Arctic EcoSens_2021

Russian-Norwegian Bilateral Cooperation Project

20-21 April 2021

ECOSENS_2021 MEETING PROGRAM

20 April 2021. Tuesday
Time Moscow (Tromsø)

10:00 (09:00)	Welcome, introduction, overview **Chair Paul Renaud**
10:10 (09:10)	**Vassily Radeshevsky** "New advances in spionid polychaete systematics #1"
10:25 (09:25)	**Andrej Sikorski** "New advances in spionid polychaete systematics #2P
10:30 (09:30)	**Geir Morten Skeie** "Marine oil spills and coastal sensitivity - assessing ecological risk and impact as a basis for oil spill response"
11:00 (10:00)	Questions and discussions
11:15 (10:15)	**Cassanadra Granlund** "Developmental effects of embryonic exposure to a water-soluble fraction of crude oil on early life stages of capelin (*Mallotus villosus*)"
12:00 (11:00)	**Marianne Frantzen** "Capelin versus Polar cod – a generic 'oil pollution risk assessment'"
12:45 (11:45)	Questions and discussions
13:00 (12:00)	**Sabine Cochrane** "Benthic macrofauna along the coast of northern Norway – do we understand it and is there such a thing as typical?"
13:30 (12:30)	**Ida Danielsen** "Communication of scientific results to Russian and Norwegian enviropnmental authorities"
13:40 (12:40)	Questions, discussions and the first day closing words.

21 April 2021. Wednesday
Time Moscow (Tromsø)

10:00 (9:00)	Session opening, participants connecting and greetings. **Chair Marina Varfolomeeva**
10:05 (09:05)	**Andrei Granovitch / Arina Maltseva** “Overview of the 3-years activities of the EcoSens Russian team”, 15 min.
10:20 (09:20)	**Anna Kursheva & Inna Morgunova** “Organic geochemistry of bottom sediments and soils of different littoral zones of the Barents Sea coast: natural background and anthropogenic pollution assessment”, 25 min.
10:50 (09:50)	**Liudmila Sergienko** “Plant and algal consortia of the Barents Sea coastal zone under anthropogenic burdens”, 20 min.
11:15 (10:15)	**Elena Golikova** “Foraminifera as a prospective tool to assess the ecological quality status of the Arctic salt marshes”, 20 min.
11:40 (10:40)	**Egor Repkin** “Host-parasites systems under pollution”, 5 min.
11:50 (10:50)	**Arina Maltseva** “Living near humans: anthropogenic impacts on *Littorinas* at the individual and populational levels”, 25 min.
12:20 (11:20)	**Polina Pavlova** “*Littorina*, its parasites and pollution: a transcriptomic analysis”, 5 min.
12:30 (11:30)	**Lisa Gafarova** “Microbiomes of the Arctic intertidal: promises and perspectives for ecological monitoring”, 5 min
12:40 (11:40)	**Sergei Korsun** “Intertidal foraminifera, their microbiome, and the prospect of bio-monitoring”, 10 min.
13:00 (12:00)	Final discussions on ‘how do we continue our collaboration’ and closing words.

ABSTRACTS *in order of the performance*

Vasily I. Radashevsky

New advances in spionid polychaete systematics

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Biological studies in European shallow waters have a long and pioneering history, resulting in a perception that the marine biodiversity in much of Europe has been sufficiently documented. Polar, deep-water and pure molecular investigations became fashionable, while studies on the systematics of shallow-water organisms came to be considered unnecessary if not outdated and have thus declined greatly in recent decades. However, many "good old" European species of polychaetes were originally minimally described without depositing type material, may have failed to mention morphological features now considered critical for identification, and were never re-described later. The result is often incorrect, confused, and opaque concepts of the identity and systematics of even common species. Not surprisingly, this lead in turn, for more than a century, to many species also being considered "cosmopolitan."

Spionids are among the most common polychaetous annelids around the world (Blake *et al.* 2020). Over 80 species have been reported from European shallow waters (Radashevsky 2012). Closer examination has resulted in the sobering discovery that there are unsolved problems with the identity of almost every species.

The examination of rich polychaete material provided by the MAREANO project and also accumulated in the Akvaplan-niva collection, and analysis of publications on polychaetes from the north European waters showed incorrect identification of several common species widely distributed in Norwegian waters. Among others, these included *Pseudopolydora paucibranchiata*, which was originally described from the Sea of Japan, Japan; *Dipolydora caulleryi*, which was originally described from northern coast of France; *Spio decorata*, which was originally described from the Black Sea, Russia; and *Malacoceros fuliginosus*, *Spiophanes bombyx*, *Pseudopolydora antennata* and *Pseudopolydora pulchra* which were originally described from the Tyrrhenian Sea, Italy. A complex of *Dipolydora* species, occurring in almost every sample from soft sediments, was discovered. Adults of these species showed overlapping variability and conventionally were referred to as *Dipolydora coeca* complex.

