

**Lomonosov Moscow State University**

**MARINE BIOLOGY, GEOLOGY  
AND OCEANOGRAPHY —  
INTERDISCIPLINARY STUDIES BASED  
ON THE MARINE STATIONS AND LABS**

**80th anniversary of the Nikolai Pertsov  
White Sea Biological Station**

**International conference**

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The conference “Marine biology, geology and oceanography – interdisciplinary studies based on the marine Stations and Labs” (November 19–21, 2018) is dedicated to the 80 anniversary of Nikolai Pertsov White Sea Biological Station. This conference is held in the framework of the scientific-practical conference “Marine Research and Education”. The conference includes following topics: physiology, developmental biology and regeneration, ecology, taxonomy and phylogeny, biology of marine animals, interdisciplinary research, marine mycology, algology and microbiology, functional structure of marine species distribution ranges, and biotopes of marine communities, studies of biota and ecosystems of relict coastal lakes performed at marine Stations and Labs, including WSBS of Lomonosov Moscow State University.

В сборник вошли тезисы докладов, подготовленные участниками международной конференции, посвященной празднованию 80-летия Беломорской биологической станции им. Н.А.Перцова «Морская биология, геология, океанология — междисциплинарные исследования на морских стационарах» (19–21 ноября 2018 г.). Конференция проходит в рамках научно-практической конференции «Морские исследования и образование». Темы конференции затрагивают следующие тематики: физиология, биология развития и регенерация, экология, таксономия и филогения, биология морских животных, междисциплинарные исследования, морская микология, альгология и микробиология, функциональная структура ареалов морских организмов и биотопическая основа сообществ, исследования биоты и экосистем реликтовых прибрежных озер выполненных на морских стационарах, в том числе на ББС МГУ.

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## Contents

NOVEMBER, 19.....	4
<b>PLENARY SESSION</b> .....	4
<b>TAXONOMY AND PHYLOGENY</b> .....	6
<b>DEVELOPMENTAL BIOLOGY AND REGENERATION</b> .....	12
<b>INTERDISCIPLINARY RESEARCH</b> .....	23
NOVEMBER, 20.....	28
<b>BIOLOGY OF MARINE ANIMALS</b> .....	28
<b>PHYSIOLOGY OF MARINE ANIMALS</b> .....	40
<b>MARINE MYCOLOGY, MICROBIOLOGY AND ALGOLOGY</b> .....	44
<b>ECOLOGY</b> .....	51
NOVEMBER, 21.....	55
<b>FUNCTIONAL STRUCTURE OF MARINE SPECIES DISTRIBUTION RANGES, AND BITOPES OF MARINE COMMUNITIES</b> .....	55
<b>STUDIES OF BIOTA AND ECOSYSTEMS OF RELICT COASTAL LAKES</b> .....	64

**Structure and diversity of the bacterial community in an insular estuarine area of Kandalaksha Bay is driven by tidal currents**

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Kandalaksha Bay is an Arctic estuarine system (White Sea). This sub-extreme marine environment shows unusual hydrodynamics due to broad sea level differences during tides and seasonal high runoff of freshwater (rivers and precipitations). In this work, to understand possible effects of water mixing on the bacterial communities, seawater was sampled in selected Kandalaksha Bay areas. Bacterial communities were characterised by 454-pyrosequencing to obtain detailed information on their diversity and structure. The phylum Proteobacteria always predominated (abundance: 67%-96%), being the class  $\gamma$ -Proteobacteria its main fraction. Cyanobacteria was the second most abundant phylum (11-15%) in surface samples collected offshore in the main tidal stream, while it was scarce in the coastal samples and very low at the maximum depth. Unexpectedly, no *Synechococcus* was detected and the diffused presence of *Prochlorococcus*, generally very low or absent in polar waters, could indicate global change effects. Bacteroidetes showed abundance  $\geq 5\%$  in surface and shallow waters (15 m). At the genus level, biodiversity decreased offshore, particularly at the highest depth showing prevalence of *Halomonas* ( $> 65\%$ ).

