmark development in the eastern Gulf of Finland (near the Gogland Island)

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The bottom of the area located to the north-east of Gogland Island was studied by VSEGEI in 1988–1993 in the frame of State geological survey (1 : 200 000 scale) using acoustic-seismic profiling (two central frequency ranges: 500 Hz (sparker) and 7.5 kHz (piezoceramic transmitter)) and sediment sampling. In 2009 and 2011 in frame of joint Russian-Finnish field cruises on board of R/V "Aranda" (SYKE, Finland) 12-kHz pinger sub-bottom profiles were fulfilled in this area. Additional information about geological structure of this area was received using acoustic-seismic profiling by VSEGEI in 2012–2014 in frame of national project "State monitoring of geological environment of near-shore areas of Russian Baltic, Barents and White Seas". Acoustic-seismic profiling allowed to reveal the wide distribution of gas-saturated muds in the area of the Gogland Island and associated large funnels on the surface of the bottom, which were identified as pockmarks.

In 2017 during the joint cruise of P.P.Shirshov Institute of Oceanology RAS (IO RAS) and A.P. Karpinsky Russian Research Geological Institute (VSEGEI) on board RV "Academic Nikolaj Strakhov" (35 scientific cruise) in the eastern Gulf of Finland the bathymetric survey of the sea bottom was fulfilled within key-area located to the north-east of the Gogland Island using the multibeam echo sounder SeaBat 8111 (operating frequency 100 kHz). This survey was accompanied by acoustic profiling using EdgeTech 3300-HM sub-bottom profiler (the frequency range is 2–10 kHz, the pulse length is 20 ms). Device control and data logging was produced in the EdgeTech Discover Sub-Bottom 3.52 software installed on the EdgeTechXStar PC terminal, which is connected via TCP/IP protocol to a digital signal processor and a transceiver unit. The sediment sampling in the area near Gogland Island was fulfilled using gravity core and box-corer from board of RV "Academic Nikolaj Strakhov" and later from board of RV "SN–1303".

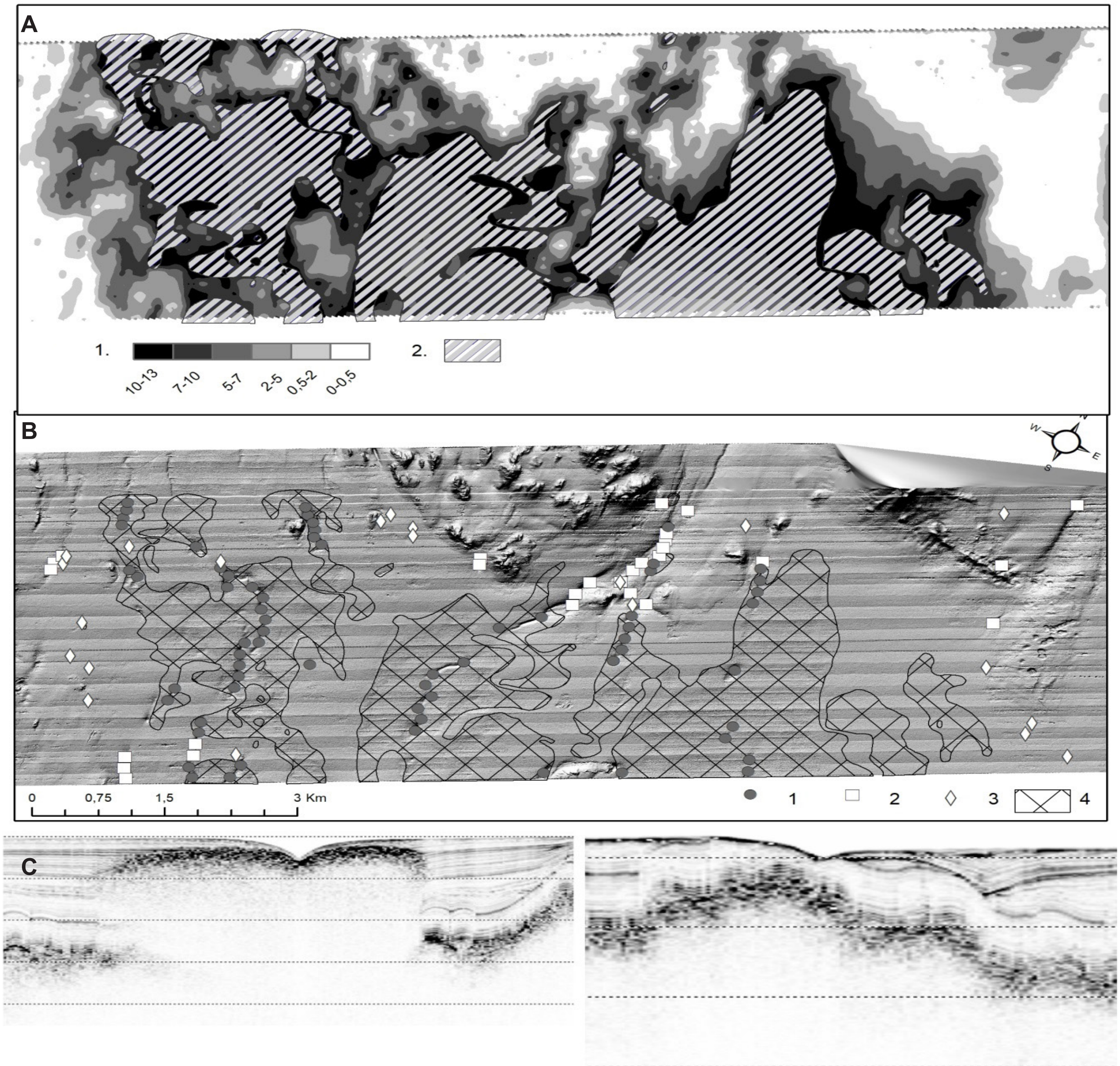
The bathymetric survey using multibeam echo sounder totally changed knowledge about the distribution and character of bottom relief forms developed in the area to the north-east of Gogland Island. It was found that the previously identified funnels are not isometric pockmarks, but the cross-sections of the narrow elongated hollows (depressions) of considerable length and complicated form.

Three types of narrow elongated hollows were distinguished: 1) hollows crossing the area of mud accumulation, where acoustic signal deteriorates or even disappears; 2) hollows cutting the sediments of different age and not associated with gas accumulation; 3) buried hollows.

The first type of hollows was mainly traced in the zones of active gas-saturated mud accumulation. It can be assumed that such linear depressions are the result of methane release from weakened zones of gas-saturated mud. This process leads to a decrease of sediment thickness and subsequent subsidence of the upper horizons of the mud. The second type of hollows, adjacent to the positive forms of relief, such as moraine ridges, cut both Holocene and glacial-lacustrine deposits. These hollows are most likely connected with contour bottom currents, but this assumption requires more detailed study. The nature of the third type is not established yet. But attention is drawn to their close location with the outcropped hollows. They extend in one direction and away from the field of gas-saturated sediments.

The obtained information showed that the extent of the linear depressions within the gas-saturated mud spreading zones can reach several kilometres, the cross-section (width) is measured by tens of meters, sometimes exceeding 100–120 m, and the depth reaches several meters. Thus, linear depressions can be associated with exogenous geological processes, which are hazardous for the construction of underwater engineering structures (pipelines, cables, communication lines, etc.).

In the north-eastern part of the key area more than 10 crater-like structures were found along the linear, gentle rise of the bottom surface in the water depth range – 60–68 m in the area adjacent to the glacial moraine ridge. Several craters are doubled; some of them are concentrated as a chain. The diameter of the mapped craters reaches 120 meters, with a relative depth of up to 4 m. Some of them are partly buried under the recent marine muds. But most of them are practically outcropped at the sea bottom. Acoustic profiles, crossing the craters, shows they are cut out in lower part of laminated



A: 1 – Holocene sediment thickness (meters). 2 – gas-saturated sediments; B: 1 – hollows located above the gas-saturated sediments (disappear of acoustic signal), 2 – hollows not associated with gas accumulation, 3 – buried hollows, 4 – gas-saturated sediments; C: examples of acoustic-seismic profiles crossing different types of elongated depressions

sediment section (glacial-lacustrine or glacial-fluvial), and their bottom is formed by glacial till. Accordingly the craters cannot be older than 13.8–13.3 ka BP. The core-sample (site # 17-GG-T-2) collected in the area of crater's location is represented by "varved clay" accumulated in local glacial lakes or Baltic Ice Lake. The bottom sediment collected from the crater's bottom and slopes (site # 17-GG-5, 17-GG-6, 17-GG-35) was represented by silty-clay mud (up to 15–20 cm thick) including sandy particles and coarse-grained granitic debris in lower part of the layer. The sediment samples also contained ferromanganese irregular cores and large (up to 12–15 cm in diameter) flat concretions. Previous investigation of ferromanganese concretion collected in the eastern Gulf of Finland allowed to determine that the age of such large flat concretion is more than 1000–1500 years [1], accordingly craters cannot be younger.

It is possible to suppose several ideas about nature of these craters:

1. Anthropogenic – appeared as a result of under-water explosion or under-water dredging. Technogenic genesis of the craters is impossible because according to concretions dating the age of crater is older than 1000 years; depth bomb can't be a reason of such crater appearance due to its specific characteristics; there are no dredgers in the eastern Gulf of Finland that can work at the sea depth more than 60 meters.

2. Pockmarks formed by gas seep or groundwater discharge. The methane content in the sediments forming craters (sites # 17-GG-35, 17-GG-5, 17-GG-6) is insignificant and close to its content in the sediments collected within the outcrops of glacial deposits outside craters. Thus, the genesis of the craters cannot be related to methane seeps from bottom sediments.

3. Crater formed by meteorite hit (meteorite shower). Geochemical analysis of the sediments and ferromanganese concretion collected in the craters did not show any anomalies that can be identified as a result of meteorite impact.

4. Frost ground subsidence. Since the last deglaciation the area of craters location (sea depth 62–69 m) was not in terrestrial conditions, so this mechanism of crater formation is hardly probable.

5. Trace of the melting grounded ice hummocks (stamukha) in the ice lake. Mostly probable process of crater formation, but it needs additional arguments.

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Biological invasions in the heated area of the Kopora Bay for the last 5 years: facilitations, limitations and perspectives

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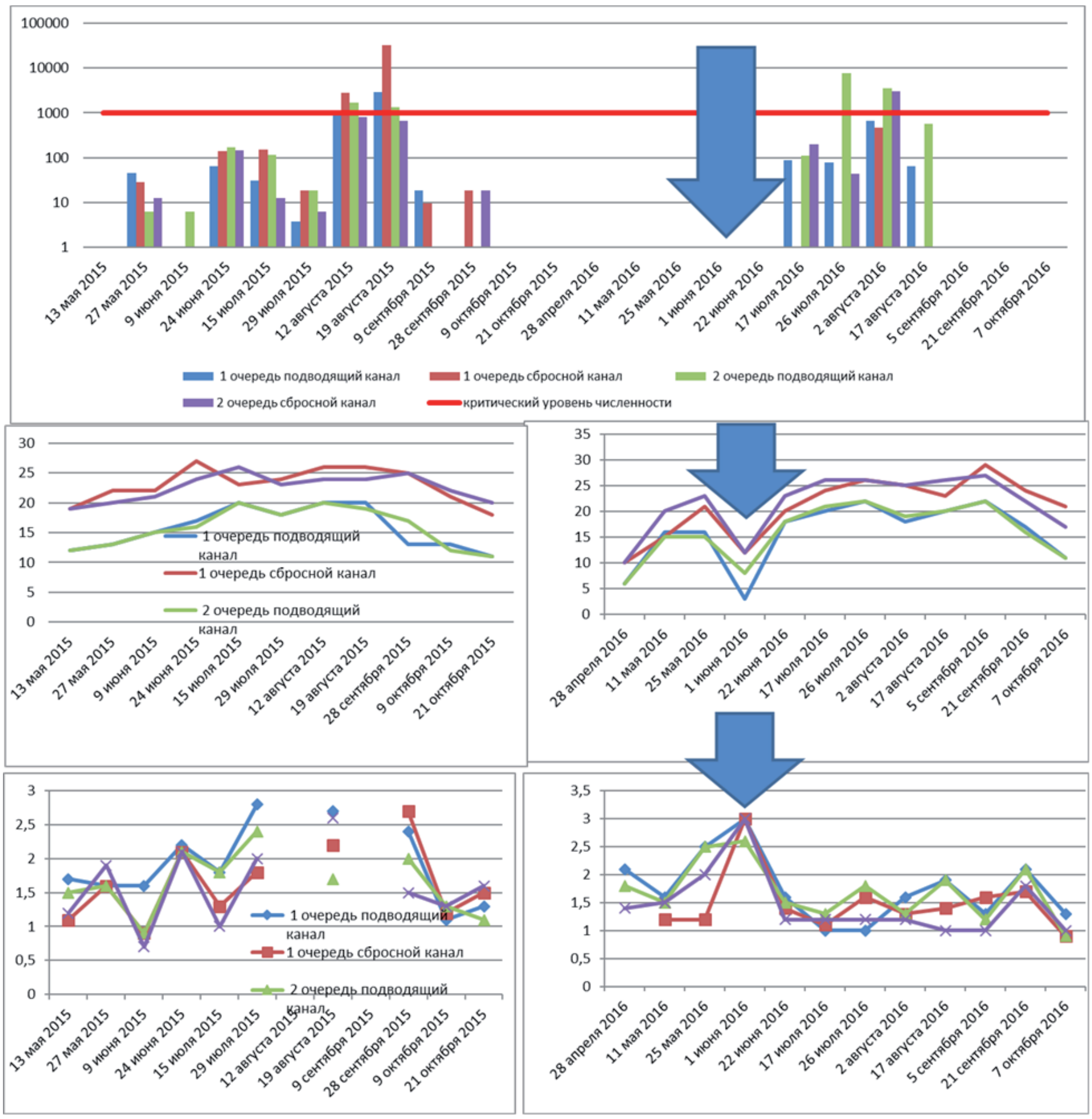
The Kopora Bay (KB) is an example of an area serving as source of water for sea users including Leningrad nuclear power plant (LNPP). KB also represents one of the threshold zones of the eastern Gulf of Finland with clearly expressed biotopic variability determined by relatively constant largescale and local natural and technogenic gradients, including heating. Also unperiodic natural processes such as upwelling and inflow and men-mediated driving forces such as involvement into world-wide shipping affect the area dramatically. All the above predisposes KB to specific spatial and temporal variations in biodiversity through accumulation of established habitat engineering invasive marine and aquatic species in the warmed vicinity of LNPP (peculiar to or demonstrating mass development only in this very area).

Following registration in 2013–2017 one bivalve, two decapod crustaceans (probably one is misidentified), one bryozoan, three fishes and one amphibian are to be considered as new non-indigenous or cryptic species in benthic compartment.