Detailed morphological examination (especially live individuals collected north to Tromsø) of the Norwegian specimens traditionally identified as *Pseudopolydora paucibranchiata* showed that they were different from what I know very well from the Sea of Japan. Molecular comparison of specimens from the two regions confirmed that they were not conspecific. Consequently, the Norwegian *Pseudopolydora* was described as a new species, *P. nordica* Radashevsky, 2021. This species is very abundant throughout northern Europe and all along the Norwegian coast, from the depth of 0.5 to 337 m.

Analysis of records of *Pseudopolydora antennata*, *Pseudopolydora pulchra* and *Spiophanes bombyx* from Norwegian waters discovered some differences between them and corresponding worms from the type locality in Italy. Their conspecificity should be verified in a future study.

Preliminary analysis of the morphological and genetic characteristics of Norwegian specimens traditionally identified as *Spio decorata* showed that they are not conspecific with worms collected myself from the type locality in Sevastopol, Black Sea. The revision of the Norwegian *Spio* species is in progress.

Moreover, in the Sea of Japan, for many years we identify one of the most common worms as *Laonice cirrata*, which is native to Norwegian waters (was originally described from Norway). Molecular analysis of the Norwegian and Russian specimens showed a situation reciprocal to Pseudopolydora case: worms from the Sea of Japan were misidentified as a Norwegian species, but actually belong to a new, yet undescribed species.

The results of my study in collaboration with Dr. Andrey Sikorski and other colleagues from Akvaplan-niva demonstrate that morphological and molecular data must complement each other, and that, in contrast to common perceptions, much remains to be learned about the biological diversity in Norwegian waters.

The following papers resulted from the joint Norwegian-Russian research project:

Radashevsky, V.I., Malyar, V.V., Pankova, V.V., Gambi, M.C., Giangrande, A., Keppel, E., Nygren, A., Al-Kandari, M. & Carlton, J.T. (2020a) Disentangling invasions in the sea: molecular analysis of a global polychaete species complex (Annelida: Spionidae: *Pseudopolydora paucibranchiata*). *Biological Invasions, 22* (12), 3621–3644. https://doi.org/10.1007/s10530-020-02346-x

Radashevsky, V.I., Pankova, V.V., Malyar, V.V., Neretina, T.V., Choi, J.-W., Yum, S. & Houbin, C. (2020b) Molecular analysis of *Spiophanes bombyx* complex (Annelida: Spionidae) with description of a new species. *PLoS One, 15* (7), (1–54) e0234238. https://doi.org/10.1371/journal.pone.0234238

Radashevsky, V.I. (2021) *Pseudopolydora* (Annelida: Spionidae) from European and adjacent waters with a key to identification and description of a new species. *Marine Biodiversity, 51* (2), 1–23 (31). https://doi.org/10.1007/s12526-020-01156-7

Geir Morten Skeie

Marine oil spills and coastal sensitivity - assessing ecological risk and impact as a basis for oil spill response

Akvaplan-niva AS, Fram Centre, 9296 Tromsø, Norway

The Arctic parts of Norway and Northwest Russia have to a large extent comparable habitats and wildlife, with their inherent sensitivity and vulnerability to acute oil pollution. In the scientific literature, there is a wealth of information on effects of oil on organisms and biota. There are also national and international standards for sensitivity maps to be applied in strategic, tactical and operational level, mainly reflected in scale.

What has been lacking is linking this information to operational opportunities and limitations of oil spill response, and the geographical areas most important for different groups of biological organisms. Akvaplan-niva has been working with national and regional response organisations to develop a systematic approach to these issues, with Spill Impact Mitigation Assessment as a background.

Further, we will present a possible way to identify areas of total potential risk taking into account presence and densities of several ecosystem components.

Cassandra Granlund, Jasmine Nahrgang, Morgan Lizabeth Bender, Juliette Lavarec, Lisbet Sørensen, Michael Greenacre, Marianne Frantzen

Developmental effects of embryonic exposure to a water-soluble fraction of crude oil on early life stages of capelin (*Mallotus villosus*)

Akvaplan-niva AS, Fram Centre, 9296 Tromsø, Norway

Department of Arctic and Marine Biology, The Arctic University of Norway

The rise in offshore oil and gas operations, maritime shipping and tourism in northern latitudes enhance the risk of petroleum pollution and impacts of oil-related compounds on sub-Arctic and Arctic organisms. There is a need to investigate the potential adverse effects of petroleum to the early life stages of capelin (*Mallotus villosus*), an ecologically and commercially important forage fish species that spawns along the coast of Northern Norway. Newly fertilized capelin embryos were exposed to a water-soluble fraction (WSF) of crude oil using oiled gravel columns loaded with either clean gravel (control) or gravel mixed with one of five crude oil concentrations ranging between 0.19 and 6 g oil/kg gravel (low to extra high groups). Embryos were exposed to decreasing crude oil WSF until hatch (25 days post fertilization) and larvae were followed in clean water until 58 days post fertilization. The initial aqueous total polycyclic aromatic hydrocarbon (PAHs) levels (sum of 44 PAHs) were ranging from 0.072 to 19.25 µg/L in the five treatment groups and decreased exponentially over time. None of the measured endpoints regarding embryo development and mortality, larval length, growth rate, cardiac activity, arrhythmia, and larval mortality showed any dose-dependent effects. Our results suggest that the early life stages of capelin are more robust to crude oil exposure than similar life stages of other fish species. The capelins demersal eggs properties, primarily the double-layered chorion, was hypothesized to be a possible explanation for this trend, however, accumulated PAH concentrations in capelin eggs did not confirm this hypothesis.