NMDS analysis confirmed that bacterial community assemblages was influenced by tidal currents, evidencing high dissimilarity for the deepest sample only; Redundancy Analysis revealed that water temperature and salinity represented the environmental factors determining the community structure.

**MARS Network - The European Network of Marine Research Institutes and Stations: an account of its current status and the future strategy**

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The Marine Stations Network (MARS) was established in 1995 as a forum for bringing together directors of marine stations throughout Europe. Many of the marine stations have a long history going back to the 19<sup>th</sup> century when there was a vision for a network of connected institutes (hence the name 'stations', as in stations on a train network) who could collaborate in addressing fundamental research questions and pressing environmental issues. These marine stations are exceptionally well located for coastal and offshore research and are also responsible for maintaining some of the world's longest biological and environmental time-series, which provide valuable insight into long-term changes in marine

environmental conditions. Most of the marine stations have also developed successful education and training programmes in addition to state of the art research facilities.

This presentation provides an account of the past and present status of the MARS Network, the problems and issues tackled by the numerous members, the marine stations, and the way forward. It also provides the principles of the future strategy and agenda of MARS to secure its operation and establish its position in the new scientific era, along with the relevant Research Infrastructures, Networks, Communities and Projects.

## **Review of the results of underwater landscapes and benthic communities mapping at the White Sea Biological Station**

**Isachenko A.**

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The report provides an overview of the results of benthic communities and landscapes integrated studies conducted in the White Sea in the framework of scientific studies, educational tasks of students of biological, geological, geographical faculties of Lomonosov Moscow State University and scientific and applied work in the interests of R&D companies. These investigations were carried out at the N.A. Pertsov White Sea Biological Station in the basis of various projects since 2004 in the Rugozerskaya Inlet, the Baby More Lagoon and the Great Salma Strait.

Parallel implementation of student practices at the White Sea Biological Station let to exchange information and formulate common research tasks. The overall goal of such studies was to describe the current state of the sublittoral submarine landscape of the area and to develop methods of integrated landscape mapping.

During the study geophysical, geological and hydrobiological methods were used. On an area of more than 35 sq. km sonar, multibeam echo sounder and continuous seismoacoustic profiling, observations with the use of ROV, sampling of bottom sediments and benthos, carried out investigations were carried out.

The results of such approach are maps of benthic landscapes, showing both the features of the bottom geomorphology and the distribution of benthic communities and the interrelation of these elements. The addition of point-like quantitative surveys using a bottom grab with the results of areal studies allows us to build reliable maps of distribution, both for individual species and groups of organisms. The combination of various research methods allows to evaluate the patterns of benthic communities distribution on a scale from fractions of a meter (underwater photography and video) to square kilometers (interpretation of geophysical methods results).

The consistent realization of individual projects led to the possibility of constructing complex maps describing the underwater relief, its dynamics, and the biotic complexes attached to them. This opens up opportunities for landscape mapping, linking the characteristics of biota and the description of environmental changes. An integrated approach to the study of benthic communities using remote sensing methods allows to obtain results of higher accuracy as compared with studies on random or planned station grids. The schemes obtained as a result of such works are a convenient model for conducting monitoring studies, and can also serve as a basis for assessing changes in benthic landscapes under the influence of a complex anthropogenic and natural origin factors.

## **Results of 60-year investigation of zooplankton communities of the White Sea at the N.A. Pertsov White Sea Biological Station of MSU and directions of the future studies**

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The results of the study of the structure of the zooplankton communities, seasonal and inter-annual variability, productivity of zooplankton and the life cycles of the dominant zooplankton species of the White Sea, obtained at the White Sea Biological Station of the Moscow State University since 1959, are summarized. In the context of accumulated knowledge, the main directions of future research are presented.