Two-years observations on the dynamics of dreissenid larvae abundance (upper diagrams) in the artificial habitats (system of canals) accompanied with measurement of temperature (medium diagrams) and Secchi depth (lower diagrams). Arrows indicate registration of upwelling event

Of these the naturalization of central American dreissenid bivalve *Mytilopsis leucophaeata* (dark false mussel) [1] and west-European (or cryptic) phylactolemate bryozoan *Plumatella geimermassargi* [2] discovered in 2014–2015 is the major reason for concern in two senses – practical meaning (pose threats of bioterioration for hydrotechnical constructions e.g. by biofouling formation) and specific biological features that distinct them from their invasive and non-invasive congeners.

However progressive expansion and dynamics of some alien species seems to be restricted/limited by abiotic conditions affecting both adults and especially planktonic dispersal stages (case of *M. leucophaeata,* figure) or facilitated/limited by biological processes such as invasion meltdown expressed in invasions of predators (case of local substitution of *M. leucophaeata* with *P. geimermassardi* via suggested predation of gobiid fishes on dreissenid mussels).

Despite the above mentioned limitations in quantitative development and variations in terms of decrease for temporal (durability) risks for technical systems colonization the general forecast for further expansion including established warm-water species is positive (for species). Also probability for new registration(s) of species with cloned reproduction exists.

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Large infrastructural projects and biodiversity conservation – the example of the Nord Stream 2 development in the Gulf of Finland

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Nord Stream 2 is a large infrastructural, transboundary project, financed by major energy companies from Russia and other European countries. The project encroaches important terrestrial and marine habitats including protected areas.

To ensure the environmental sustainability and the bankability of the project Nord Stream 2 has committed to implementing a Biodiversity Action Plan, with the objective to improve biodiversity values throughout the areas of influence of the project.

The Biodiversity Action Plan includes field research and tangible initiatives to combat existing threats to biodiversity and, where possible, preserve or re-introduce rare species of flora and fauna in their natural habitats.

Coastal dynamics of the eastern Gulf of Finland: toward a quantitative assessment

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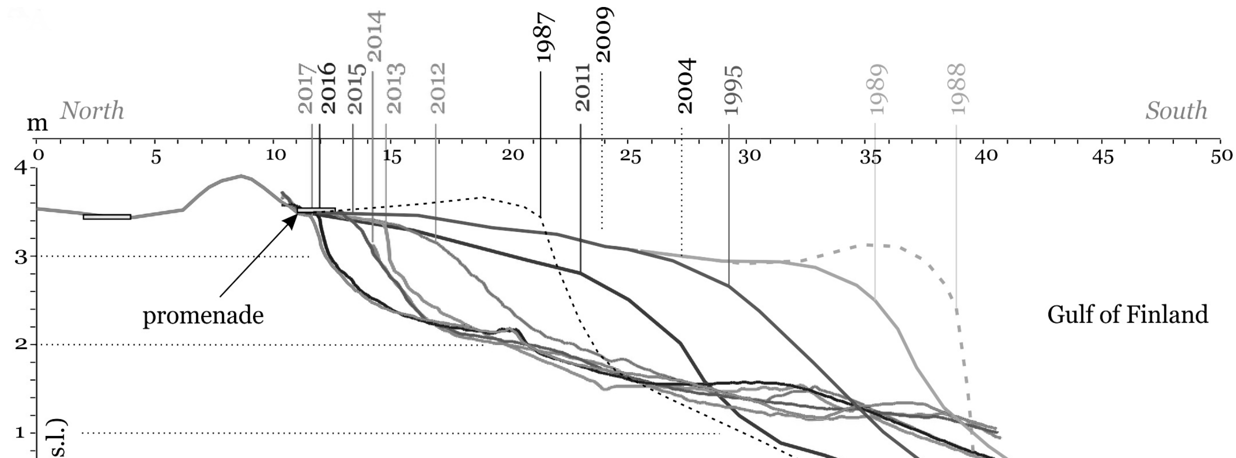
The easternmost part of the Gulf of Finland is characterized by intense coastal processes dominated by where erosion. The main goal of this study based on results of terrestrial laser scanning was to establish volumes of eroded, transported, and redeposited sand during storm surge events that occurred between 2012 and 2017 within key areas located in the Kurortny District of St. Petersburg (Gulf of Finland, Baltic Sea), where the longest set of levelling and terrestrial laser scanning was conducted (Sergeev et al., 2018).

In 1987–1990, one of the first field morphodynamic observations were carried out by Estonian scientists (as a contribution to "Geology of the Gulf of Finland" volume; Orviku, Granö 1992). The result of levelling and photo archiving provided the framework of this research a unique source of information for comparative analyses of coastal development along the eastern Gulf of Finland. Since 2000, VSEGEI has undertaken annual coastal observations in this coastal zone. Since 2010 – onshore levelling and ground-penetrating radar imaging.

Based on the results of statistics analyses of coastal monitoring and hydrometeorological data during 2004–2010, it was demonstrated that the most extreme erosional events occur within the study area when three unfavorable conditions take place simultaneously: 1) long-lasting west or southwest storms; 2) high water level, and 3) the absence of stable sea ice (Ryabchuk et al. 2011). The results of coastal monitoring for 2011–2017 support this hypothesis. The extreme erosion events led to significant damage of the coastal dunes, which was observed in 2011, 2013 and 2015 – after severe autumn-winter storms of W, NW and SW directions, accompanied by a water-level rise in the absence of ice.

Levelling. Study profile in Komarovo village is located in the area of experimental sand nourishment, undertaken in 1988. As shown in figure, in 1987 the terrace width was approximately 9.5 m (distance from promenade) and the erosional scarp was very sharp and steep. Along a 430 m long section of the coast at Komarovo village, a 2-m-high artificial beach was created. In 1988, the beach-face escarpment moved 17.5 m seaward and during the first year (1988–1989) of artificial beach phase, the equilibrium profile attained a gentler slope and the scarp retreated to 3.5 m. According to surveys since 1989, the average annual rate of retreat of the terrace scarp was 0.86 m/year. The maximum rate of shore erosion was recorded in the 2011–2012 storm season and reached 6.5 m/year.



Dynamics of beach erosion in the area of artificial beach backfilling performed in 1988 in Komarovo village. Levelling profiles from 1987 to 1995 according to K. Orviku data, from 2011 according to VSEGEI data

Terrestrial laser scanning (TLS). TLS was carried out by "Alpha-Morion ltd." using the terrestrial laser scanner "RIEGL VZ-400" (Austria) from twelve stable points (scan positions). Geodetic referencing to the local coordinate system SK64 and the Baltic System of Heights 1977 was established using a Trimble R8 and Javad Legacy-E satellite. Post-processing was performed using "Pinnacle" software. Horizontal and vertical fixes of the position marks were made by a total station "LEICA TS06 Ultra (2")" (Austria).

For Komarovo village site, TLS data were collected every summer from 2012 to 2017. TLS was also conducted before and after storm events of December 2015. This technology allowed calculation of the volume of transported beach sand. The data of relief transformation formed the basis for establishing key parameters representative of the peak storm conditions. The 3D laser scanning covered the beach surface and the foredune ridge or scarp.

Results and Conclusions

According to the results of levelling, the rate of annual coast retreat is uneven. It is less than 0.5 m/year during low storminess periods, whereas for stormy years it is 3.3 m/year. So the infrequent events of structural erosion occurring in relation to certain extreme events give rise to a clearly pronounced step-wise manner of coastal development in this area. An important feature of annual beach transformation is a recent acceleration of annual coastal escarpment retreat, which has been 0.56 m/year in 1989–2009 and reached 1.45 m/year in 2009–2017.

Results of TLS data analyses allowed quantification of the volumes of sedimentary material that is eroded, transported, and redeposited as a result of extreme storms. Detailed 3D GIS models of coastal relief, compiled based on high-resolution geodesic surveys, allowed the establishment of a highly reliable database of beachface transformation under the extreme storm impact and quantitative assessment of erosion volumes and sediment loss. In the stormy years, pronounced degradation of the foredune and coastal escarp was accompanied by a sharp reduction in the thickness of sand deposits by 0.6–1.2 m in a narrow strip of the backshore. The surface of the beach, in turn, undergoes less noticeable transformations, mainly with sediment thickness decreasing in the upper and lower parts of the beach to 0.3 m, and increasing to 0.3–0.6 m in the central and shoreline zone in the form of a discontinuous bar.

Data analyses were carried out in frame of project № 17-77-20041 of Russian Science Foundation.

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Capacity Building in Sustainable Shore Use

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In the coastal zone of the Eastern Gulf of Finland (EGoF) both on Russian and Finnish sides, a network of new ports has been established aimed at diversification of traffic flows and sustainable development of the coastal infrastructure. This network is the carcass of the «coastal technosphere» of the EGoF region. The operation of the network ensures the exchange of goods, raw materials and intellectual information between the eastern and western Baltic countries, which is a prerequisite for sustainable development of the Baltic region as a whole.

At the same time, the coastal zone of the EGoF is recognized as a valuable natural object, highly sensitive to anthropogenic impact and effects of global warming. It is characterized by the diversity of biotopes and biological communities and plays a key and comprehensive role in many ecological processes (reproduction of aquatic biological resources, the formation of migration channels of birds and fish, self-purification of water ecosystems etc.).

Development of the «coastal technosphere» is accompanied by an increase of uncertainty levels in the coastal zone of EGoF, and significant environmental risks, including those occurring at a transboundary level. These process can be considered in a comparative aspect by the example of the new Bronka port (Russia) and the modernized port complex Hamina-Kotka (Finland).

In the area of both these ports, a specific «port environment» is being formed, supported by the development of transport infrastructure facilities. Within the «port environment», contradictions between natural and technospheric objects of the coastal zone come out. Prevention and solving of these contradictions is possible only on the basis of a balanced, holistic approach to the management and use of the coastal zone, ensuring a stable interaction between the natural and technospheric sectors (components) of the «port environment» for the long-term perspective.

In this connection, the way to achieve this objective is capacity building in the field of environmental and professional education and training of stakeholders and decision-makers in the region by developing and implementing educational and training programs for a wide range of specialists and students, using the accumulated experience and the best practices in the region of Bronka (Russia) and Hamina-Kotka ports (Finland).

Therefore, the main objective of the new project is to increase the READINESS of the cross-border region to the existing and expected challenges by introducing examples of the best practices on both sides and applying innovative solutions in the field of sustainable shore use. Obviously, the achievement of this objective is only possible through the efforts of highly qualified specialists, who have the necessary knowledge and professional competencies.

In this connection, the way to achieve this objective is capacity building in the field of environmental and professional education and training of stakeholders and decision-makers in the region by developing and implementing educational and training programs for a wide range of specialists and students, using the accumulated experience and the best practices in the region of Bronka (Russia) and Hamina- Kotka ports (Finland).

Effectiveness and sustainability are provided by a bridging together of research institutes (science) – business (production/innovation) – university (education/training). The development and implementation of professional education and training programs is expected at universities – partners in the project, and also on the basis of a specially created Russian-Finnish Center for Education, Research and Innovations in Coastal Zone Management CERINCO.

The described problem has been identified as a result of the identification of a number of indicators of the status of the «port environment» in the EGoF region, namely:

– the number of migratory birds (including swans), stopping and staying in the ports' territory during the spring and autumn migrations, has a tendency to decrease due to a reduction of the areas of wetlands and shallow water during the first decades of the 20th century;

– dredging, which regularly carried out during the ports construction and fairways repair works, causes turbidity trails of significant square and duration;

– catches of commercial fish are constantly reduced, primarily due to the destruction and/or covering of spawning grounds by silt;

– the coastline is characterized by a high level of instability due to a reduction of wetlands, as well as due to changes in the structure of currents under the influence of hydraulic engineering construction;

– under the pressure of commercial structures, there is a periodic re-planning of protected areas adjoining to the ports;

– there is a lack of enough of storage sites for «dredged material»;

– there is no legal basis for the interaction between ports and adjoining protected natural areas;

– stressful anthropogenic factors enforce the natural (rising of the ocean level, swamping, floods) and «masked» by them.

All the listed indicator processes point at the urgent need of forming a holistic port environment and minimizing the accumulated contradictions in the ecosystem of EGoF. The overall strategy for the integrated management and use of the coastal zone on the basis of a holistic approach should ensure optimal neighborhood and safe interaction of «coastal technosphere» and valuable natural objects.

The objective of the project: is capacity building and training of highly professional staff for the formation of a holistic port environment, the main components of which should be:

– a technologically safe technosphere based on innovative and environmentally friendly solutions;

– highly professional, scientific approach to shore use and coastal management;

– trained personnel who serve both objects of the technosphere and specially protected natural areas;

– sufficient protected natural areas having a regime for the prohibition or minimization of anthropogenic activities;

– effective legal framework regulating the relationship between port facilities and adjoining environmental protection zones.

The following challenges were identified, facing the EGoF region.

1. Scientific challenge: a clear gap between strategies of port development and capacity of the environment to counteract negative impacts.

2. Educational and professional skills challenge: the lack of environmental thinking among stakeholders (especially youth), managers and experts.

3. Innovative and technologic challenge: insufficient information about innovative technologies which can reduce the impact on the environment, and the lack of effective implementation of these technologies in the practice of shore use.

Expected changes are:

– Improving scientific base for coastal zone management and decision making;

– Improving the level of education and ecological knowledge;

– Improving the effectiveness of implementation and use of innovations.

The project's stakeholders include authorities of the ports Bronka and Kotka-Hamina, municipalities of Saint Petersburg and Kotka-Hamina areas, regional and national authorities, residents of areas next to the ports, general population of the coastal zone in EGoF. The project will bring added value and benefit to all groups of actors: project stakeholders, project partners, general population, and, indirectly, another parts and regions of Russia, Finland and other geographic areas outside the program area who will be able to learn from the project's experience through information dissemination. The project will play an important role in disseminating best practices originated in South-East Finland and Northwest Russia, thus strengthening the reputation and position of the program area on the world scale.

Main outputs of the project are:

– creation of innovative holistic port environment, with adopted technological and engineering innovations;

– elaboration of the development strategy for the environmentally friendly port;

– establishing the Russian-Finnish Center for Education, Research and Innovations in Coastal Zone Management CERINCO;

– development of original training programs for the Russian-Finnish Center for Education, Research and Innovations in Coastal Zone Management CERINCO, and multimedia courses having international certification;

– formation of a cohort of highly educated specialists and experts;

– development and publishing of methodological materials in Russian and English.

The principal methodologies and technics of the project are:

– interdisciplinary approach;

– holistic thinking that combines problems of the Russian and Finnish sectors of the EGoF within a single common ecosystem;

– support to scientific results, aimed at studying of the coastal ecosystems of the EGoF;

– support of innovation activities at enterprises and educational institutions;

– analysis and exchange of best practices of Russian and Finnish experts;

– problem-oriented learning at the CERINCO, based on the «case-method»;

– encouraging cooperation between enterprises and educational institutions and scientific and research institutions.

Geological and geotechnical conditions of Cambrian-Ediacaran terrigenous rocks in the Estonian side of Helsinki–Tallinn tunnel route

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A plan to establish the tunnel between Helsinki–Tallinn became more realistic after finishing feasibility study accomplished in the course of FinEst project in 2018. One of the most considerable of the tunnel construction point of view are geological, geotechnical and hydrogeological conditions of the Cambrian-Ediacaran terrigenous rocks. This 150 m thick complex consists of two quite different layers: upper complex (ca 90 m) of Cambrian blue clays and lower complex (up to 60 m thick) of Ediacaran sandstones.