Marianne Frantzen, Jasmine Nahrgang, Morgan Bender, Cassandra Granlund et al.

Capelin versus Polar cod – a generic "oil pollution risk assessment"

Akvaplan-niva AS, Fram Centre, 9296 Tromsø, Norway

Department of Arctic and Marine Biology, The Arctic University of Norway

Capelin (*Mallotus villosus*) and polar cod (*Boreogadus saida*) are both key species in the Barents Sea ecosystem, representing major food sources for several predators in the ecosystem, including cod (*Gadus morhua*), marine mammals, and sea birds. In this presentation we will compare the sensitivity of the early life stages of these two species to oil pollution, and discuss potential risks based on published literature of their life cycle and ecology.

Cochrane, S.K.J., Blanchet, H., Palerud, R., Ramasco, V., Greenacre, M., Renaud, P.

Benthic fauna along the coast of northern Norway – is there such a thing as typical?

Akvaplan-niva AS, Fram Centre, 9296 Tromsø, Norway

Department of Pharmacy, The Arctic University of Norway

Norway has one of the world's longest coastlines, and marine substrates span the entire range from bare rock, gravel and pebbles, shellsand/mærl to sands, muds and clay. The Norwegian continental shelf generally has a depth of between 100 and 400 m, but typically is around 200 m (Norwegian Geological Survey). The continental shelf break occurs close to land in the Lofoten-Vesterålen area in Northern Norway (Figure 1), and some coastal fjords and sounds can have depths of over 500 m. Most fjords in Norway have one or more sills, with basins on either side, but those in very northern and north-facing areas tend to lack sills and be directly exposed to the open sea.

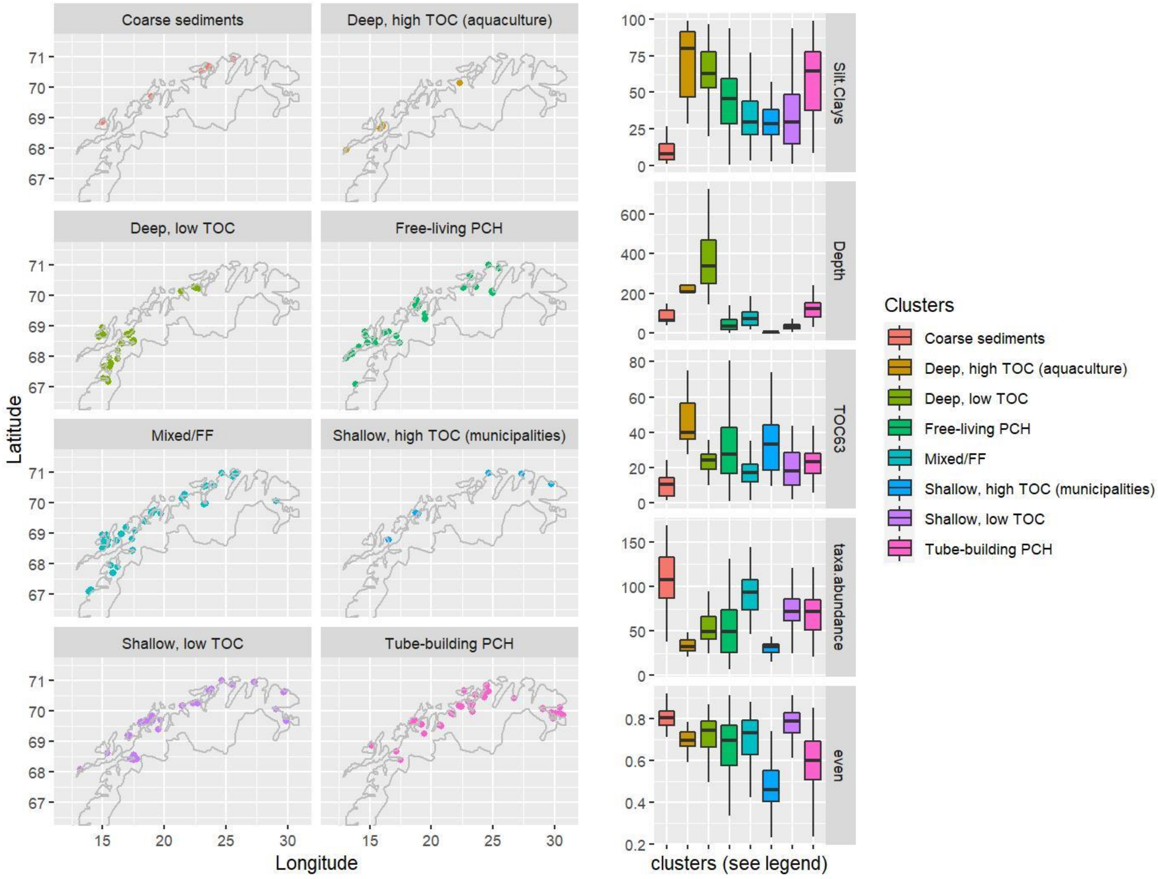

Figure 1. Eight station groups, clustered in terms of faunal similarity and related to sediment/functional characteristics.