### **TAXONOMY AND PHYLOGENY**

#### **Research Infrastructures and their collaborative potential in addressing challenging scientific questions at global scale**

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Research Infrastructures (RIs) are facilities, resources and services used by scientists to carry out research and develop innovation. A number of EU research infrastructures (e.g. LifeWatch ERIC, ELIXIR, EMBRC ERIC, EuroBioImaging ERIC) have been developing various virtual research environments (VREs), which include many virtual laboratories (vLabs) offering, one stop-over point access, high computational capacity and collaborative research platforms that supporting the needs of digital biodiversity science. This presentation provides examples on the use of the vLabs initially developed by LifeWatch ERIC but then taken up as examples by other RIs. The RvLab operating on a high-performance computer cluster, has been used in order to address the global question on the *taxa equality*. The virtual micro-CT laboratory (Micro-CT vLab), which can be used by the members of the scientific community interested in the digitisation methods and biological collections, makes the micro-CT data exploration of natural history specimens freely available over the internet. The taxonomic

research community has developed a system for describing, classifying and naming taxa across multiple categories. This taxonomic information on marine biota is organized and made publicly available through the World Register of Marine Species (WoRMS) that delivers more than 250,000 described valid species names. Although scientists consider an *equal* status (in terms of contribution to overall diversity) to each taxon used in taxonomy, biogeography, ecology and biodiversity, the question “*are all taxa equal?*” has never been tested at a global scale. We present evidence that this question can be addressed by applying relatedness indices (Taxonomic Distinctness) over the entire WoRMS metazoan tree.

Micro-CT vLab makes it possible the online exploration and dissemination of micro-CT datasets, which are only rarely made available to the public due to their large size and a lack of dedicated online platforms for the interactive manipulation of 3D data. Examples of how these vLabs can be used by other RIs are provided.

Acknowledgements: LifeWatchGreece (MIS: 384676), BioImaging\_GR (MIS: 5002755), CMBR (MIS: 5002670).

### **Nemerteans of the White Sea**

***Cherneva I.A., Ekimova I.A., Schepetov D.M., Nemeretina T.V., Malakhov V.V.***

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Nemerteans are a widespread group of predominantly marine invertebrates. These ambush predators, armed with a venomous inverting proboscis, play an important role in the ecology of marine communities and are often seen by biologists. But due to the lack of more readily available determinants, this group is difficult to define. Even in such a well-studied reservoir as the White Sea the species composition of the fauna of the nemerteans has been studied incompletely. We ventured to correct this situation with classical morphology and molecular phylogenetic methods. The purpose of this study is to determine the number of nemertean species of the White Sea. This work is not finished at the moment and it is a preliminary result.

Based on the analysis of the gene sites of *COI*, *16S* and *ITS*, it can be argued that the tidal zone of the White Sea is inhabited by three species of the genus *Lineus*, rather than two, as previously assumed. It was possible to find morphological differences, allowing to clearly distinguish between *L. ruber*, *L. viridis* and *L. clandestinus*. Based on the analysis of *COI* gene of species *Cerebratulus fissularis*, *S. fuscus*, *S. borealis* and *S. marginatus* is prefatory possible to talk about combining them in one species. There is a question of the presence of the species *Ramphogordius sanguineus* in the intertidal zone of the White Sea. It is mentioned in the literature, but has never been found by us in typical habitats.

### **Chaetae of the White Sea Nephtyidae (Annelida: Polychaeta)**

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Presently, six species of the Nephtyidae are known from the White Sea: *Micronephthys minuta*, *M. neotena*, *Nephtys ciliata*, *N. longosetosa*, *N. paradoxa* and *N. pente*. SEM micrographs were taken in a Camscan S-2 Cambridge Instrument Scanning Electron Microscope. The SEM photographs were taken at the M.V. Lomonosov User Facilities Center, Moscow State University. Line drawings were prepared by tracing the photographs in CorelDRAW. All chaetae of Nephtyidae are simple; noto- and neurochaetae are similar, they form pre- and postacicular rows in parapodia. Worms of the White Sea have barred

chaetae in preacicular rows; chaetae with spines and capillary chaetae in pre- and postacicular rows, sometimes above, and below the acicular lobes also. Chaetae with spines are of two types: chaetae with the “comb” of spines and chaetae with small spines randomly scattered along one side of chaeta, both types are in the postacicular rows.