About 90 m thick complex of Early Cambrian (Lykati and Lontova Formation) blue clays form regional aquifer and it is a good environment for the tunnel construction. Other examples of construction in blue clays are the St Petersburg Metro and the underground fuel storage at Miiduranna in Viimsi peninsula. The underground fuel storage near Miiduranna in Cambrian blue clays are located 30 m below the surface. The complex was established 1969–1972 for military purpose (for tanking submarines) and it consists of three 780 m long and 5 m in diameter concrete tubes which can hold 50 000 m^3 of fuel.

In 1979–1982 prospecting Maardu granite deposit in the complex of Ediacaran sandstones was penetrated numerous (38) drill holes. This region located 5 km eastward of possible entrance of the tunnel. During investigations geophysical loggings: natural gamma ray, electric resistivity and conductivity were made for all these wells. Unfortunately, core output from that extremely weakly (<1 MPa) lithified and water saturated quartzose sandstones complex is very low (less than 10 %). Received core is represented more strongly lithified (compressive strength 10–40 MPa) silt- and sandstones.

To clarify the density of Ediacaran sandstones additional gamma-gamma ray logging was performed (in well sections where the casing pipes is absent). There is good recovery between the results of densities measured in rock samples from drill cores and gamma-gamma logging. The density measured by gamma-gamma logging in these wells were 1,8–2,2 g/cm^3. The density 1,9–2,3 g/cm^3 measured in rock samples correspond to extremely to weakly lithified (0,4–9 MPa) Cambrian sandstones.

Before planning the location of the possible tunnel route at least three drillings on Viimsi peninsula and Aegna Island needed for gathering geological-hydrogeological-geotechnical data. There will be used contemporary drilling methods (wire-line double or triple tube drilling) for guarantee required ouput of core from weakly lithified intervals of Ediacaran sandstones.

Problems of monitoring geodynamic processes in the Gulf of Finland and Lake Ladoga

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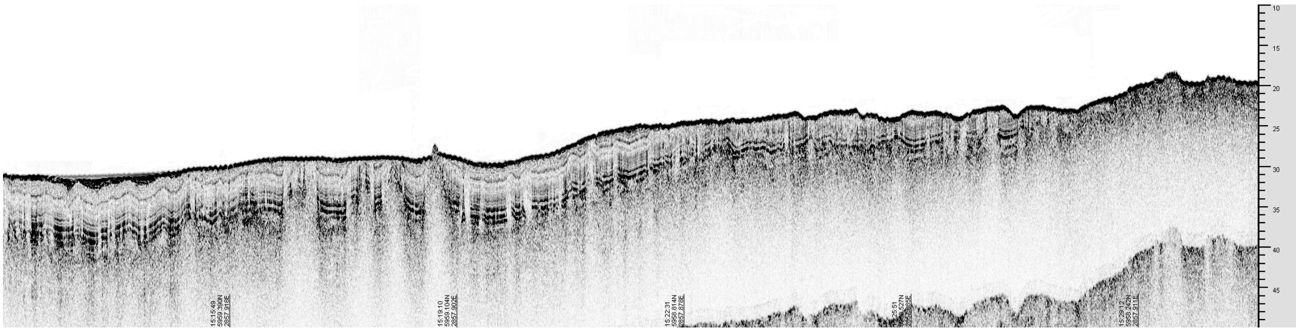
The main attention in the Tree-Lateral Cooperation Finland-Estonia-Russia on the ecology of the Gulf of Finland is paid to the problem of clean water. Pollution of bottom sediments and stability of shores are also considered. At the same time, the seabed is used wide now to build engineering infrastructure. These are SEG-1 and SEG-2 gas pipelines, various cables, expansion of the network of ports and access routes to them. In this regard, increasing attention is drawn to the sustainability of engineering facilities on the seabed and the environmental safety of construction. One of the factors of this safety is the consideration of modern geodynamic activity and seismic stability of the constructed objects, especially pipeline transport and other linear objects.

Traditionally it is believed that manifestation of geodynamic movements on the territory of the East European Plate and the Fennoscandian Shield, where located both the Gulf of Finland and the Ladoga Lake, absent. However, as the literary [1, 3] and our data [5], obtained in recent years, indicate that modern movements take place at the bottom of marine and lake basins, located along the eastern periphery of the Fennoscandian crystal shield. So, recent seismoacoustic profiling in Lake Ladoga using multi-channel equipment [4,5] has separated several structural ridges in the northern part of the lake basin. The relative height of these ridges can reach 80–100 meters or more. They were previously covered by a thick layer of glacial-lacustrine sediments, but post-Pleistocene movements led to a sharp shift and rupture of this horizon, which is clearly visible on seismograms. Sometimes these dislocations also break up the Holocene lacustrine sediments, which allows one to assume the possibility of manifesting geodynamic movements in Holocene times. Holocene and late Pleistocene neotectonic movements are accompanied by gravitational movement of sedimentary masses down the slope. This leads to both the crushing of soft sediments at the foot of the structural ridges, and to the "extrusion" of bottom sediments away from of these ridges. This leads to the appearance of positive relief forms, composed of postglacial deposits. It can be assumed that this happened as a result of another seismic event, the subsequent gravitational slip of sedimentary masses from a steep slope and the displacement of previously deposited sedimentary strata.

Other manifestations of modern geodynamic movements are noted. To the south of Valaam islands the tectonic fault dissects already moraine ridge. In this case, both horizons of glacial-lake clays and layers of lakustrine muds are displaced relative to each other. Amplitudes of such displacements are up to 5 m, and the glide mirror is inclined relatively weakly (up to 15 degrees). Additional materials were obtained from high-frequency (1–4 kHz) geolocation profiles in the western part of the lake. Seismograms clearly show disturbed horizons of glacial-lake clays, which reflect the "subsidence" of blocks of crystalline rocks under the influence of Holocene geodynamic movements, which were accompanied by the formation of landslides on the slopes of elongated depressions. Along with a clear displacement of seismoacoustic horizons, accumulative bodies are formed which are practically devoid of structural features. Perhaps, these are powerful sedimentary deposits, the emergence of which is associated with the processes of clay material swimming and the formation of semi-liquid formations with the complete disappearance of primary textures.

The data on seismic activity in Lake Ladoga are evidenced by B. Assinovskaya [1], wich summarized materials on seismic events in the Ladoga region, and also brought numerous data on seismic dislocations in the Valaam archipelago. These data are also confirmed by direct geological observations. In particular, during the geological survey of Lake Ladoga in 1991, the facts of the location of crushed band clay on the bands of Holocene lacustrine sediment were established.

The signs of recently Holocene movements were also established in the Gulf of Finland. It should be noted that at the present time a sufficiently large number of facts have accumulated, which indicate



Development zone of pok-marks in the Eastern Gulf of Finland (arrows) [geoechogram]

the manifestation of endogenous processes of Holocene time and their direct influence on modern processes of sedimentogenesis and, to a lesser extent, on the nature of relief formation. In particular, it is known that in 1976 in the Gulf of Finland in the Saarema Island area in 1978 there was an earthquake up to 6 points. Data on the heat flux in the area of Kotlin Island. High-resolution acoustic profiling performed within the framework of geological monitoring established direct signs of low-amplitude geodynamic movements (modern tectonics) in the zone of passage of the North European Gas Pipeline (NEG). They are associated with the movement of blocks of crystalline rocks, which react to modern tectonic stresses by the formation of splits along ancient lines. As a rule, they are expressed in the form of extensive ledges, on which the loss of correlation zones of all layers of quaternary deposits occurs. Of fundamental importance is the fact that under these ledges, underwater landslides and other phenomena associated with manifestations of endogenous geodynamics are often noted. Another sign that indicates the manifestation of endogenous geodynamic processes is the so-called pok-marks – crater-like forms, the channels to which cut through the entire thickness of Quaternary deposits. In the craters themselves, gases of the methane group were selected, and the thermal survey data made it possible to single out temperature anomalies of 3–5° at a distance of hundreds of meters. The elongated form of craters and their confinement to linear forms of relief are typical, which are the morphological expression of zones of tectonic disturbances in the basement, which, apparently, are also activated in modern times. On seismograms, such pok-marks are well expressed in the form of vertical forms that cut the entire section (figure). On the sonograms crater-shaped forms with loose ridges of loose sediments framing them clearly stand out. In 2012–2014 polygon work was done on mapping of pok-marks. Poligon, measuring 13 × 4 km, was located to the west of Cape Shepelev and stretched towards the Demainsts shallow. It carried out seismoacoustic profiling, side-scan sonar and interpretative geological sampling. More than 100 crater were identified, most of which were clearly associated with a fault that determined the outlines of the southern shore of the Gulf of Finland from Lomonosova to Cape Shepelev. These data are also supported by the VSEGEI materials, which also examined the this field of pok-marks [2]. It is quite clear that the presence of such mobile and highly permeable zones poses a real danger for objects that must come into contact directly with the seabed. In this case, the morphological classification of pop-marks indicates their unevenness: there are very fresh forms, some of them are already blurred and, probably, finished its development. And this indicates the possibility of the emergence of new structures, including directly in the zone of constructed engineering structures.

The revealed signs of Holocene and modern geodynamic movements, as well as the active seabed mining by engineering objects, make it possible to raise the issue of organization of specialized complex geophysical studies (multi-channel seismo-acoustic profiling, side-scan location and multi-beam echo sounding) with the participation of Finnish specialists in identifying and mapping the zones of modern geodynamic processes in the eastern part of the Gulf of Finland, including in the area of distribution of rocks Fenoskandinavian crystalline shield. Subsequently, these studies may develop into specialized geodynamic monitoring in the areas of proposed construction and pipeline facilities already built. Similar works should also be organized on Lake Ladoga, which is part of the catchment area of the Gulf of Finland, where the level of manifestation of these processes is already much higher than in the Baltic Sea

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Potential of reducing nutrient load from Russian “hot spots” of HELCOM in the catchment area of the Gulf of Finland

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The object of the study is “hot spots” – industrial enterprises, municipal treatment facilities, agricultural enterprises, as well as other economic activities located on the Russian part of the Gulf of Finland catchment area and causing significant impact to the environment. The methodological basis of the work are the principles and criteria developed HELCOM and regulating the procedure for excluding “hot spots”; methods of statistical data processing and analysis of reference literature.

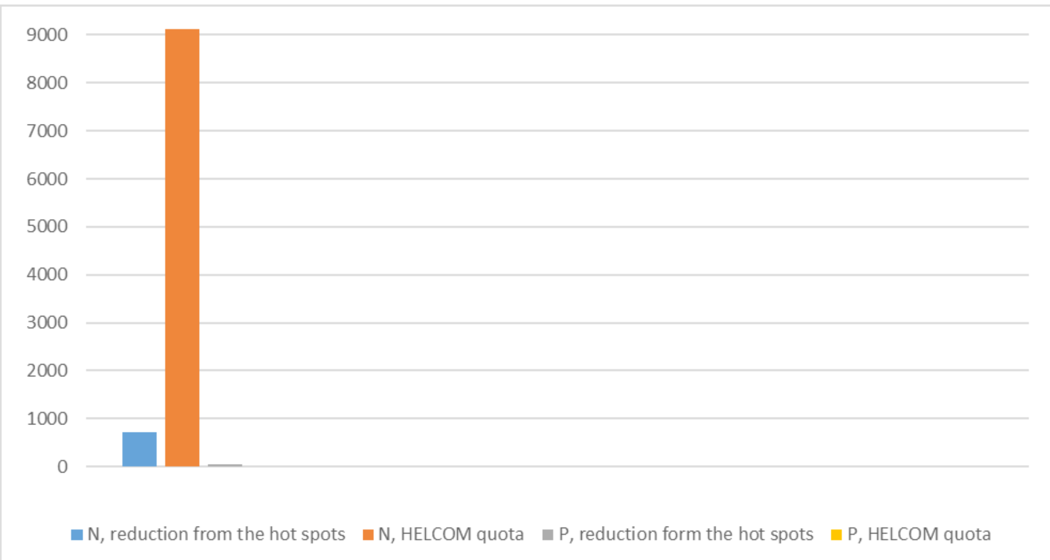
EEP method for determination manure quantity and its nitrogen and phosphorus content is used to assess the organic fertilizers production and its nutrients content.

All HELCOM countries have to provide reports about reduction of N and P in accordance with BSAP and HELCOM quotes. We have compared the potential reducing load from “hot spots” with the limits established by HELCOM. It is the best tool to evaluate implementing measures are provided by countries.

As can be seen from figure, the phosphorus quota for the Gulf of Finland has already been reached and no additional measures are required. On the other hand, an additional reduction the nitrogen from the other sources, for the Gulf of Finland is relevant.

Potential of reducing nutrient load from Russian “hot spots” of HELCOM in the catchment area of the Gulf of Finland

“Hot spots”	Potential of reducing nutrient load	
	N, t	P, t
18.15 – Municipal waste water treatment (Metalostroy)	55.8	16
23 – 2. № 23 «Hazardous Waste Landfill “Krasny Bor Landfill”»	0	0
14 – «Syas Pulp and Paper Mill»	31.4	1
15.3 – «Volkhov Aluminium Plant (Limited Liability Company “Metankhim”)»	0	4
24 «Large livestock farms (sewage water treatment and sediment processing)»	626.5	19.58



Comparative analysis of the reduction potential and of the remaining reduction (in accordance with the HELCOM quota), minus the estimation error

The EMODnet-Geology project – delivering harmonized geological maps of the European seas

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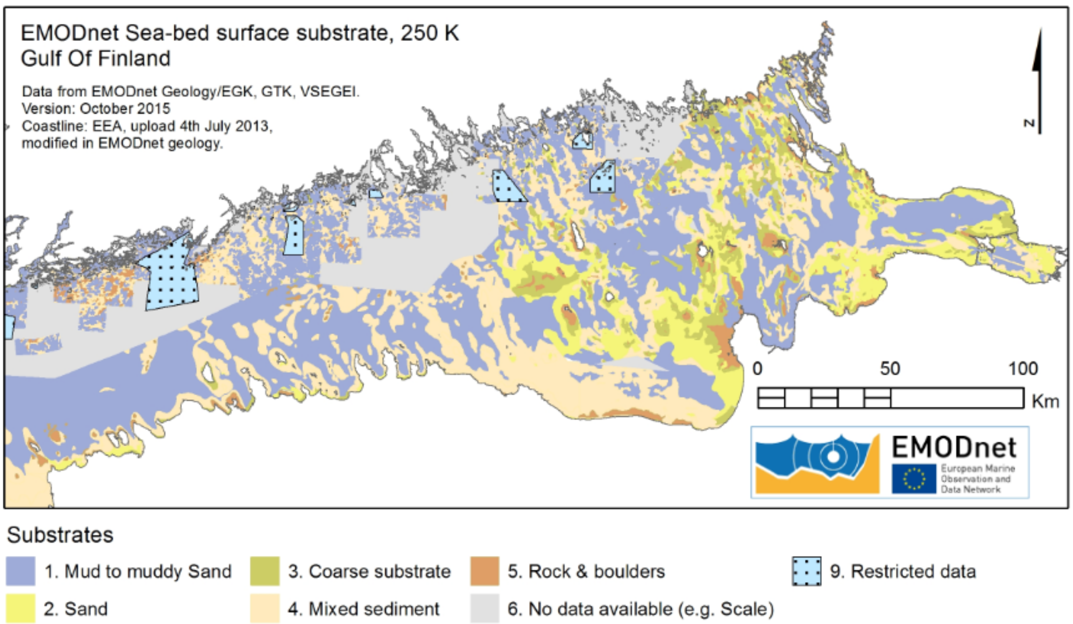
Numerous national seabed mapping programs worldwide have demonstrated the necessity of proper knowledge of the seafloor. Maritime spatial planning, management of marine resources, environmental assessments and forecasting all require good seabed maps. There is also a need to support the objectives to achieve Good Environmental Status in Europe's seas by 2020, as set up by the European Commission's Marine Strategy Framework Directive. Consequently already in 2008 the European Commission established the European Marine Observation and Data Network (EMODnet), which is now in its third phase (2017–2019, with an option of 2 more years). The EMODnet concept is to assemble existing but often fragmented and partly inaccessible marine data into harmonized, interoperable and publicly freely available information layers which encompass whole marine basins. As the data and data products are free of restrictions on use the program is supporting any European maritime activities in promotion of sustainable use and management of the European seas.