Because of the high substrate heterogeneity, the benthic faunal communities also are highly diverse. We analysed benthic infauna from around 150 stations along the coast of northern Norway, to assess whether there exist "typical" assemblages and, if so, what characterizes them. Only very few species were present at all stations, and we identified eight main groups of faunal communities (Figure 1). Most communities were spread across the sampling area and largely corresponded to sediment qualities and depth, but stations near human settlements and aquaculture plants had some typical shared faunal characteristics.

Shallow stations (< 50 m) with coarse sediments typically were dominated by brittle stars and robust-shelled molluscs, whereas deep stations (< 200 m) supported communities of burrowing polychaetes and molluscs. Mixed and course sediments tended to support filter-feeders and free-living organisms, whereas tube-building polychaetes were notably dominant in finer, stable sediments. The high functional and taxonomic diversity of benthic fauna would suggest a high general resilience to disturbance – the communities generally contain rapidly-reproducing species amenable to re-colonisation. However, changes in sediment composition likely will cause changes in faunal composition.

Ida Kristin Danielsen

Communication of scientific results to Russian and Norwegian environmental authorities

Norwegian Polar Institute, Framsenteret NO-9296 Tromsø, Norway

End-user outreach for the Arctic EcoSens project was envisioned to focus on tight collaboration with the Joint Russian Norwegian Environmental Commission, and specifically through its OCEAN 3 project for integration of scientific data into environmental management programs. This worked well and established good trust during the earlier EMAP project. Reorganization of the Russian structure has left OCEAN 3 without Russian leadership for much of the EcoSens project, severely limiting our ability to use this venue. Two other OCEAN projects were identified as potential outlets where our input may be valuable, but Corona has prevented any useful interaction. These challenge and potential solutions will be discussed.

Kursheva Anna and Morgunova Inna

Organic geochemistry of bottom sediments and soils of different littoral zones of the Barents Sea coast: natural background and anthropogenic pollution assessment

Academician I.S. Gramberg All-Russian Scientific Research Institute for Geology and Mineral Resources of the Ocean" FSBI "VNIIOkeangeologia", St.-Petersburg, Russia

Arctic nearshore habitats are the most likely recipients of point sources of hydrocarbon (HC) contamination. The major human impact in the Arctic is associated with the urbanized territories (cities, ports, oil terminals etc.) located in the inner part of bays and fjords where the contaminants accumulate entering the environment both from the sea and from land. Additional risk of the Barents Sea intertidal zones pollution is associated today with the construction of the coastal infrastructure of the new oil and gas complex (Patin, 2017). In this context, the use of the detailed organic-geochemical approach for the study of sediments and soils of salt marshes, muddy sand coasts and rocky shores of the Barents Sea littoral zones is a new step in ecological monitoring of the Arctic.

The samples for the study were collected along the subtidal-intertidal-supratidal transects from the littoral zones of the Russian and Norwegian part of the Barents Sea during the scientific expeditions in 2018, 2019 and 2020 (RFBR № 18-54-20001, 2018 – 2020; NFR #280724, 2018 – 2020). The analytical procedure includes determination of natural and anthropogenic components of HCs in the environment, their group (oils, resins, asphaltenes, humic acids) and molecular (n-alkanes, isoprenoids, steranes, hopanes, polycyclic aromatic hydrocarbons - PAHs) composition.

PAHs are traditionally the most important molecular markers commonly used as indicators of petroleum HCs in sediments and soils, and include hazardous and toxic compounds from liquid and solid fuels and their combustion products (Dahle *et al.*, 2006; AMAP, 2010; Morgunova *et al.*, 2019). During the project we studied the expanded list of the traditional 16 US EPA PAHs (EPA, 1984) to understand the influence of the other parent and alkylated PAHs, whose toxicity was not previously taken into account, on the state of the environment.

The assessment of the toxic input of individual PAHs has been made using the toxicity equivalency factor (TEQ). This factor is more correct and important for assessing damage to biota than traditional PAH indices (total PAHs, PAH sources *etc.*).

Thus, the complex organic-geochemical study of the littoral sediments and soils including determination of the detailed composition of the hydrocarbon molecular markers allowed us to make an assessment of the natural background and the level of anthropogenic pollution in the region. Using these data, the organic-geochemical passport of the intertidal zone of the Barents Sea coast has been prepared.