### **Mitochondrial diversity in calanoid copepods from Nordic seas**

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Data on DNA sequence variation in copepods *Pseudocalanus* and *Centropages* of the Russian sector of the Barents Sea are lacking. Here we provide original data on mitochondrial cytochrome oxidase subunit 1 (Coi) variability in populations of *Pseudocalanus* and *Centropages* from Lake Mogilnoe and neighboring marine (Eastern Murman) Barents Sea populations in comparison with data from other Seas deposited in the NCBI sequence database.

### **Genetic structure of Atlantic and Pacific populations of some nudibranch species (Gastropoda: Nudibranchia)**

***Ekimova Irina*<sup>1</sup>, *Chichvarkhin Anton*<sup>2</sup>, *Mikhлина Anna*<sup>1</sup>, *Antokhina Tatiana*<sup>3</sup>, *Schepetov Dimitry*<sup>1</sup>**

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Until recently many species of nudibranch molluscs were believed to have a wide distribution range. It was also the case of amphiboreal species, which distribution pattern includes both north Pacific and north Atlantic areas with a breaking-up in the Arctic. However, molecular phylogenetic data often suggest the presence of cryptic species complex with a strong geographic correlation. It caused a tendency to describe Atlantic and Pacific populations as two distinct species even when molecular data were limited or not available. In this study we focused on testing the species identity of eight species from genera *Dendronotus* and *Coryphella*. The main goal was to explore the genetic structure using mtDNA data of either amphiboreal species (*Dendronotus frondosus* and *D. kalikal*) or phylogenetically sister species with exclusively Pacific and Atlantic distribution (*Coryphella pseudoverrucosa* and *C. verrucosa*, *C. amabilis* and *C. gracilis*, *Dendronotus dalli* and *D. niveus*). In all cases a comprehensive morphological analysis was also provided to test inter- and intraspecific variations of taxonomically important characters. Our results indicate a strict correlation between genetic structure and distribution pattern of each species. All studied species are not panmictic, but the level of divergence between Atlantic and Pacific populations/species is different. *Coryphella verrucosa* and *C. pseudoverrucosa* were found to be a single species due to the low level of genetic divergence (only 3 substitution rates). This is also the case of trans-Arctic populations of *Dendronotus frondosus* and *D. kalikal*. The species identity of sister *Coryphella gracilis* and *C. amabilis*, *Dendronotus dalli* and *D. niveus* was confirmed.

Material collection was supported by Grant Council of the President of Russia (grant No. MK-4797.2018.4), molecular and morphological studies – by Russian Science Foundation, Grant No. 18-74-00062.

## **Cryptic diversity of genus *Leucosolenia* (Porifera: Calcarea) of the White and Barents Seas**

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Calcareous sponges of the genus *Leucosolenia* are a model object for evolutionary developmental biology studies. However, recent studies on the class Calcarea, and in particular on the subclass Calcaronea, indicates the presence of high cryptic diversity within most genera. Our study was aimed on the comprehensive analysis of the species *Leucosolenia complicata* from the White and Barents Seas using molecular, morphological, embryological and ecological data. We have shown that the species *L. complicata* dwells only in the North Atlantic. In the White and Barents Seas, the diversity of this genus is represented by a complex of widespread critical species.

## **Some features of the population structures of White Sea invertebrates species**

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Conditions in the White Sea are different from those in the North Atlantic and the main part of the Arctic by lower average temperature (−1,2°C in winter и +4,2°C in summer), lower salinity (24–25‰) and low concentration of phytoplankton caused by the polar night and the long period of ice all these differences may effect the effective abundance and, correspondingly, the level of diversity of invertebrates populations, and the direction of this effect may be different in different species depending on the details of their ecology and physiology.