The whole package of separate EMODnet-projects ("lots") covers the marine disciplines geology, chemistry, biology, bathymetry, seabed habitats, physics, human activities, as well as a data ingestion project.

In this third phase the EMODnet-Geology project will deliver integrated geological map products that include seabed substrates, sediment accumulation rates, seafloor geology including lithology and stratigraphy, geomorphology, coastal behavior, geological events such as submarine slides and earthquakes as well as marine mineral resources and as a new feature map products on submerged landscapes of the European continental shelf at various timeframes. All new map products will be presented at a scale of 1:100,000 all over but finer where the underlying data permit. A multi-scale approach will be adopted whenever possible.

The EMODnet Geology project is executed by a consortium of 39 partners which core is made up by 24 members of European geological surveys (Eurogeosurveys) backed up by 15 other partners with valuable expertise and data. The partnership includes the GoF Trilateral cooperation participants: A.P. Karpinsky Russian Geological Research Institute (VSEGEI), Geological Survey of Estonia (EGT), and Geological Survey of Finland (GTK).



EMODnet seabed surface substrate map of the Gulf of Finland

Spatio-temporal variability of dissolved organic nutrients in the Gulf of Finland

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The eutrophication of Gulf of Finland (GoF) is determined by inputs of nitrogen and phosphorus from the catchment area of the gulf, water exchange with Baltic Sea, transport of matter between various areas of the gulf and internal chemical processes [11]. To study different processes and spatiotemporal variability of nutrients the model SPBEM-2 is used. SPBEM-2 is a three-dimensional coupled eco-hydrodynamic model with a modular structure. The modern hydrodynamic module is based on the ocean circulation model of the Massachusetts Institute of Technology general circulation model (MITgcm) in the hydrostatic approximation and on a model with viscous-plastic rheology for sea ice dynamics [3, 8, 16, 13].

The biogeochemical module describing cycles of nitrogen, phosphorus, and silicon in the water column and bottom sediments is based on the BALTSEM model [10], which was expanded by equations and parametrizations representing the dynamics of labile and refractory fractions of dissolved organic nutrients. The formulations of this expansion are largely borrowed from the "carbon version" of BALTSEM [4]. As before [9], the pelagic subsystem is presented by biomasses of zooplankton, three functional groups of phytoplankton (diatoms, flagellates, cyanobacteria), concentrations of detritus nitrogen, phosphorus, and silica, inorganic ammonium and oxidized nitrogen, phosphates, silicates, and dissolved oxygen. Benthic sub-model describes the dynamics of three variables representing total amounts of bioavailable fractions of nitrogen, phosphorus, and silica in the upper "active" layer of bottom sediments. In the present modification, the dynamics of labile and refractory fractions of dissolved organic nitrogen and phosphorus in pelagic sub-model are described with additional four equations. In contrast to earlier formulations, the products of detritus decomposition are not directed into inorganic nutrient variables but enter the labile dissolved organic variables that are then mineralized further. The specific rates of decomposition and mineralization are temperature dependent. The refractory fraction transforms into the labile one solely due to the process of photo-transformation, which specific rate depends on the underwater light distribution. Parametrization of zooplankton excretion is also changed. Products of catabolism are now distributed between not only inorganic nutrients (ammonium and phosphate) but also are a source of labile and refractory fractions of dissolved organic nutrients.

To prescribe the initial and boundary conditions, as well as to compare simulations with field observations, the international database compiled within the international project The Year of the Gulf of Finland 2014 was used [14]. This database contains most of the field measurements made by Estonia, Finland, and Russia during 1999–2014. Continuous time series of sea level variations at several locations have been borrowed from the Copernicus Marine Environment Monitoring Service (http://marine.copernicus.eu). Calculations of the annually averaged total nutrient pools were made with the Data Assimilation System [2] from all the data available within the geographical coordinates of the model domain.

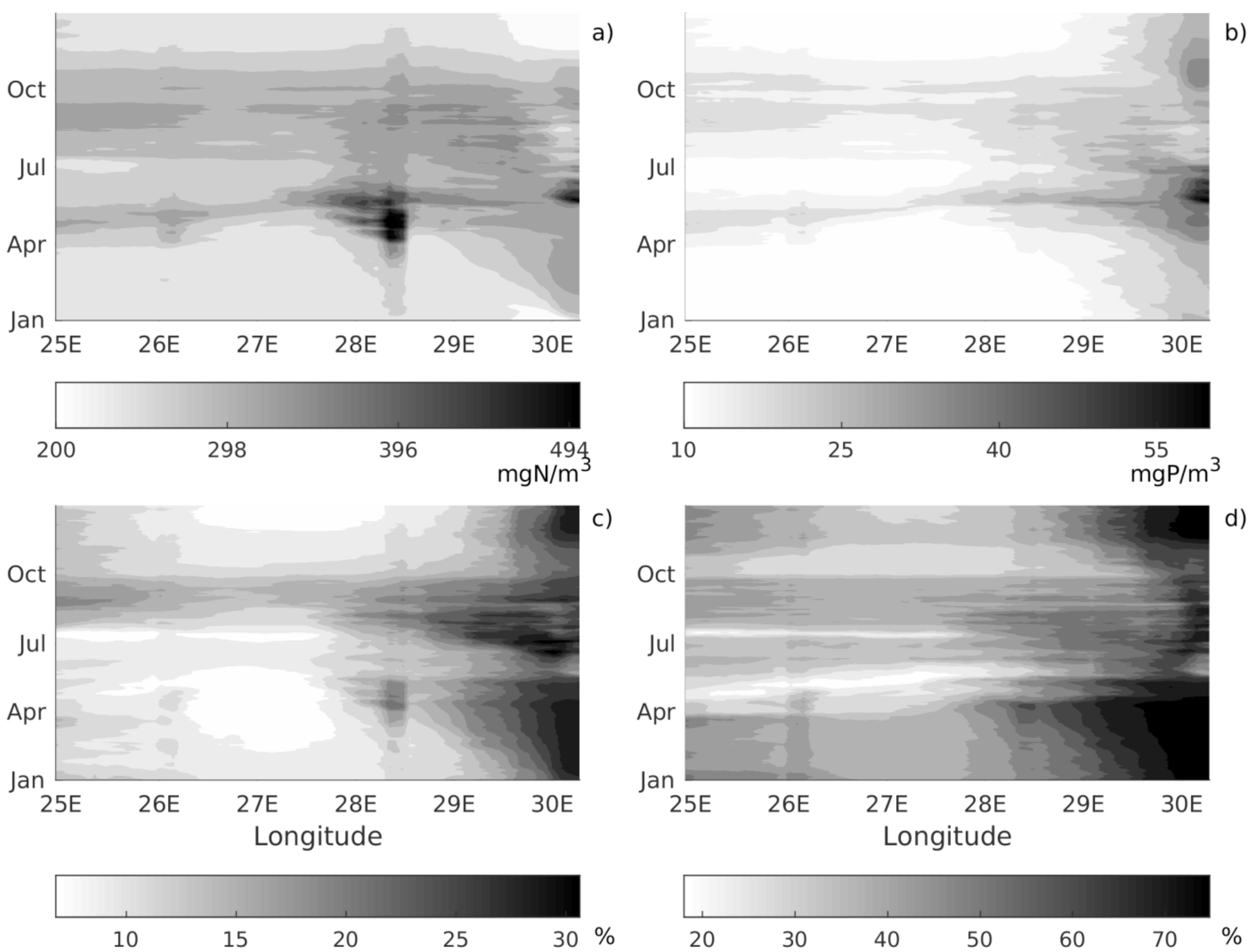
Simulation domain covers the Gulf of Finland from the easternmost Neva Bay to the open liquid boundary at 24.08° E. The horizontal resolution of the spherical grid is 2' by latitude and 4' by longitude, which approximately corresponds to 2 NM along both meridian and parallel. The vertical resolution is 3 m from the surface to bottom in the z-coordinate grid.

The initial distributions of temperature, salinity, and biogeochemical variables were constructed by interpolation of field observations, made during the winter months of 2002–2012, into grid cells. Concentrations of dissolved organic nitrogen (DON) and phosphorus (DOP) were calculated as a difference between concentrations of total nutrients and their inorganic fractions. Initial distributions of benthic variables were prescribed by using results of simulations from BALTSEM model for 1970–2006 [12].

The hourly sea level values at the boundary were taken from the observational data at Paldiski station. The atmospheric forcing was prescribed from the ERA-Interim reanalysis fields (https://www.ecmwf.int). The average monthly values of river runoff and nutrient land loads were taken from the Baltic Environmental Database at the Stockholm University [1] and the latest load compilation by HELCOM [6].

This test simulation was run for 2009–2014 using numerical values of parameters borrowed from [5] without any calibration.

The validity of simulated dynamics of organic nutrients is confirmed by its close resemblance with results of the goal-oriented analysis of sea surface samples collected by the ship-of-opportunity on repeated cross-sections in the Eastern Gulf of Finland from April till December in 2005 [15]. Matching these results to the average (2009–2014) seasonal dynamics of simulated total organic nitrogen (TON) and phosphorus (TOP) demonstrates a reasonable comparability of their spatial-temporal dynamics (figure). The major conspicuous feature is a sharp increase in TON concentration for a few weeks in April-May, caused by the spring bloom of diatoms and especially pronounced in the open Eastern Gulf of Finland (28° E – 29° E). There and then, the TON concentrations exceed 500 mg N m-3, both in the model and in the field. Cyanobacteria blooming generates summer maximum of TON over the entire gulf, albeit slightly decreasing westward. In the model, this maximum looks more prolonged, over July-September vs. July-August indicated by the infrequent cross-sections, and less pronounced, around 350 mg N m-3 in the model vs. up to 450 mg N m-3 in surveys. In the winter, TON concentrations are at comparable minimum levels, less than about 250 mg N m-3. The most specific feature of both simulated and observed TOP variations is a significant eastward increase of its concentrations, up to 30–40 mg P m-3 in the Neva Bay. According to Fig. 1, the relative contribution of labile fraction of dissolved organic nitrogen (LDON) is around 25 % in the Neva Bay and decreases westward, less sharply during a summer development of cyanobacteria that, in contrast to fast-sinking diatoms, decompose largely in the surface layers. Following approximately the same pattern, the contribution of labile fraction of dissolved organic phosphorus (LDOP) is higher and decreases westward less sharply, from about 70% to 40 %. The plausibility of such disaggregation of TON and TOP into fractions is difficult to evaluate because of the almost total absence of relevant



Simulated seasonal and latitudinal distribution of TON (*a*), TOP (*b*), proportion of LDON in TON (*c*) and proportion of LDOP in TOP (*d*) averaged over 2009–2014

measurements. Nevertheless, simulated proportions are similar to a few reported estimates of 25 % and 64 % [10] and 0–41 % and 44–46 % [7], for LDON and LDOP, respectively.

Within all the uncertainties, inherent to a model-data comparison and generated by the set-up of simulation, the test can be considered as rather successful. Spatial and temporal dynamics of both hydrophysical and biogeochemical variables appear quite realistic, especially assessing the model skill by the comparability of concentrations, as is common in modelling practice. There is almost a perfect match between the reconstructed and simulated total amounts of organic nutrients, the latter being a major goal of SPBEM-2 modification.

Acknowledgements

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Transformation of geological environment of the eastern Gulf of Finland and its coastal zone as a result of anthropogenic impact

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Data based on the study of the sediment cores shows that the waters of the Baltic Ice Lake were lifeless and accordingly living conditions at its coasts for ancient people were too heavy for colonization. It is possible to suppose that first people could come to the coasts of the eastern Gulf of Finland only during the Holocene, and especially after beginning of Littorina transgression when the climate became essentially warmer and marine bioproductivity principally increased. Such statement can be based upon the fact that the content of organic matter in the mud sediments accumulated during this time has sharply increased. Archaeological data confirm that first people diffusion to the coastal areas of the eastern Gulf of Finland began about 9000 years ago during Mesolithic Time, and became very active about 7500 calendar years ago [2]. The sites of ancient settlements of different age (6500–3100 cal.y. BP) were found at the Neva River delta including the mouth of the Ohta River, lower course of the Narva River, at the northern coast of the gulf within the Sestroretsky Razliv area, within Narva-Luga Klint Bay area, etc. [1]. This first stage of human reclaiming of the gulf coast was characterized by very low impact on the natural environment. Man was adjusting to the natural processes. In particular geoarchaeological researches in the coastal areas of the Gulf of Finland have shown that settlements migrated together with the movement of the gulf shoreline during the transgressive-regressive cycles of the Baltic Sea development. Consequently this period can be named as a time of human forced adaptation to changing environmental conditions.

Constant settlements began to appear on the coasts of the eastern Gulf of Finland in the Middle Ages. These were ports and fortresses founded on the main transport routes. In that time people chose the most convenient and safe places for construction of their settlements. So Vyborg was established on not retreating and most erosion resistant shores. Later, in the delta of the Neva River, the Nyenskans fortress was built on a territory that was not overflowed even during periods of severe flooding. The anthropogenic impact at that time was minimal and very local. This time can be specified as a time of human selection of optimal environmental conditions.

Since the beginning of the eighteenth century new epoch, characterized by local, but aggressive transformation of coastal environment, started. Foundation of St.Petersburg city by Peter the Great in 1703 was accompanied by technogenic uplifting of low swampy territories and changing of river network. For the city defense in the western part of the Neva Bay several artificial islands with 17 fortresses were built. The first fortress "Kronshlodt" was constructed in 1704. Bay bottom was crossed by special defense constructions – wooden crib-bars for prevention of ships movement outside fairways. Nowadays these crip-bars are well traced on the sea bottom by side-scan sonar profiling. These artificial islands and crib-bars can be consider as a first real technogenic impact which transformed geological environment by partly changing the hydrodynamic and lithodynamic schemes in the easternmost part of the Gulf of Finland.