Acknowledgements

We would like to thank Andrey Granovich, Arina Maltseva, Elena Golikova and St.-Petersburg State University for the support in organizing the expeditions. We also express our special gratitude to Paul E. Renaud and Akvaplan Niva for assistance during the fieldwork and results publishing.

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Patin S.A. Oil and continental shelf ecology: in two volumes. 2nd edition revised and extended. V. 1: offshore oil and gas industry: present situation, prospects, factors of impact. M: VNIRO publishing, 2017. 326 p.; color illus. I–XVI p. ISBN 978-5-85382-438-6.

Liudmila Sergienko

Flora and vegetation of the coastal zone of the Barents Sea under anthropogenic impact

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The state of the Arctic coastal ecosystems reflects to the global dynamic processes associated with both climate changes and the consequences of local anthropogenic impacts. The studies were conducted both at the species and biocoenoses levels. Sea plantain was chosen for a more detailed consideration of the plant's response to anthropogenic pollution and, due to its broad morphological plasticity – was considered in a broad sense (*Plantago maritima* L. s. l.)

Studies of coastal plant communities were conducted in the summer periods of 2018-2019 years around the city of Tromsø: 1-Oil terminal (water, coast); 3-Kvaløysletta; 4 - SW Tromsø beach and on the southern shore of the Varanger Peninsula, Finnmark province, Norway, in the vicinity of Vadse - Smalfjord (intermediate branch of the Tanafjord); Austertana (eastern branch of the Tanafjord); Varangerfjord; Mishukovo (Kola Bay); Kulonga (Kola Bay).

On the tidal zones of sea coasts (in the direction from the sea coastline to the plane coasts), model territories (MT) were laid within the natural boundaries of the coastal phytocoenoses. The species composition, the total projective cover and the cover of all vascular plant species (in %), were determined on all MT. The main types of habitats that are buffer systems for the deposition of anthropogenic pollutants on the Barents Sea coast are: saline flat complex marshes on silty primary drainage, middle salt - marshes on structured muddy substrate (peat deposit)-at a higher position from the low water line, brackish low and middle marshes in estuaries, fjords, lagoons bays, and high salt-marshes on beaches, bars and spits. Arctic circumpolar halophytic species of sedges and grasses (*Puccinellia phryganodes*, *Agrosrtis straminea*, *Calamagrostis deschampsioides*, *Carex subspathacea*) dominate on all coastal habitats with turf. *Plantago maritima* s. l. with varying degrees of abundance was noted for all study points. On the Murmansk coast, in more humid places, there are moss curtains of *Brium* sp. closer to the high plane shore, a community with Cochlearia officinalis is found on the sand-and-pebble substrate. Individuals are quite large, have the powerful habitus.

On the example of *Plantago maritima*, certain indicators of the anatomical structure of the leaf were selected that can be measured and calculated in the field: the thickness of the leaf, the length and width of the epidermal cells, the length, width and volume of the cells of the palisade parenchyma, the length, width and volume of the cells of the water-retaining parenchyma, the length, width, area and number of stomata.

The thickness of the leaves is bigger in the sample areas in the Tromsø than in the Vadsø region. According to the study, the greatest leaf thickness was observed in *P. maritima*, which grows on "Smalfjord (shore)" in "conditionally clean" conditions. A slight decrease in leaf thickness was observed in plants on "Varangerfjord".

The leaf epidermis cell size of *Plantago maritima* also is bigger in the Tromsø region. The leaves of *P. maritima*, which grows on " Austertana ", are characterized by the smallest cells of the upper and lower epidermis, palisade parenchyma and water-retaining parenchyma.

The size and volume of the cells of the palisade mesophyll of the leaves of plants in all model territories varies slightly. At the same time, in cleaner conditions – "Austertana" and "Smalfjord" – *P. maritima* leaves showed a decrease in the width and length of the cells of the palisade parenchyma and an increase in the length and width of the cells of the water-saving parenchyma, respectively.

Stomata in *P. maritima* are located on both sides of the leaf blade; on the upper side their number is greater. In plants in all model territories, the number of stomata on the upper and lower sides of the leaf varies very little. Thus, it is established that the number of stomata and their area in the leaves of the indicator species *P. maritima* can use as a sensitive indicator of anthropogenic influence on the coastal wetlands on the shores of the Barents Sea.

The length of the cells of the upper leaf epidermis (increase in size), the volume of cells of the palisade and water-retaining leaf parenchyma (increase in size) can use like the biological indicators for the man impact influence. In contrary – the thickness of the leaf and the size characteristics of the stomata of the leaf show the stability of their characteristics under the different environmental conditions.