The characteristics of the White Sea have a significant impact on the genetic structure of the populations of its species. On the one hand, we can observe a low genetic polymorphism within populations. On the other hand, in some cases, populations form carriers of two significantly different haplotypes. And one more characteristic feature found in some plankton species is the presence of “endemic” haplotypes, which so far have been found only in the White Sea population.

## **Meroplankton of the White Sea: identification of planktonic larvae using molecular tools**

**Prudkovsky Andrey A., Neretina Tatiana V.**

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Specific knowledge of individual biologies will greatly improve our understanding of the forces shaping ecosystem structure. Biological properties of organisms such as life cycles peculiarities determine seasonal processes in the sea. There is a huge diversity of marine invertebrate species. Nevertheless our knowledge of invertebrates' life cycles is not comprehensive. Meroplankton is useful to estimate the biodiversity and reproduction time of invertebrates inhabited bottom biotopes. But planktonic larvae often

were missed during monitoring studies because of identification difficulties. New results can be achieved using molecular tools.

Planktonic larvae were collected using plankton net near White Sea Biological Station (WSBS MSU) in 2016-2017. The larvae were identified in molecular laboratory of WSBS. We used mitochondrial (COI, 16S) DNA fragments to identify our specimens. In total we obtained 22 sequences of different species including 10 species of polychaetes (*Neoamphitrite figulus*, *Bipalponephtys neotena*, *Eulalia viridis*, *Glycera capitata*, *Laonice cirrata*, *Lepidonotus squamatus*, *Lagis (Pectinaria) koreni*, *Phyllodoce maculata*, *Polydora sp.*, *Scoloplos armiger*), 10 species of molluscs (*Limecola (Macoma) balthica*, *Modiolus modiolus*, *Mya arenaria*, *Alderia modesta*, *Ancula gibbosa*, *Eubranchus rupium*, *Flabellina (Coryphella) verrucosa*, *Paracoryphella islandica*, *Palio dubia*, *Lacuna vincta*), bryozoan *Electra pilosa* and echinoderm *Asterias rubens*. Our results increase the knowledge of invertebrates' life cycles in the White Sea. Also the results may be useful for estimation of invertebrates' biodiversity in the White Sea.

### **Clarification of the taxonomic status of the White Sea redfish (genus *Sebastes*) by molecular genetic methods**

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Knowledge about biodiversity of the Arctic Ocean is still limited in spite of a large body of scientific research. Some unresolved issues regarding fish fauna of the White Sea still in place. For instance, in literature you can find information about redfish (genus *Sebastes*) catches in Kandalaksha Bay (White Sea, Russia), however, to date there is no reliable data about taxonomic status and biological features of these fish.

In this paper we studied two museum samples (Zoological Institute RAS, St. Petersburg) of the White Sea redfish as well as two specimens were being caught in White Sea by the authors.

For clarification of the taxonomic status of the White Sea redfish, we studied nucleotide sequences of the control region (*D-loop*) of mtDNA and the second intron of the *S7* ribosomal protein gene (*RP2 S7*). Genetic results clearly demonstrate that the White Sea redfish belongs to species *Sebastes norvegicus*. New biological data were obtained as well.

### **What are cryptic species? – A process-driven perspective**

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‘Cryptic species’ is nowadays a commonplace term in systematics, evolution, and ecology and with the advent of barcoding approaches increasing numbers of species are shown to be supposedly cryptic. However, the usage of the term is inconsistent in the literature, a unifying framework for studying cryptic diversity is lacking and related processes such as recent divergence, parallelism, convergence, and stasis are not taken into account. This causes confusion and imprecision in attempts resolving origins and evolutionary trajectories of cryptic species. Herein, a conceptual framework for cryptic species is presented based on phenotypic disparity set in relation to temporal scales, phylogenetic context, and

evolutionary processes. The practical importance of such an approach is shown by a literature survey indicating the lack of a hypothesis-driven framework for understanding the evolutionary basis of cryptic species. The survey further underscored the need for much higher genetic and morphological standards in the empirical investigation of cryptic species as a lack of consistency and experimental rigor was evident. This inconsistency can hamper the designation of taxa into different categories of cryptic species, complicating analysis of underlying process. The refined concept of cryptic species has the potential to reveal hidden patterns and processes.