Construction of the Neva River woody and stony embankments in St.Petersburg prevented erosion of the Neva delta coasts and essentially decreased sediment load into the Neva Bay. As a result of several Swedish-Russian wars in this century the first anthropogenic objects in particular navy vessels equipped with guns made using heavy metals were sunken. It was the start of the beginning of sediment pollution of the Gulf of Finland. "Petrotrans ltd." company in the process of ferromanganese concretions extraction in the Vyborg Bay in 2006–2007 uplifted several cannon balls from the sea bottom. Thus this time can be named as the period of significant, but very local, transformation of geological environment of the eastern Gulf of Finland and its coastal zone.

The nineteenth century was characterized by slow, but permanent expansion of anthropogenic activity modifying marine and coastal geological environments. For example, as the natural water depth within the most part the Neva Bay is about 2 m, and St.Petersburg harbor is located in the easternmost part of the Bay, for navigation purposes ship channels dredging has been constantly carried out. In 1885 so called Marine Channel with water depth up to 12 m – the main fairway to St. Petersburg – was constructed.

The beginning of the twentieth century was marked by the rapid growth of the population of St. Petersburg and its surroundings and sharp increase in industrial production, including metallurgy. Replacement of sailing ships by steamships with a significant increase in the transport flow, the expansion of ports, the mass use of cars, coal-fired boiler plants, etc., contributed to the growing of diverse pollutants discharge into the gulf. Two world wars left on the bottom of the Gulf of Finland numerous sunken navy and transport vessels, as well as different kind ammunition, which are also sources of pollution. By the middle – end of the twentieth century, the pollution of the eastern part of the Gulf of Finland and especially the Neva Bay became comprehensive. This was due not only to the continued expansion of industrial production, including chemical production, but also to the massive use of various pesticides and nitrogen fertilizers on the agricultural lands adjacent to the shores of the Gulf. In twentieth century St.Petersburg – Petrograd – Leningrad became a huge city with 5 mln. population, high developed industry and transport infrastructure (including several ports). It caused enormous increasing of anthropogenic load to the Gulf of Finland ecosystem. The eastern coastal zone of the Neva Bay at that time presents several examples of "waste beaches" appeared as a result of waste disposal in this areas which are characterized by very high level of different pollutants (e.g. heavy metals and radioactive material). Construction of St. Petersburg Flood Protective Facility which started in the 1970's and finished in 2011, transformed the Neva Bay into a special "technogenic lagoon". Geochemical investigations of the silty-clay sediment cores revealed a trend of increasing of heavy metal concentrations from "pre-industrial time" to 1950s–1990s. Thus the second half of the century was characterized by maximal level of bottom sediment contamination.

Since 1950s millions tons of the aggregates (sand and sandy-gravel mixtures) were extracted from the bottom of the different areas of the eastern Gulf of Finland. For example in 1970-s submarine sand extraction took place even in the neashore of St. Petersburg (Leningrad) close to the Lahta Bay forming bottom depressions up to 12 m deep. As a result of under-water mining the natural seabed relief locally was completely transformed that essentially changed the sedimentation processes.

In 2011–2016 in the framework of the State monitoring of geological environment of the shelf areas of the Barents, White and Baltic seas carried out comprehensive survey of the areas of underwater mining in the eastern Gulf of Finland. These investigations included continuous seismic profiling; side-scan sonar profiling; multibeam echo sounding; bottom geological sampling; hydrophysical sounding; seafloor video-observations and analytical study of the mechanical and chemical composition of bottom sediments. As a result of these studies the degree of transformation of the natural seabed topography, as well as the direction and dynamics of sedimentation processes change in the areas of underwater mining were assessed.

The aggregates (sand and sandy-gravel mixtures) economic deposits in the eastern Gulf of Finland were formed during the different stages of water basin development. In particular, some of them have been formed in the Late Pleistocene as a result of fluvioglacial processes. But mostly the aggregates are extracted within near-shore sand terraces formed in Middle Holocene during Littorina Sea transgression-regressions cycles. One of the examples of such economic deposits is "Pesky", located in the northern coastal zone of the Gulf of Finland between the capes Pechany and Flotsky, where sand mining was carried out in 1972–1992. The surface of the terraces here is covered mainly by coarse-medium and fine-medium-grained poorly sorted sand. Study of the areas of sand under-water mining using side-scan sonar and seismic acoustic profiling allowed finding numerous technogenic depressions with relative depth up to several meters. It was supposed that these bottom relief forms have to be filled in by surrounding sand. But sediment sampling within these depressions near the northern coast of the gulf showed accumulation of laminated silty-clayey mud layer more than 50 cm thick. It may be stated that even in conditions of active wave processing in coastal zone, restoration of sand deposits within the former underwater quarries does not take place. The silty-clayey mud accumulated in the coastal zone can be regarded as potential traps of pollutants. The vertical distribution of ^{137}Cs in the sediment core sampled within the area of under-water mining characterized by two maximums of activity. The first – a slight, located at depths of 8–10 cm, and the second – a high activity with a maximum depth range of 30–32 cm. According to VSEGEI data maximum concentration of ^{137}Cs in bottom sediments of the eastern Gulf of Finland were observed in 1989, which was due to active processes of redistribution after the initial "Chernobyl" fallout in 1986. Study of ^{137}Cs distribution in the sediment core with Chernobyl peak fixing allowed determining high sedimentation rate (up to at least 1.2 cm/year).

Resembling situation was found within the area, where in 2006–2008 "Petrotrans ltd" carried out an experimental underwater extraction of ferromanganese concretions using dredge pump vessel "Lauwer". Totally, it was extracted about 60 000 tonnes of concretions. The area of underwater mining was investigated in 2012–2015 using side scan sonar and multibeam echosounding profiling, as well as underwater video-observations and sediment sampling. Within the trenches (0.5–1.0 meter depth) left by mining vessel, conditions of sedimentation were markedly changed. Former slow or almost zero clastic sediment accumulation accompanied by concretions growth within this area was changed by intense silty-clayey mud accumulation. The thickness of silty-clayey mud surface layer suggests abnormally high (up to 1–1.5 cm/year) recent sedimentation rate. Spheroidal concretions (up to 1 cm in diameter) and their debris are rare and mainly found buried in the sediments at a depth of 5–10 cm. Lack of microconcretions and smoothed surface of buried concretions indicate that the concretions at present do not grow. Concretions are conserved or, more likely, dissolved.

Construction of St. Petersburg Flood Protection Facility has solved the problem of coastal erosion and floods within the Neva Bay. But further anthropogenic transformation of its coastal areas as a result of sharing of city urban area (e.g. high-rise busyness districts), development of industry and transport infrastructure (marine merchant and passenger harbors, expansion of high-way construction etc.) will still cause growing of technogenic load on the Neva Bay.

In 2006 the new stage of intense anthropogenic impact of the Neva Bay started. In the eastern part of the bay, near Vasilievsky Island, 476.7 hectares of new territory for the St.Petersburg Passenger harbor was created using sand dredging technology (www.mfspb.ru). For deepening of ship channel for huge fairies up to 14 m, big amount of bottom sediments (e.g. clayey material) was dredged, removed and damped within former carriers of sand extraction in the bay nearshore. As a result annual geochemical monitoring study of the bottom sediments allowed tracing the essential increase of the pollution level in 2006–2008 caused by sediment redistribution due to active dredging, and a slow decline since 2009. In 2008 the other harbor construction (Bronka) started in the western part of the bay. Harbor will include several terminals. For its construction new territories are creating and active dredging work carrying out. Project is going to finalize in 2020.

On the other hand it is obvious that the sustainable regional development, implementation of nature protection and healthy and safe environment for St.Petersburg population demand choosing of “environmental friendly” technologies. These tendencies accompanied in 1990s by reduction of industrial and agricultural production in St.Petersburg led to a significant decreasing of the pollution of the bottom sediments of the Gulf of Finland and its coastal zone by the beginning of the 2000s. Only locally especially in the Neva Bay the level of coastal pollution (e.g. waste disposals beaches) is still very high.

In 2011–2016 the concentrations of heavy metals were again lower than observed in sediment cores for the time period of 1950’s – 1990’s. The present trend of improvement of the geological environment is mainly caused by measures of St. Petersburg city water purification system.

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Compensation measures to the Gulf of Finland fishery undertaken by Nord Stream 2 project in 2018 year

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Offshore construction of Nord Stream 2 gas pipeline is linked with local marine environment disturbance and damage to coastal fishery arising thereof. These projected processes of offshore construction studied preliminary and potential damage for local fishery was estimated. The measures were undertaken even before the construction work start offshore.

The measures consist of several releases of two salmonid species (Atlantic salmon and brown trout) parrs to several scientifically selected sites in rivers of the Gulf of Finland catchment area. Atlantic salmon and brown trout juveniles grown on fish-breeding plants of FGBU Glavrybvod North-West branch. Their quality and average weight were determined and agreed by the Federal Fishery Agency of RF. Totally about 170.000 specimens of these two species fingerlings (100.000 of salmon & about 70.000 of trout) were released in May of 2018 for the compensation of potential lost for fishery in the Gulf of Finland.

Dynamics of the catch of herring and sprat in the Baltic Sea and Gulf of Finland: assessment of climate impact

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Fish stocks of the Gulf of Finland (GoF) are a raw material base of fishery, fish processing industry of Finland, Estonia and Russia. Fishing for herring and sprats, the most abundant species of marine fish in the GoF, plays an important role in the economies of the three countries. In this regard, the regulation of their fishing and the development of science-based forecasts of catches of these species is very relevant.

Almost a hundred fish species altogether have been caught in the GoF or in the waters running to it. The catch of marine fish species is more than 80 % of the total annual catch. Most freshwater species have also adapted to live in the estuaries and coastal brackish waters. More than one third of the species consist of both fresh water and brackish water populations and most of them are also anadromous ones [1].

It's known [2–4] that the productivity of the Baltic Sea waters depends on many natural factors (freshwater balance, volume of river flow, inflow of North Atlantic waters, etc.), the dynamics of which are due to large-scale climatic processes over the Atlantic sector of the Northern hemisphere.

The monthly mean values of the ocean surface temperature for the period 1900–2017 in nodes of a regular grid with a step of 2°x 2° in latitude and longitude from the archive NOAA NCDC ERSST version 3b were used [5]. These data were averaged for the period when there is no ice in the Baltic Sea (May–October), followed by obtaining the average values of the parameter for each year for all (12) nodes of the grid. Thus, a sample of the average surface temperature of the Baltic Sea over a 118-year period was formed.

In the interannual fluctuations of the thermal content of the Baltic Sea water masses according to the data of 1900–2017, there is a linear upward trend, which contributes 44 % to its overall variability. In addition to the linear trend in the spectral composition of the interannual variability of the thermal content of the Baltic Sea water masses, there are energy-carrying frequencies corresponding to the periods of 70, 11–12, 7–8 years, as well as 4 and 2 years [6] (fig. 1). Calculations of the wavelet spectrum of this series 1900–2017 showed that the 70-year quasi-periodicity was the most stable and its contribution to the dispersion of the initial data was 21 % (fig. 2). The superposition of these parameters determines 65 % of the surface water temperature variability and characterizes the long-term climate dynamics of the Baltic Sea [7].

The climate dynamics of the Baltic Sea is well correlated with the fluctuations of the total catches of herring and sprat (1977–2017) that dominate the ichthyocenosis of the Central Baltic Basin and Gulfs (fig. 3). The degree of correlation between the surface temperature (May–October) and herring

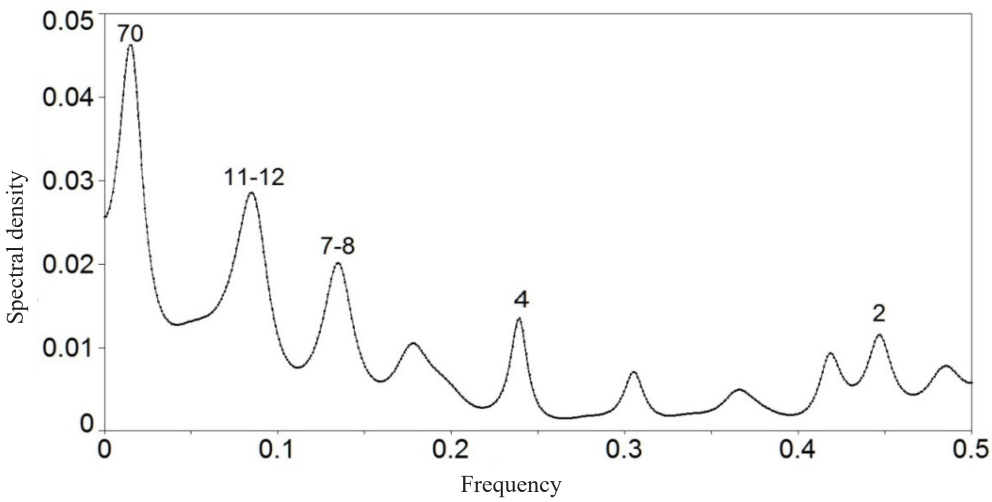

Fig. 1. The spectrum fluctuations of the surface temperature of the Baltic Sea 1900–2017. The period (years) is indicated above the significant peaks of the spectral density

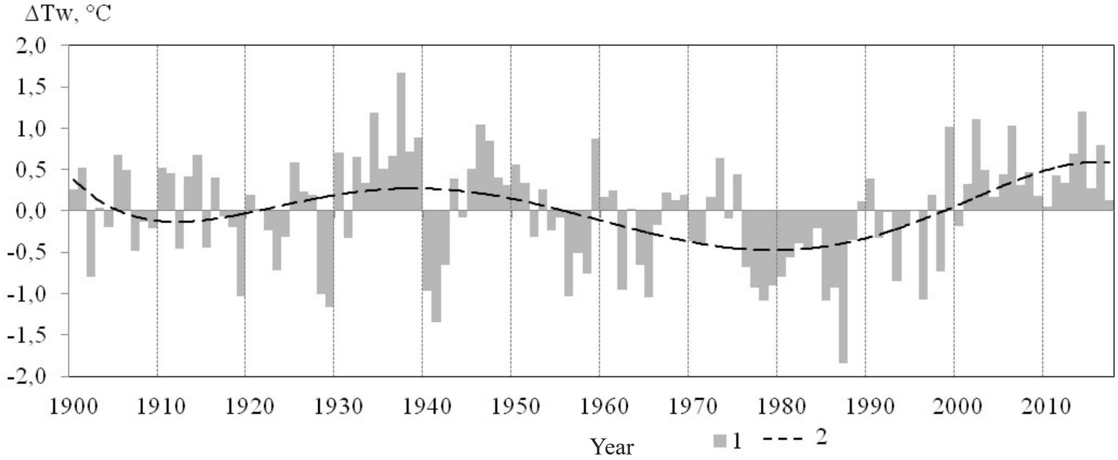

Fig. 2. Changing the difference between the original surface temperature of the Baltic Sea and their values of linear trend (1), 70-year cyclic component (2)