Also, at some test sites, the content of heavy metals in plants of sea plantain (*P. maritima*) and spoon grass (*Cochlearia officinalis*), as well as in the littoral soil of the plant root zone, was studied. It was revealed that the plants of the sea plantain on the Murmansk coast of Kulonga actively accumulate mainly in the roots of plants, metals such as Pb -5622; Ni-7969, Cr-40544, Ti-24129 mg/100 g on absolute dry soil), which is several times higher than the phone parameters. The obtained data indicate that the littoral soils of the coastal territories of the Barents Sea are sandy or stony-sandy, medium-saline, poor in organic matter, the manganese, zinc, nickel, titan, *etc*., and contain the background amounts of iron and copper, that is, they are not contaminated with heavy metals. On the Murmansk coast, the coastal soils are contaminated with manganese, zinc, and titan and their background values are in several times higher (Titov, Talanova, and Kaznina, 2011).

References:

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Elena Golikova, Marina Varfolomeeva, Liudmila Sergienko, Anna Kursheva, Inna Morgunova, Sergei Korsun

Foraminifera as a prospective tool to assess the ecological quality status of the Arctic salt marshes

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Coastal salt marshes are coastal wetlands that develop as vegetated areas in the upper intertidal zone in temperate and high latitudes. Towards the Pole, they become less diverse and have scattered distribution along the coast. Nevertheless, in high latitudes, salt marshes remain a vital element of the coastal ecosystem as breeding and food sites for many migratory waterfowl, nursery ground for fishes, *etc*. Due to their coastal location, salt marshes are very susceptible to various anthropogenic impacts, especially those associated with oil exploration and transportation. Their location puts them at risk as the petroleum industry develops at high latitudes.

At low latitudes, salt marsh foraminifera have been well scrutinised and proved themselves as a promising tool for environmental monitoring associated with oil pollution (Sabean *et al*., 2009; Brunner *et al*., 2013). At high latitudes, foraminiferal assemblage composition, structure, and response to the pollution remain unknown. In this study, we described for the first time, assemblages of salt marsh foraminifera from the Barents Sea coast and attempted to evaluate their potential as a tool for environmental monitoring at high latitudes.

In 2019-2020, we collected samples at the seven salt marshes stretched along the 700 km of the Norwegian and the Russian Barents Sea coasts. The following locations are listed in west-to-east direction: Smalfjord (intermediate branch of the Tanafjord; 70°25.430′ N, 28°02.453′ E), Austertana (eastern branch of the Tanafjord; 70°27.004′ N, 28°30.743′ E), Varangerfjord (70°10.332′ N, 28°33.824′ E), Mishukovo (Kola Bay, 69°02.484′ N, 33°01.643′ E), Kulonga (Kola Bay, 69°04.588′ N, 33°07.516′ E), Yarnyshnaya Inlet (69°05.056′ N, 36°02.516′ E), Porchnikha Inlet (69°04.683′ N, 36°14.883′ E). We assessed the density of living foraminifera, proportion of deformed tests, vascular plants composition, environmental parameters (pH, temperature, salinity) along the transect of 4-5 stations (three replicates, 10 cm3, top 0-1 cm of sediment). The concentrations of polyaromatic hydrocarbons (PAH) were determined from the closest sample from the same zone along the parallel transect (two samples on the tidal flat and one on the vegetated marsh). We calculated the total PAH concentration and the toxicity equivalency factor (TEQ) based on all determined PAHs. In addition, we determined the concentration of 13 of the 16 high priority pollutants (PAH13 of PAH16 determined by the US EPA, 1984) because the measurement of the three low molecular weight compounds (naphthalene, acenaphthene and acenaphthylene) was not compatible with the PAH extraction method used.

The number of foraminiferal species varied from 3 to 7 per salt marsh; not all species were found live (2-5 species per salt marsh). In total, ten species of foraminifera were encountered. Mean living densities of foraminifera were generally low (7-67 ind./10cm^3). Max living density of individuals per salt marsh was 20-313 ind./10 cm^3 which is much lower than in the subarctic White Sea (74-3040 ind./10cm^3) (Golikova *et al*., 2020) but twice as high as in other subarctic salt marshes (Scott, Martini, 1982; Lübbers, Schönfeld, 2018). Foraminiferal assemblages of salt marsh and tidal flats are dominated by a single species (monospecific). The vegetated marsh was dominated by *Jadammina macrescens*, *Balticammina pseudomacrescens* or *Ovammina opaca*; the unvegetated tidal flat was dominated by *Elphidium albiumbilicatum*, *Ovammina opaca*, *Aubignyna sp*., and rarely *Elphidium clavatum*; *Elphidium williamsoni* was less abundant; *Miliammina fusca* was extremely rare. Such monospecific communities are common in stressed environments such as intertidal zone, especially in high-latitude climate (Hayward, 2014; Kemp *et al*., 2017).