## **Morphology of genital structures in calanoid copepods**

### **Yurikova Daria**

*Lomonosov Moscow State University.*

The calanoid copepods *Calanus finmarchicus* and *C. glacialis* are common species in the plankton communities of the North Atlantic and the Arctic Ocean. Both species are often co-occurring in the same regions and are almost indistinguishable in morphology. The morphological similarity and overlapping of their distribution ranges allowed a number of researchers to put forward a hypothesis about a possibility of hybridization of these two species. This hypothesis was supported by molecular genetic data, but soon it was disproved on the basis of more detailed molecular studies.

In the present study, we examine the morphological features of the reproductive system of adult *Calanus* specimens that could prevent cross mating and, subsequently, hybridization of these species. Females of *C. glacialis* and *C. finmarchicus* were collected in the White and Norwegian Seas. Light microscopy, scanning electron and confocal laser microscopy, as well as computer microtomography were applied to examine the morphology of their reproductive systems. The following structures of the female genital segment were studied: the genital operculum that covers the genital atrium, the morphology of spermathecae; slit-like copulatory pores; and the muscle bundles which are involved in the transfer of seminal contents into the spermathecae.

We found the differences in the shape of the genital segments and genital operculum, in the structure of the copulatory pores, and in the shape and location of the spermathecae between *C. finmarchicus* and *C. glacialis*. However, these differences presumably cannot absolutely exclude cross mating (the transfer and successful attachment of the spermatophores). The morphology of the genital segments of females cannot be used as an independent criterion for distinguishing between *C. glacialis* and *C. finmarchicus* either, but it can be used as an additional feature to confirm species identification based on other morphological criteria. The internal structures of the reproductive system in adults require additional examination by other methods. Apparently, the evolutionary divergence of *C. glacialis* and *C. finmarchicus* involved development of various adaptations to environmental conditions, and emergence of differences in their biology, phenology, and life cycles that have resulted in the species separation.

## **Cryptic species of *Scoloplos* gr. *armiger* (Orbiniidae, Annelida) in the White Sea**

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In the White Sea, two polychaete species of the genus *Scoloplos* are identified as *S. armiger*. Both species are numerous; they occupy different ecological niches: one inhabits the intertidal and the second inhabits the subtidal zone; at depths of 0-3 m these species can be found together. They differ in mitochondrial as well as in nuclear genes; the absence of hybridization is shown for them. Studies of morphology showed slight differences in the external structure: the intertidal species has more hook-shaped chaetae in thoracic neuropodia and more segments with such chaetae, but the values of these features overlap in two species. Comparison with data from Genbank showed that the sublittoral species coincides with individuals from *S. armiger* type locality, and the intertidal one differs from all other genetic lineages and will be described as a new species.

## **DEVELOPMENTAL BIOLOGY AND REGENERATION**

### **Wnt/ $\beta$ -catenin signaling in thecate colonial hydroids: changing one body plan to another**

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Colonial hydrozoans are animals with one of the most diverse body plans within the Metazoa. Because of this traits they are felicitous organisms for studying the evolution of metazoan body plans. Canonical Wnt signaling plays a central role in the specification of the main oral-aboral axis of the body during Cnidaria development. However, the question of the involvement of the Wnt pathway in the regulation of the spatial organization of complexly organized colonial organisms is still obscure. Here we used the non-model colonial hydroids *Dynamena pumila* (Linnaeus, 1758) to study molecular mechanisms of the hydrozoan colony spatial organization. *D. pumila* has a monopodial colony with terminally located growing tips on the shoots. In this type of branching morphogenesis, during each internode formation, the shoot growing tip is divided into three parts: two lateral hydrants and the central one – which remains a growing tip. Investigation of expression patterns of Wnt/ $\beta$ -catenin signaling components revealed that for growing tip patterning responsible at least three Wnt pathway genes:  $\beta$ -catenin, TCF and Brachyury 2. Functional experiments have shown that prolonged activation of the Wnt signaling during the metamorphosis of the *D. pumila* inhibit shoot growing tip formation, but not a stolon growing tip. This result in a stolonial colony formation, characteristic for other hydroid species. Our results suggests that the fine-tuning of the Wnt/ $\beta$ -catenin signaling activity level was one of the leading factors in the evolution of the colony spatial organization of the thecate hydroids.