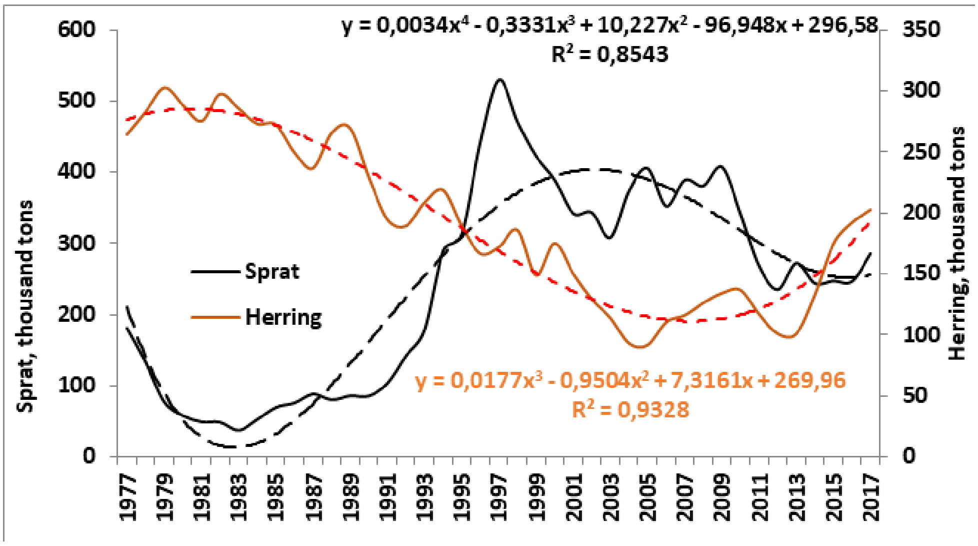

Fig. 3. Herring and sprat catch in the Baltic Sea (solid line) and their linear trends (dashed line) for 1977–2017

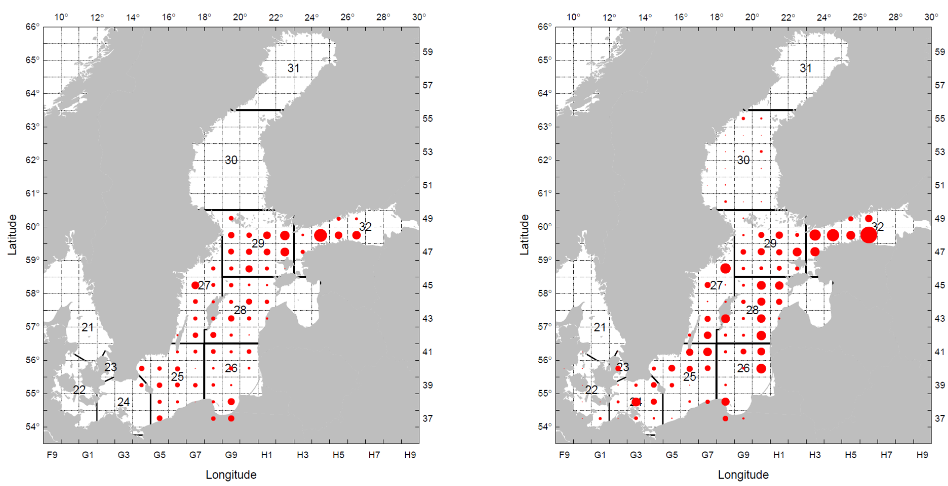

Fig. 4. Distribution of herring (left panel) and Baltic sprat (right panel) in Sub-divisions 25 to 29 and 32, excluding the Gulf of Riga, from the acoustic survey (BIAS) in the 4th quarter 2013

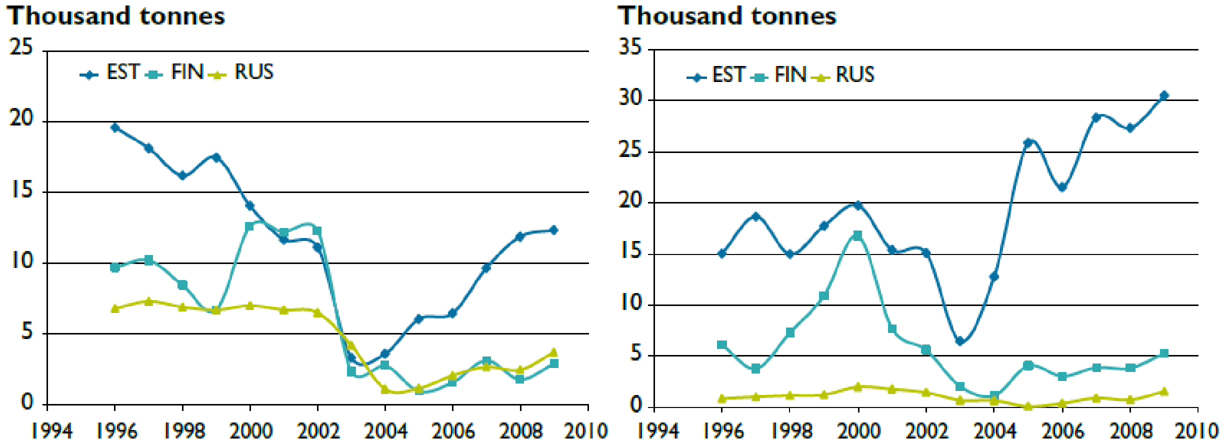

Fig. 5. The catch of herring (left) and sprat (right, thousand tonnes) in the GoF as a function of time. Note: also Sweden, Denmark, and Germany contributed to the catches, only their impact was minimal and are not presented [1]

catch was minus 0.76, sprat catch – 0.54, which confirms the patterns identified earlier [8].

It is noted that the increase of surface temperature has led to a change of herring and sprat catches, as well as the spatial distribution of their concentrations. The total herring catches decreased and sprats increased as the waters warmed. At the same time, there was a clear shift of fish concentrations in the North-East direction. So, the acoustic survey in 2013 (BIAS) found that of all Baltic Basins, the GoF and the Northern Gotland Basin had the highest abundances of herring and sprat (fig. 4) [1].

Studies have shown that the dynamics of herring and sprat catch in the GoF is well connected with the interannual variability of the total catch these species in the Central Basin of the Baltic sea (fig. 5).

This suggests the possibility of using the identified cyclical changes in temperature and its relationship with the catch of commercial fish in the development of long-term forecasts of herring and sprat.

In the last decade, the GoF has witnessed a restructuring of the ecosystem, structure and population of biological resources. However, the assessment of the role of the natural factor in the dynamics of the number of fishing facilities is hampered by the need to take into account the practically unexplored and diverse nature of anthropogenic impact.

The analysis of scientific publications has shown that the influence of anthropogenic factors has a greater impact on fish stocks in shallow areas of the Gulf. The Eastern part of the GoF, where large-scale hydrotechnical work is carried out, which are accompanied by ecosystem monitoring is a good example of it. The development of these works in the waters of the Gulf requires further detailed study of the climate and anthropogenic impacts on the ecosystem of the GoF, taking into account the activities of Maritime spatial planning.

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The possibility of usage a bioelectronic system based on the control of changes in the cardioactivity of freshwater crayfish for detection of cases of instantaneous pollution of brackish waters in the eastern part of the Gulf of Finland

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The bioelectronic system using the synchronous increase in heart rate in a group of freshwater crayfish as a reference parameter for more than 10 years has been used at the State Unitary Enterprise "Vodokanal Saint-Petersburg" as a means of continuous monitoring for real-time detection of cases of instantaneous pollution of water intakes from freshwater reservoirs, accompanied by an increase in the degree of biological hazard (toxicity) of water to a level comparable to LD50. The advantages of choosing freshwater crayfish as bioindicators are based on the high sensitivity of the heart rate to the effect of stress factors (an increase in the heart rate by a factor of 2 or 3 in 10–30 seconds – when passing from a state of relative rest to a stress state). In the process of laboratory modeling, we have previously shown that freshwater crayfish Astacys leptodactylus are capable of demonstrating the same characteristics of cardioactivity being for at least 2–3 months in water with a content salt of 6–7 g/l (heart rate in stress and rest state), as in the control group in fresh water. In order to find out the principal possibility of using the bioelectronic system for detection the instantaneous water pollution in the Gulf of Finland with the waters of the rivers and streams flowing into it, the dependence of the threshold concentrations of sensory reactions on a number of model pollutants (mineral and organic acids, ammonium salts) on the salinity of water in range from 2 to 6 g/l was studied in laboratory conditions.

A review of multidisciplinary research on sustainable maritime traffic in the Gulf of Finland

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Shipping, a maritime traffic system, or even the successful journey of one cargo item or a person by sea, involves interactions of various socio-technical and environmental processes and variables. Understanding such a system so that one can make optimal decisions and improvements is a multidisciplinary problem and there is a reason to believe it benefits from a collaborative work of experts from several areas [1, 2].

Kotka Maritime Research Centre (KMRC) was founded in 2007 to produce high-quality joint research on marine traffic, marine safety and the marine environment. During the past ten years, KMRC partners have coordinated and participated in various multidisciplinary research efforts regarding marine traffic in the Gulf of Finland. This review summarizes some of these efforts. It focuses especially on oil and chemical transportation in the Gulf of Finland, safety culture in shipping, leisure boating and on winter navigation. In addition, the study discusses the implications of the results and presents ideas for sustainable maritime traffic research in future.

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Experience of the Marine Spatial Planning tool using for Russian part of the Gulf of Finland

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Such as Russian Federation still has no national legislation for Marine spatial planning (MSP) tool realization, that for pilot application given approach for Russian part of the Gulf of Finland (GoF) the Guidelines of the Intergovernmental Oceanographic Commission for MSP [4] was used.

According to [4] the Marine spatial planning is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, social, and economic objectives that are usually specified through a political process.

Guidelines [4] define the steps for realization MSP procedure:

Step 1. Identifying the need and establishing authority (for planning and implementation)

Step 2. Obtaining financial support

Step 3. Organizing the process through pre-planning (creating the MSP team and work plan)

Step 4. Organizing stakeholder participation

Step 5. Defining and analyzing existing conditions (collecting and mapping information about ecological, environmental and oceanographic conditions and kinds of the human activities, identifying current conflicts)

Step 6. Defining and analyzing future conditions

Step 7. Preparing and approving the spatial management plan (alternative, zoning, restrictions)

Step 8. Implementing and enforcing the spatial management plan

Step 9. Monitoring and evaluating the performance

Step 10. Adapting the marine spatial management process

On December 2010 in Russian Government accepted the "Strategy of the marine activity development before 2030". The Strategy recommends using for defined goals achievement the tool "Marine spatial planning".

On August 2012 the Ministry of the Environment of the Republic of Finland, the Ministry of Natural resources and Environment of the Russian Federation and the Ministry of the Environment of Republic of Estonia the Memorandum of Understanding on the Implementation of the Gulf of Finland Year 2014 Programme was signed.

The Memorandum recognized the following:

– the marine environment of the Baltic Sea is under increasing anthropogenic pressure, including eutrophication, hazardous substances, and climate change. All these factors reduce the quality of the ecosystem services provided by nature to the society, and also reduce the level of biodiversity sustaining these services;

– the Gulf of Finland has a unique character taking into account its natural factors such as high salinity differences and harsh climatic conditions, and because of the increasing amount of anthropogenic pressure, including the high riverine nutrient inflow and maritime traffic.

The given Memorandum defines the five following themes for collaboration during GoF-2014:

1) marine spatial planning;

2) safety of maritime traffic, especially in winter conditions;

3) hazardous substances and the health of the Gulf of Finland;

4) fish resources and fishing;

5) biological and geological diversity.

In Russia, on 2014 the Ministry of Natural resources and Environment (Minpriroda) organized the fulfillment investigations for themes 1, 3–5. Minpriroda selected State company "Sevmorgeo" as coordinator for this investigations.

The MSP Russian Team included the next organizations with corresponded field of the activities:

– JSC "Sevmorgeo" – geodiversity, sediment and bottom water pollution, MSP;

– GOSNIORH – fish biodiversity and fish pollution, fisheries, fish feed statement;

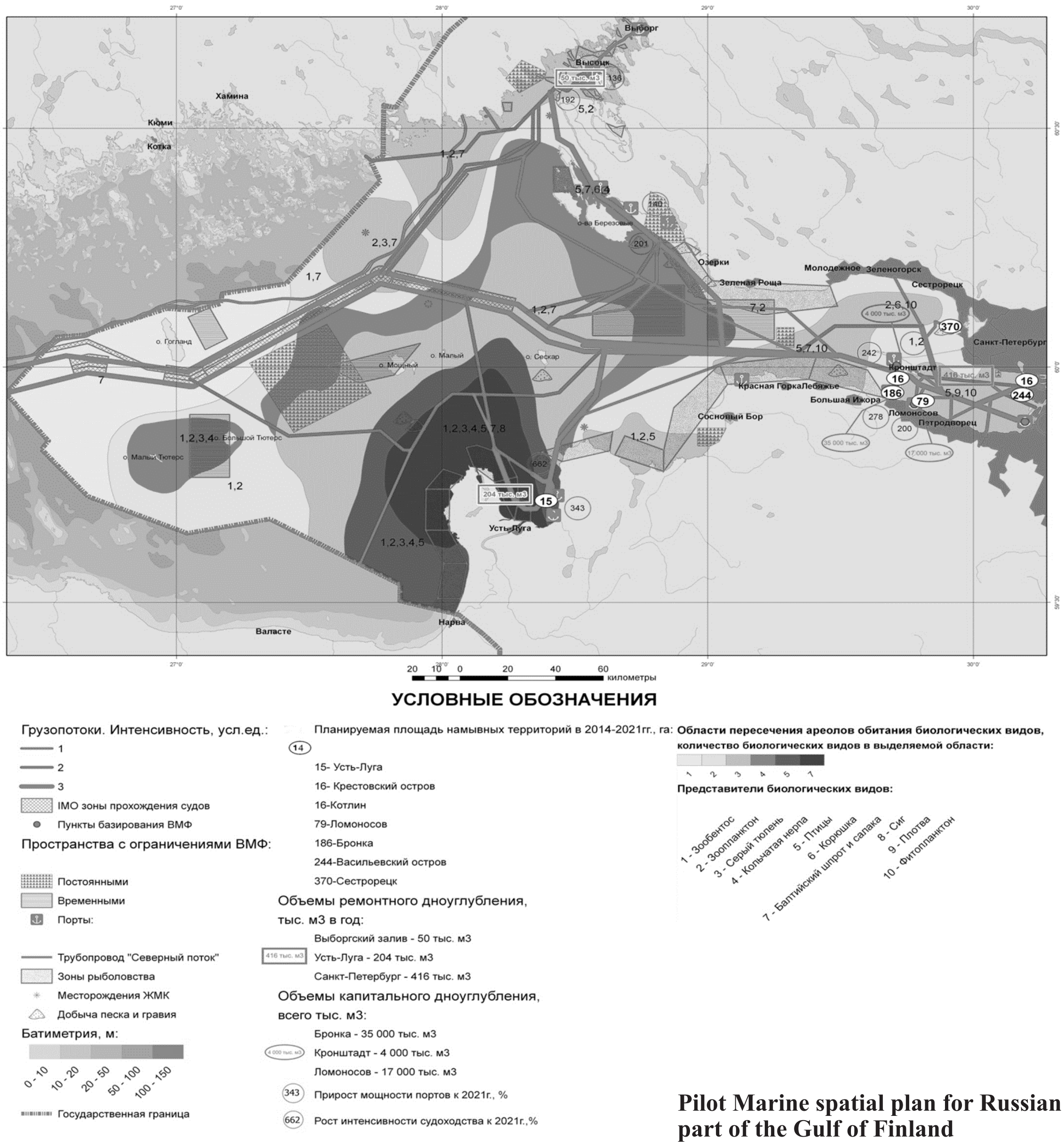
– Zoological Institute of RAS– biodiversity (phytoplankton, benthos, alien species);

– North-West Hydrometeorological Service – monitoring of the air pollution, GOF and rivers water pollution;

– Baltic Fund for Nature – biodiversity (mammals, birds), rare species;

– State Hydrometeorological University – GoF water nutrient pollution;

– SPb State University (Biofaculty: A. Anculevich, M. Verevkin) – macrobenthos, birds, mammals, alien species.