The assemblage composition of vegetated (marsh) and unvegetated parts (tidal flat) significantly differed according to perMANOVA, and was affected by pH (more acidic at the vegetated part of the salt marsh). Total PAH concentration and the toxicity equivalency factor (TEQ) significantly affected the assemblage composition. Our data did not reveal the effect of salinity on assemblage structure. The average proportion of deformed tests among living foraminifera varied between 0-5% (Austertana and Kulonga) and 42% (Porchnikha), and, surprisingly, did not correlate with the level of PAH contamination. The diversity (the effective number of species $\exp(H`_{bc})$; Chao and Shen, 2003) varied between 1 at Austertana and 1.83 at Porchnikha. It was significantly negatively correlated with the total PAH concentration, PAH13, and TEQ (Spearman's correlation -0.89, $p < 0.05$ in all cases). The high negative correlation of diversity index $\exp(H`_{bc})$ with hydrocarbon pollution indices suggests using $\exp(H`_{bc})$ to determine ecological quality statuses. As no criteria exist for determining EcoQs using salt marsh foraminifera, we defined them using the methods outlined in Bouchet et al. (2012). The range between the lowest and the highest diversity ($\exp(H`_{bc})$ 0-2) was divided into five equal-sized intervals corresponding to the five classes of EcoQs. The diversity-based EcoQs well corresponded to the EcoQs based on the concentrations of

PAH13 (following the limits for PAH16; Bakke et al., 2010). We conclude that the diversity of living foraminifera is a promising tool for assessing the ecological quality status of the Arctic salt marshes. Supported by RFBR 18-54-20001.

Repkin E.A, Maltseva A.L., Varfolomeeva M.A., Gafarova E.R., Aianka R.V., Granovitch A.I.

Parasitic systems under the influence of anthropogenic pollution

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Anthropogenic pollution inevitably affects the physiology of any organism. This is fair for parasites and their hosts. Moreover, pollutants could influence infected and uninfected hosts in different ways: (a) reducing the host's immune defenses and predisposing it to heavier parasitic invasion; (b) increasing the mortality of the intermediate and final hosts, as well as the parasites themselves and reducing the density of parasites in the population; (c) alleviating negative impacts on the host due to accumulation of some pollutants by parasites themselves (inside the host).

In this study, we analyzed the populations of several species of periwinkles (subgenus *Neritrema*, Littorinidae, Gastropoda) and their parasites in polluted and unpolluted habitats. We described the density, age and sex structure of periwinkles populations, biodiversity of mollusks and their trematode parasites and the extensiveness of invasion of different species of trematodes. Collection and study of the material was carried out in the summer of 2018-2019 in the following geographical locations: Tromsø (Norway, Norwegian Sea); vicinities of the Kiberg village (Norway, Varangerfjord, Barents Sea); vicinities of Murmansk (Russia, Kola Bay, Barents Sea).

Six species of periwinkles were recorded in Tromsø and the vicinity of the Kiberg; two species were found in the mouth of the Kulonga river and only one species near the Mishukovo village (Kola Bay, Barents Sea). No significant differences were found in the density, age and sex structure of mollusk populations depending on the presence of pollution.

Ten species of trematodes have been identified in mollusks from Tromsø; seven species near the Kiberg village; four species near the Mishukovo village; five species near the Kulonga river. The most frequently recorded and abundant species in all locations analysed were microphallids (Microphallidae, Digenea). In the populations of Tromsø, the biodiversity of trematodes in snails was significantly higher in the polluted points than in the clean (Shannon's diversity index H = 2 and 1.6 in polluted sites *versus* 0.8 and 1.3 in clean ones). Nevertheless, the species richness of trematodes in other locations in most cases did not varied significantly: H (Kiberg) = 1.5 and 1.8; H (Mishukovo) = 1.5; H (Kulonga river) = 1.2. Probably, the presence and density of the final hosts (birds) for trematodes in different locations played a decisive role or the biodiversity of parasites, while the pollution was less important.

The highest extensiveness of invasion was noted in two contaminated sites of the Kola Bay (9.6% in the Mishukovo, 26.3% in the mouth of the Kulonga). Rather high values were also detected in the presumably clean sites of the Varangerfjord (8.8 and 13.6%). Noteworthy, relatively higher extensiveness of invasion was recorded in the polluted sites near Tromsø compared to the clean ones (2 and 1.6% *versus* 0.8 and 1.3%). This may be due a number of factors and their interactions: the over-crowding of birds near human settlements at the polluted sites, stressor-induced immunity-compromise of the intermediate hosts, closeness of some sites to migratory routes of birds.

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Living near humans: anthropogenic impacts on Littorinas at the individual and populational levels

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There were 14 collection sites (impacted or unimpacted by humans) in four geographic locations (Norwegian and Barents seas) in our study. As expected, we detected six *Littorina* species in the Tromsø, Kiberg and Yarnyshnaya side (Barents Sea) sampling sites (*L. littorea, L. saxatilis, L. arcana*, *L. compressa, L. fabalis, L. obtusata*) and four species in the Yakovleva (White Sea) site (the same with *L. arcana* and *L. compressa* lacking); three species (*L. littorea, L. saxatilis, L. obtusata*) in Yarnyshnaya head and Porchnikha (Barents Sea). Only one species *L. saxatilis* was found at the Abram-Mys and Mishukovo coasts, while *L. obtusata* and *L. littorea* were additionally registered in the third (most open part) Kola-Bay site (Kulonga) which agrees with earlier reports (Afoncheva *et al*., 2012). The observed severe shrinkage of species diversity in the Kola-bay sites surely cannot be unambiguously interpreted as a pollution effect.

In our study, we also analysed the correlations between reproductive function (total fecundity, developmental abnormalities and recruitment efficacy) in *Littorina saxatilis* and PAHs-pollution as an anthropogenic stressor and salinity as a natural one. Gamete production and fertilization success have been shown to be affected by diverse stressors in marine metazoans (Lewis & Ford, 2012). We expected the lowering of mean decedents number per female in polluted sites, which turned out not to be the case: we were not able to detect any relation between total fecundity and pollution presence. Populations studied varied significantly in values of total fecundity with the latter correlating significantly with water salinity. Besides total fecundity, we determined several characteristics of pollution in sites studied and estimated not only the mean ratio of abnormal embryos in population (regarding age and size), but the number of females with abnormalities in the broods and variability in percentage of abnormal embryos as well. We showed that all three parameters do vary between populations demonstrating correlation with pollution level (not with salinity). The strongest embryotoxic effect was observed in Kola-Bay populations with lowest salinity among tested sites. This phenomenon is in line with idea of synergy between different kinds of stresses (caused by pollution and low salinity in our case). The observed differences (in percentage of abnormal embryos, its variability among females and relative number of females with abnormalities in the broods) correlated with the degree of pollution and cannot be explained by pollution-neutral between-site variability (detected in case of shell-shape).

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Host-parasite relationships and pollution: transcriptomic analysis

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The effects of a parasite on its host are multifaceted. Trematode infection in the *Littorina* snails can lead to behavior changes, castration, and replacing liver tissue by local hemipopulation of trematodes; consequently, significant shits occur in the physiology of the host organism. Environmental stress can affect the impacts of parasites on its hosts. Pollutants may increase host susceptibility to parasitic invasion due to host's immune system compromise; or *vice versa*, pollutants can decrease parasitism if hosts suffer high mortality under such conditions. In our study we aimed for revealing transcriptomic changes in the organism of *Littorina saxatilis* occurring after infection with trematodes *Microphallus piriformes* from polluted and reference sites.

Samples for analysis were collected from natural populations from three geographical sites: Kola Bay (polluted), Dalnye Zelentsy (Barents Sea, reference) and Chupa Bay (White Sea, reference). The collected samples were acclimated to standard conditions in the aquarium for two weeks. RNA was extracted from tissues not directly damaged by parasites, and libraries for Illumina NovaSeq sequencing were prepared. The reference transcriptome was assembled de novo and the expression levels of the transcripts were estimated.

Exploratory analysis of gene expression showed that mollusks with trematodes invasion demonstrated higher variance of the expression levels; the mollusks from polluted sites had lower variance of the expression levels. For exploratory analysis of differentially expressed transcripts by the PLS-DA method, 20 transcripts were selected that contribute stronger to the differences between the transcriptomes of infected and healthy mollusks from polluted and reference site. Among the annotated transcripts, we observed the higher expression levels of protease subunit and ubiquitin-conjugating enzyme U2 in polluted sites which is a classical response to stress. Also, we found aminopeptidase N which can increase susceptibility of invertebrates to some toxins (its expression was higher in reference sites and in infected snails). Nuclear RNA export factor and membrane transporter also were found to have higher in infected snails.

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Intertidal foraminifera, their microbiome, and the prospect of bio-monitoring

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The foraminiferal work package of the ongoing collaborative project 'Arctic Ecosens' has revealed pronounced local variability in the in the dominant species of intertidal foraminifera. This finding, when applied to bio-monitoring, brings a conclusion that diversity-based indices (*e.g.*, Shannon diversity) are more reliable than sensitivity-based indices (such as AMBI) in quantification of the ecological quality status of naturally stressed habitats, including the Arctic and sub-Arctic intertidal zone. A potential follow-up of this effort is a sub-project that will focus on the microbiomes of the dominant foraminiferal taxa. Foraminifera are protists, which do not depend entirely on the presence of oxygen in their microhabitat. For example, they have been recently shown to be able to utilize nitrate as the electron acceptor, the ability unique in the eukaryotes. The very high natural enrichment with organic matter is typical of soft intertidal sediments. Oxygen of pore-water is exhausted quickly and then the decomposition of organic carbon goes to a large part with sulfate reduction. Foraminifera have been shown to harbor sulfate-reducing and sulfur-oxidizing bacteria. We plan to quantify bacterial populations in foraminiferal cells and in the environment using 16S rRNA gene metabarcoding. The results will be relevant to the bio-monitoring concept as hydrocarbons of anthropogenic pollution add up to the pool of natural organic carbon. The second task of the sub-project would be feeding biology of the dominant foraminifera. Foraminifera including those present in the study area are known to harbor sequestered chloroplasts of their microalgal prey. The applied tool (16S rDNA metabarcoding) will help elucidate the diet of the dominant species and thus to better understand ecological preferences of the studied species.