Pilot Marine spatial plan for Russian part of the Gulf of Finland

Also under the collaboration, we use the grey and ring seal data from the Estonian Fund for Nature.

So, the main MSP goal during conducted investigations was: ensure sustainability of economic uses for Russian part of GoF on the base of conservation of marine ecological structure on a sustainable good level.

For achievement of the MSP goal, the next kind of the human activity has been studied:

1 – shipping (increased shipping in %);
2 – dredging (mln m3);
3 – hydraulic filling (hectares) ;
4 – ports (cargo turnover growth in %);
5 – Navy (closed areas);
6 – mining operations (areas);
7 – fishery (areas and volume of fish stocks);
8 – marine tourism (routes and seasonality).

For the study of the Russian part of GoF geodiversity, the main lithology characteristic and pollution level of the water and sediments have been used [2, 3, 5].

According to IOC MSP Guide, both base and future time frames were chosen. The basic time frame was defined as a period from 2011 to 2013. The future time frame was consistent the time horizon planning of the Strategic documents and was defined as a period from 2020 to 2030.

The Strategic official plans for the development of each kind of the human activity have been a base of the studies [5].

During the estimation of the GoF biodiversity, the next bio components were studied [5]:

1 – zoobenthos; 2 – zooplankton; 3 – grey seal; 4 – ringed seal; 5 – seabirds; 6–9 – main fish species; 10 – phytoplankton.

During the study of the human activity, geo and biodiversity, the next steps of the research were conducted [5]:

– the collecting and digital mapping information about biological, lithological and oceanographic conditions;

– the development of the integral map of the biodiversity;

– the collecting and mapping information about all kind of the human activities;

– the identifying current spatial conflicts and compatibilities between geo and biodiversity and areas of the human activities;

– the projecting current trends in the spatial and temporal needs of existing human activities;

– the identifying possible alternative future human activity for the planning area;

– the selecting the preferred spatial sea use scenario;

– the development of the MS Plan: development of the environmental requirements for necessary constraints of the human activity before an acceptable level.

On the base of the conducted investigations, the pilot Marine spatial plan was developed (see figure). The main area with high level of the biodiversity in the Russian part GoF has been identified near Kurgalskiy peninsula. The all-digital maps were combined in ARC Gis project.

On base using of the spatial data of bio and geodiversity, human activity and climate changing, the environmental restrictions for all kind of the human activity were presented to Ministry for Natural Resources and Environment of Russia for 2015.

At present, for enhancement MSP procedure the Intergovernmental Oceanographic Commission for 2014 was approved the new document: "A Guide to evaluating Marine spatial plans" [1].

In Euro Union, on 2014 the Directive of the European Parliament and of the Council 2014/89/ EU от 23.07.2014 for establishing a framework for maritime spatial planning was accepted. According to this Directive, the EU countries must conduct the consultations with "third countries". So, at present, we have begun this process with colleagues from Finish institute SUKE using our experience for MSP realization in the Russian part of GoF.

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Active coastal population in the process of maritime spatial planning. MSP Business Game as an effective channel of communication and dissemination

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There is currently no concept of Maritime Spatial Planning (MSP) in the normative framework of the Russian Federation. There is also no authorized federal authority (and, naturally, no authorities on all power levels) responsible for marine planning management. Nevertheless, interaction with neighboring countries, primarily the countries of the European Union, has revealed the urgent need for at least minimal level of education of Russian coastal population in this field. The common sea requires us an awareness of common approaches to marine use, thereby necessitating for educational activities in this direction.

Scientific and Research Institute of Maritime Spatial Planning Ermak NorthWest in cooperation with Coalition Clean Baltic (CCB) and World Wildlife Fund (WWF) and with the financial support of SIDA within the framework of the Barents-Baltic Program "Nature and People" develops a methodology and conducts a series of business games on MSP for the different segments of the population. The goal of the game is the participants' awareness of the importance of applying the ecosystem-based approach in planning processes of the marine and coastal area uses and demonstrating the capacity of public organizations and the active population to influence their activities in the planning processes.

To date, five games were held on two playing fields. The Gulf of Finland and the Pechora Sea served as a models for them. Next playing field will be produced for the Kaliningrad region sea area for one of the future games.

All playing fields have their unique characteristics with the regional specificities. The problems under consideration are based on low standards of living of the coastal population and the complex ecological state of the area. Expectations of the local population are pinned with massive investments that should create new jobs, provide the necessary conditions for economic growth and new standards of living. At the same time, involvement of renewable and non-renewable natural resources into active industrial use can be hazardous to ecosystem.

Players are invited to address and evaluate several options for investment proposals. They are divided into three gaming teams – "Red", "Blue" and "Green", each of which has its own target settings. In every team, there are representatives of the administration, population, and main sectors of the economy, environmentalists and other experts.

In addition, there is the team, called “White”. Initially, we planned that it would be people representing the local population, but as the game experience gained and methods of playing improved, the tasks of this team expanded significantly and now it is a full-fledged team of players with their own special functions. Now White team includes not only representatives of the local population, but journalists, investors, representatives of neighboring countries, international and Russian public organizations.

The interests of all teams, players in accordance with the developed script and game motivational cards are organized in such a way that the conflicting interests of different layers of society in the course of the game firstly lead to internal conflicts, and subsequently find their solution in the jointly developed maritime spatial plans.

Upon completion of the plan, each team presents it for general consideration and describe planning decisions. Despite the contradictory nature of the game roles and their motivations, the general message of the game is that all the participants want their lives to become better, and this applies to not only economic conditions, but also living in a healthy and pollution-free environment. The criteria for evaluating marine plans developed by the teams is the best fulfillment of the goals set before them, and each team have its own goals - they are different, thus resulting plans are different too, with the winner selected via voting of all game participants.

According to the experience of the games held, it can be noted, that the events are of great interest to participants of different ages and from different social groups. They actively participate in the simple model of decision-making process, and realize that the voice of every active member of society can be heard and taken into account. Especially active are young people (three of the five games were held in higher and secondary educational institutions), for whom the game is some kind of the insight into the adulthood, which they will enter very soon.

Air temperature extremes in the Baltic region

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Climate change is one of the most important global challenges of the twenty-first century, which goes beyond the scientific problem and represents a complex issue affecting the environmental, economic and social aspects of sustainable development of countries and individual regions.

The main objectives of climate change policy in accordance with the climate doctrine of the Russian Federation are: scientifically based reliability of information on the state of the climate system, anthropogenic impact on the climate, current and future climate changes and their consequences; mitigation of anthropogenic impact on the climate; adaptation to climate change.

Patterns of modern global warming are manifested in uneven changes in air temperature in the Russian part of the Baltic Sea basin and are characterized by significant differences in seasons.

In recent decades, there has been an increase in the variability of meteorological parameters, including air temperature against the background of climate change. Such changes lead to an increase in the number of weather anomalies, which indeed have the negative impacts on the environment, including the ice regime of land and sea, marine and terrestrial biota, as well as on social and economic activities.

The issue of the meteorological regime of a particular region is of great importance for climate research and the impacts of its changes, and for scientific and applied purposes.

The data of 9 meteorological stations of the Leningrad region with different period of meteorological observations have been studied. The air temperature data of the meteorological station of St. Petersburg, as the longest observations, were considered taking into account the influence of the urban heat island.

The increase in air temperature is observed throughout the region, throughout the year, in all seasons and almost all months. The estimates of linear trends in average annual air temperature have reached +2 °C over the past three to four decades. In these last decades, global warming has become most visible against the background of natural intra-century variability.

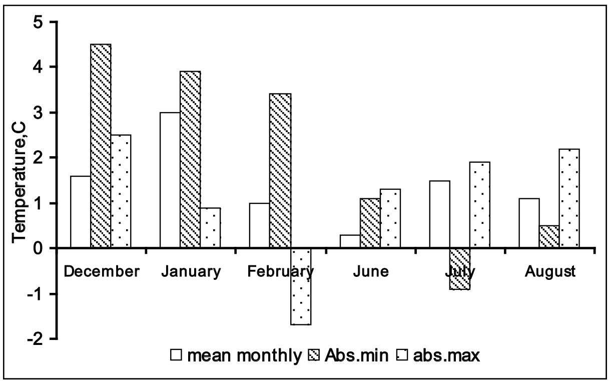
The main contribution to the positive trends in winter air temperature makes two months - January and February, and in spring – March, and April. However, the most noticeable increase in temperature was in the Northern part of the region in January and July (2.5–2.8 °C/35 years). The largest statistically significant positive trends obtained for the summer months.

The change in mean values may have a significant impact on nature and economy, but even more important may have changes in the minimum and maximum values of air temperature. Increasing the maximum temperature in winter increases the frequency and duration of thaws, rains, and floods, as well as the melting of snow and ice. The increase in temperature in summer leads to more frequent droughts and fires.

The anomalies of mean and extreme values of air temperature relative to the climatic norm were calculated. Data for the period 1961–1990 were used as the climate norm, in accordance with the recommendations of the World Meteorological Organization.

The figure shows the anomalies of average monthly and extreme values of air temperature in winter and summer for the meteorological station of Vyborg for the period 1980–2015 relative to the climatic norm. There is an increase in the average monthly air temperature in all months, as well as a decrease in extremely low temperatures in winter and July. This means that in the sense of extremely low temperatures, winters have become warmer, but in July the average of the absolute lows of temperature has decreased from 6.7°C to 5.8°C.

Analysis of individual years showed that since 1961 the coldest winter months were: 1963, 1966, 1968, 1969, 1972, 1985, 1987 since the 1980s, the number of warm winters has increased significant-



The anomalies of average monthly and extreme values of air temperature in winter and summer for the meteorological station of Vyborg for the period 1980–2015 relative to the climatic norm

ly, with the warmest winters: 1981–1984, 1989, 1993, 1994, 1998, 2001, 2005, 2007, 2008. The absolute minimum temperature in winter was reduced compared to the climatic norm at 3–13 °C, and such low temperatures as observed in 1961–1990, the last years was observed. Also, for 2–3 days reduced the period of continuous severe frosts with temperatures below –25 °C. Warming has led to an increase in 3–5 days the number of days with thaw, and warm and growing periods increased by 7–9 days.

If the warming will progress, according to the calculations using climate models for the study area is expected to increase air temperature in winter at 1–2 °C in the Southern areas and 3–4°C in the North region. In summer the temperature will rise by no more than 1–2 °C. Thus, up to 2030–2050, it is expected an increase in air temperature, particularly strong in winter and a bit less in the summer in the Russian part of the Baltic region. Also, the variability of the air temperature, the frequency of occurrence of phenomena such as thaw in winter and spring frosts will increase. In the summer, will increase the fire hazard in the forests. It is possible to increase the annual amount of precipitation and changing the intra-annual distribution of precipitation, and the change in the ratio solid/liquid/mixed types of precipitation.

To avoid the negative effects of climate change in the future, it is necessary to take measures for their mitigation and for adaptation. The measures on adaptation have been proposed for agriculture, construction and transport industries, water resources and forestry in the future on the basis of our studies.

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Geosciences supporting urban flood mitigation

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Urban flood modelling became increasingly topical during the 21st century due to heavy flooding events which have caused a threat to human lives as well as very expensive damages to infrastructure and buildings. The increase of the heavy intensity rainfalls, the new housing development in areas previously covered with permeable ground and old drainage systems have been identified to be the main factors of the increase in stormwater flooding within urban areas.

The Geological Survey of Finland (GTK) has created a simplified GIS-methodology to identify areas prone to urban floods. These problem areas were identified by using data from overall soil infiltration capacity, surface topography, and soil sealing. It is possible to identify the areas prone to urban floods with multiple factors contributing to flooding by reclassifying and combining datasets in ArcGIS. Resulting maps were verified by comparing potential flood-prone areas with known flood occurrences in cities.

Urban flood risk maps are based on an overlay of flood maps (hazards) and land use plans (vulnerability). Land use plans are used to describe vulnerability as an indicator of functionality and safety of the society. The resulting urban flood risk map enables estimating the most suitable areas for building and development, as well as areas that are in need of stormwater control. Such risk maps can also offer support in securing the infrastructure and daily functions of a city in estimating accessibility for rescue services.

Analysis of the risk maps revealed that many areas with a high flood potential were actually designed to be built up. The inadequate land use planning practices comprised also excessive soil sealing where natural conditions would not enhance flooding – thus, artificially creating flood-prone areas. To better manage the urban floods nature-based "green" and "blue" solutions, such as wetlands, , and retention ponds can offer several benefits in preventing and mitigating urban floods. Such flood mitigation can be created by utilizing the natural characteristics of a site. These solutions have often high social acceptance and can be used as non-regret and multi-functional structures (parks, meadows, sports areas). In addition, to mitigate floods, nature-based solutions may improve air quality, support local biodiversity, reduce heat island effects and offer well-being and recreation to local inhabitants. As practice has shown, urban geological applications can strongly support the development of safer, more sustainable and healthier living environments. It would benefit land use planning practices to determine whether the geological environment is favorable for urban development planning.

This work was carried out in the framework of the South-East Finland – Russia ENPI CBC 2007–2013 in the project "CliPLivE – Climate-Proof Living Environment". The project participants included the State Geological Unitary Company "Mineral" (SC Mineral) and two other project partners from St. Petersburg: the A.P. Karpinsky Russian Geological Research Institute (VSEGEI) and the Committee for Nature Use, Environmental Protection and Ecological Safety of the city of St. Petersburg, as well as four partners from Finland: GTK, the Regional Council of Kymenlaakso, Uusimaa Regional Council and Helsinki Region Environmental Services Authority (HSY). The project aimed to recognise the geological and environmental risks in the urban environment on the coast of the Gulf of Finland and has produced preliminary recommendations on how to mitigate the vulnerability of these areas to climate change impacts. The study areas were the city of St. Petersburg, the Kymenlaakso Region, the Uusimaa Region, and the Helsinki Metropolitan Area. In addition, the project enabled the sharing of expertise and experiences on climate change adaptation in Finland and in Russia. Urban floods and their management were identified as one of the major hazards with high significance in urban areas.

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A GIS system for biological monitoring data from the Neva Bay and the Eastern part of the Gulf of Finland and its possible applications

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Consistent biological monitoring of the Neva Bay and the Eastern Gulf of Finland started in 1981 and apart from a few missing years still continues. The data collected during that period includes phytoplankton, zooplankton and zoobenthos samples, photosynthetic pigments such as chlorophyll a, b and c, bacterioplankton and hydrological data with local weather conditions and some other information. The majority of that data has not been digitized until recently and was stored in yearly paper-reports on library shelves.

In 1990s biological data in the Neva Bay was collected irregularly but starting from 2000s and nowadays in 2010s the amount of collected data is increasing each year. Large amounts of data bring forth the problem of building a computer-based information system (IS) to store, manipulate and research that data. Combining together in one database all available biological data of Neva Bay and Russian part of the Gulf of Finland for the last 30 years is important for solving data mining tasks, analysis of human impact and of Neva Bay ecosystem's dynamics.

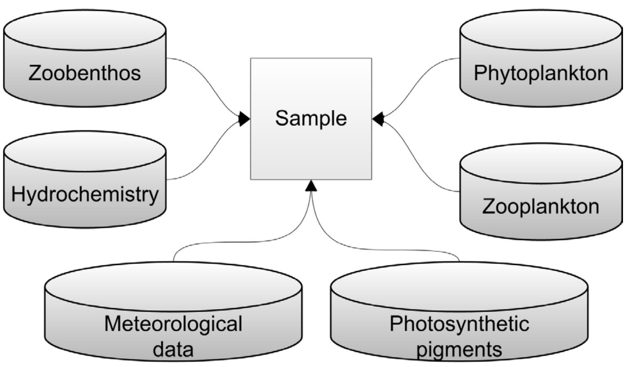
The main goal of this work is to bring all the data sources of biochemical monitoring of the Neva Bay in one place and build a regional geographic information system (GIS). Such a system would implement data analysis algorithms and mathematical models to evaluate and predict ecosystem health, pollution risks, eutrophication, etc. Currently, we have investigated phytoplankton and chlorophyll models only.

Working with time-spatial data is not trivial, so a special database was developed to store information efficiently. A simplified structure of this database is shown on the figure a. The key element is a description of a "sample" such as date, time and exact location where the sample was taken. The results of all biochemical analysis are linked to the corresponding sample information. Available biochemical monitoring data includes:

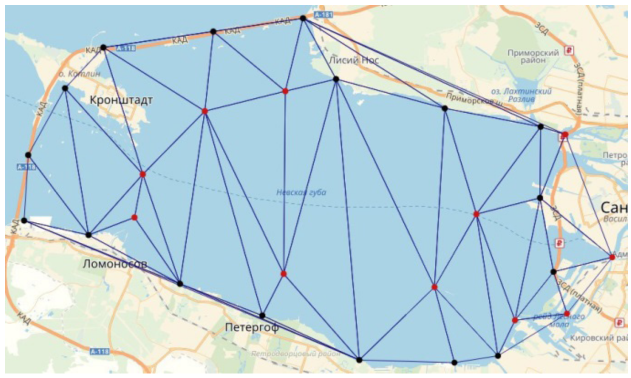
• phytoplankton data such as species, their biomass, and abundance;
• zooplankton data;
• zoobenthos data;
• photosynthetic pigments concentrations (mainly chlorophyll a observations);
• weather conditions and hydrology data;
• hydrochemical characteristics of the water such as dissolved oxygen, concentrations of nitrogen and phosphorus, heavy metal pollution, etc.

Among different cartographic services Yandex. Maps was chosen for visualization of the data. It has a decent Application Programming Interface (API) and allows to easily visualize different types of data on a cartographic basemap. It has an (arguably) more detailed map of Russia than other services such as Google Maps, OpenStreet Maps, etc. Yandex.Maps API provides basic functionality to draw heatmaps, create mark points and even pie charts on the map. It allows to create interactive objects on the map and basically draw anything on top of the basemap using JavaScript programming language. An example of such visualization is shown in figure b.

a



b



Database structure (*a*) and the results of Delaunay triangulation of stations in the Neva Bay visualized with a Yandex. Maps cartographic service (*b*)

The designed web-based GIS provides several interfaces to access and manipulate the monitoring data. For example, the photosynthetic pigments data can be accessed with the following tools:

• visual query builder for selecting an area of interest, which is based on the Yandex.Maps cartography service with selectable monitoring stations displayed in a separate clickable layer on top of the basemap;

• heatmap data visualization tool, which can be used to create a colored layer on top of the Neva Bay and Eastern Gulf of Finland basemap. Color intensity is correlated with one of the monitored parameters (e.g. chlorophyll a concentration) and also depends on the distance from the observation point;

• report generation tool which is a RESTful web-service that can be used to extract data either in Excel table format to be used by a researcher or in JSON format to be used by other web applications.

Remote sensing techniques can be used to monitor some water quality parameters from space, i.e., suspended sediments (turbidity), chlorophyll concentration, salinity, water temperature, and some other parameters and indexes. A web-based GIS can be easily set up to display such remotely sensed monitoring data [1].

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Research programme
“Macrophyte thicket ecosystems in the Eastern Gulf of Finland”

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Research programme “Macrophyte thicket ecosystems in the Eastern Gulf of Finland” was developed and is carried out by the St. Petersburg company “Eco-Express-Service” LLC. Beginning in 2016, spatiotemporal dynamics of macrophyte thicket ecosystems in case of hydro-construction and its consequences are studied in Neva Bay and adjacent Eastern Gulf of Finland.

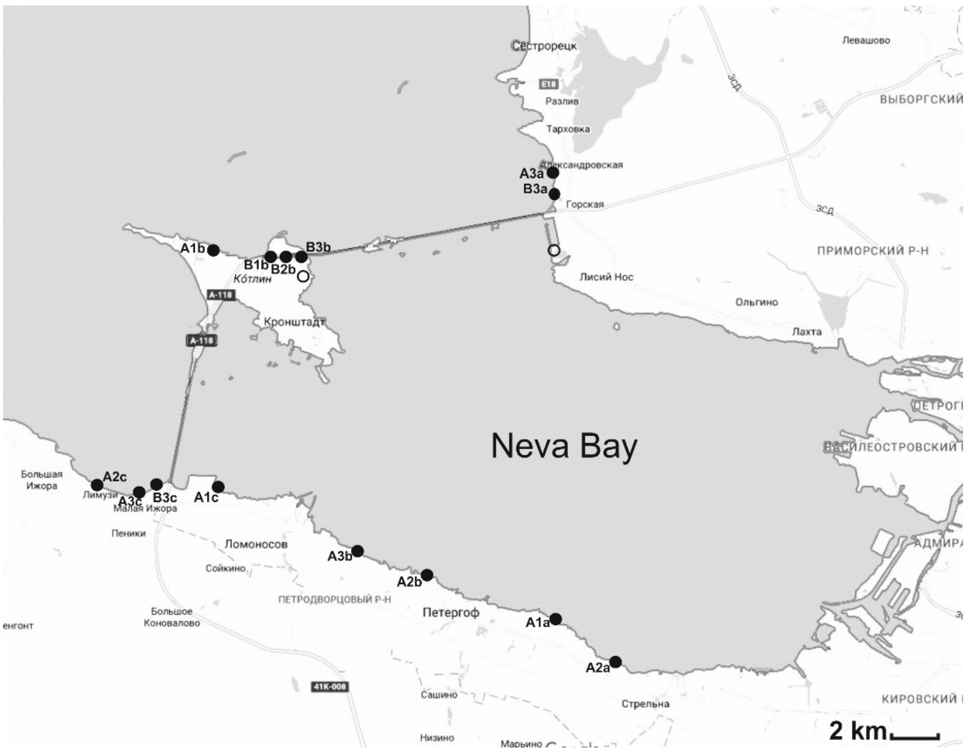
The technogenic influence on thicket ecosystems of various age is studied separately. The age of thickets includes 3 gradations: “old” thickets which existed before the Saint Petersburg Flood Prevention Facility Complex (FPFC) construction; “middle-aged” which has been formed during its construction; “new” that has appeared after FPFC construction.

Impact level of hydraulic works and their consequences on thicket ecosystems is also divided into three gradations: “strong” impact is in the zone of direct works or their recent consequences impact; “moderate (indirect)” and “background” are in case of absence of significant technogenic water and soil changes.

A system of macrophyte thicket ecosystems model parcels was created (parcel area is about 1 km2). It reflects all real combinations of thicket age and hydraulic works impact level gradations. Such combinations are distinguished in two variants:

– firstly, far from FPFC (all 9 possible combinations of vegetation age and technogenic impact gradations were found);

– secondly, near FPFC (only 5 combinations of 9 are realized).



Location of the 14 system model parcels (dark circles) and 2 non-system sites with the highest biodiversity (unfilled circles)

Model parcels are marked with a triple code:

– a capital letter A or B means "far from FPFC" or "near FPFC", respectively;

– a figure 1, 2 or 3 reflects the thickets age: "old", "middle-aged" or "new", respectively;

– a lowercase letter a, b or c characterizes the technogenic impact level: "strong", "moderate" or "background", respectively.

For example, the model parcel with the A2c index is far from FPFC and represents middle-aged thickets at the strong impact of hydraulic works.

Besides, there are two additional (non-system) sites in macrophyte thickets with the highest identified biodiversity.

The figure shows the location of all model parcels.

Thus, 16 model parcels, representing the main combinations of thicket ecosystems age and effect level, are observed.

Comprehensive comparative quantitative assessment of macrophyte thicket ecosystems of different ages in the Eastern Gulf of Finland in the gradient of hydraulic works is carried out for the first time.

Annual comprehensive studies at model parcels include the following: aerial survey and mapping of aquatic communities (more than 35 km2); phytocenological studies; water, soil, phytoplankton, zooplankton and zoobenthos sampling and analysis at 28 stations tri-annual; observations of aquatic and semi-aquatic birds at spring and autumn migration and nesting; studying of phytophilous fish species spawning, breeding and fattening.

At this moment, the majority of the collected materials undergo various stages of processing. Some preliminary results are as follows.

Macrophyte thickets, which has been existed before the FPFC construction ("old"), have a clearly expressed zonal distribution. Usually, they are formed by unistratal and pluristratal groups of macrophytes with a predominance of 2–3 layers. These thickets in many cases are dense and stable. The possibilities for their further expansion are exhausted. The projective cover degree of the water surface by vegetation in "old" thickets far from FPFC is 39–41 %, near FPFC it reaches 66 %. The additional cover degree of the bottom by submerged vegetation far from FPFC is 3–11 %, near FPFC – up to 23 %.

Macrophyte thickets, which has been formed during the FPFC construction ("middle-aged"), are long-term balanced and replaceable communities of macrophytes with a predominance of simple 1–2-layers groups. Usually, these are less dense thickets, they continue to gradually expand and thicken. The projective cover degree of the water surface by vegetation in "middle-aged" thickets, respectively, is less: far from FPFC is 14–35 %, near FPFC up to 40 %. The additional cover degree of the bottom by submerged vegetation far from FPFC is 2–7 %, near FPFC – up to 43 %.

It is characteristic that thickets with the highest identified biodiversity turned out to be "middle-aged" (both non-system model parcels). The projective cover degree of the water surface by vegetation at these sites is 14–49 %, the additional cover degree of the bottom by submerged vegetation is 1–12 %.

Macrophyte thickets, which has been formed after the FPFC construction, in the last 10 years ("new"), are long-term pioneer communities of macrophyte thickets with a predominance of simple 1-layer groups. So far, they occupy a small percent of the biotopes and actively expand. The projective cover degree of the water surface by vegetation in "new" thickets is minimum: far from FPFC it varies from 2 to 12 %, near FPFC up to 20 %. The additional cover degree of the bottom by submerged vegetation far from FPFC is 0–10 %, however, near FPFC in some places it reaches 23 %.

Thus, the projective cover degree of the water surface by vegetation is quite directly related to the thickets age and the proximity to FPFC.

The Neva Bay of the Gulf of Finland is an extremely important place of migratory aquatic and semi-aquatic birds' concentration in the North-West of Russia in the spring. Significant clusters of migrants were observed at all model parcels in "old" and "middle-aged" thickets. The "old" and "middle-aged" thickets during the nesting period also have the highest "ornithological value". "New" thickets are minimum used for nesting.

In general, for the whole observation period, during the periods of spring migration within the boundaries of model parcels:

– the maximum number of bird species in migration clusters outside the technogenic impact in the "old" thickets is 11, in the "middle-aged" – 10, in the "new" – 8 (in zones of "strong" impact numbers are 8, 7 and 7, respectively);

– the maximum number of birds outside the technogenic impact in the "old" thickets is 330 specimens, in the "middle-aged" – 410, in the "new" – 15 (in zones of "strong" impact numbers are 115, 180 and 11, respectively).

At the same time, the maximum number of species reaches 13 and the number of birds is 405 at the water area of non-system sites with the highest biodiversity ("middle-aged" thickets). It should be also mentioned that successful nesting of Cygnus olor was noted in the Neva Bay for the first time.

Thus, during spring migrations and nesting birds sometimes prefer "middle-aged" thickets but not "old" as its' lower density and presence of open space allow birds to freely maneuver and feed.

Autumn stopovers of wetland birds in the Neva Bay seemed to be expressed much worse than spring. The total number of birds in the Neva Bay during the autumn migration 2016-2017 doesn't exceed 4-5 thousand individuals.

It is obvious that FPFC and its economic activity do not have a negative impact on the birds' distribution. Moreover, the FPFC construction has provided new biotopes for migratory and nesting sites to birds.

"Old" and "middle-aged" thickets were found to be the most attractive for the spawning of phytophilous fishes. They are characterized by the greater accessibility of the internal part of the plant massif, have the biggest spawning surface and are quite effective shelters for juveniles. The peripheral zone is used more actively for spawning in denser "old" thickets. "New" spaced thickets are mostly used for breeding of juveniles.

The most productive spawning areas have been identified and studied at Strelna, Znamenka, Bronka, Limuzi, Gorskaya, and Kotlin Island. Some regularities in the distribution of spawning and juveniles breeding characteristics of different phytophilous fishes' species have been determined in the thickets of different age, structure, and level of anthropogenic impact. These regularities are quite species-specific and can't be considered by way of this report. Studying of the dependence of spawning indicators on soil types and projective cover degree of the water surface by vegetation are also carried out as part of the programme.

In general, thickets, which have appeared during FPFC construction, are not behind the older thickets in the most important environmental properties and, in some cases, they even prevail. The environmental role of younger thickets, that formed after the completion of FPFC, is still less significant, but they have a good potential.

The following results of the research programme implementation are expected:

1. Established and regularly updated database on hydraulical, hydrochemical, phytocenological, hydrobiological, ichthyological and ornithological parameters of macrophyte thicket ecosystems in Neva Bay and adjacent Eastern Gulf of Finland;
2. Proposals on the improvement of technical and methodological documents on environmental impact assessment of hydraulic works on macrophyte thicket ecosystems of Neva Bay and adjacent Eastern Gulf of Finland, and estimation of environmental damage of such works considering the background dynamics;
3. Developed methods of quantitative evaluation of compulsory compensation payments for negative technogenic impact on macrophyte thicket ecosystems. Materials for including corresponding methods and clauses in environmental legislation;
4. The established system of environmental monitoring of model parcels of macrophyte thicket ecosystems in Neva Bay and adjacent Eastern Gulf of Finland.

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