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## **Larvae of the pycnogonid *Nymphon brevirostre* Hodge, 1863: way of life and behavior**

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For most of the pycnogonid species the life cycle, development and reproductive biology are poorly studied. *Nymphon brevirostre* is very common in the upper subtidal zone of the White Sea. Oviparous males are found from September to April, larvae (instar 1) and postlarvae (instars 2-5) develop from April to July. All postembryonic stages of *N. brevirostre* dwell on the hydrozoan polyps *Obelia*. The offspring of *N. brevirostre* kept in aquarium, were observed and photographed regularly to estimate number of molts and duration of intermolt periods. Instar 1 is a protonymphon larva (six-legged larva), and in the course of anamorphic development the pairs of walking legs appear in a successive pattern.

Instar 1 leaves the male's oviparous legs and starts feeding on *Obelia* polyps. Larvae intrude into the hydrothecae and use proboscis to suck prey while only chelae fingers and terminal claws of larval legs touch the hydrant tissue directly to minimize contact with nematocysts. Up to three protonymphon specimens may occupy the same hydrotheca. Up to instar 3 larvae show the same style of feeding and the whole larval body fit in a hydrotheca. As larvae grow, their walking legs and the rear part of the body protrude from the hydrothecae, and instar 5 can only put its cephalic region into a hydrotheca.

To walk over the *Obelia* colonies the larvae use the spinning apparatus located on the chelifores. Silk is produced by the silk gland of two giant cells and extruded from the tip of the spinning spine. The larvae wind the silk threads around the hydrocaulus of *Obelia* to make a secure net on the surface of the perisarc and clamber on it using chelae and claws of the larval legs.

Molting usually takes place outside the hydrothecae. Exuviae are shed in three parts. First, chelifores molt, their exuviae stay fastened to perisarc with silk threads, then larva attaches again and perform characteristic movements to let the rest of the body and legs exuviate and cast the remains of the cuticle in a single piece.

The spinning apparatus is functional in instars 1 to 5, and later disappear contemporaneously with the regression of the provisory larval ambulatory legs before they are replaced by the definitive palps and oviparous legs. These regressive events correlate with transition to the adult manner of locomotion and feeding and mark the beginning of the juvenile phase in the life cycle.

## **Repertoire of TGF-beta signaling pathway ligands in sponge *Halisarca dujardini***

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TGF-beta pathway is one of the major signalling mechanisms that orchestrate development of multicellular organisms together with Wnt, Hedgehog, Delta/Notch tyrosine-kinase receptors pathways. Axial patterning in embryo development is the brightest example of its role. Thus, asymmetric expression of TGF-beta superfamily ligands determine of dorso-ventral axis in bilateral animals. Ligands from several families (BMP, GDF, nodal, activin/inhibin, Lefty) manage the different embryonic morphogeneses through regulation of proliferation, differentiation, apoptosis, cytoskeleton, adhesion and cell migration. Functions of TGF-beta pathway established early in evolution of multicellularity as ligands

or receptors not found in Protista, whereas in Cnidaria this pathway determines the directive axis of body. At the same time, TGF-beta expression data from sponges' development tell us about involvement of TGF-beta pathway in axial patterning of Porifera embryo. Number of ligands may be as many as eight in demosponge *Amphimedon queenslandica* or twenty-two in calcisponge *Sycon ciliatum* so sponges are not simple in sense of ligand repertoire in comparison to Bilateria. In this study we search through transcriptome and analyze ligands of TGF-beta superfamily in sponge *Halisarca dujardini* (Demospongiae). Eight ligand sequences were identified, and their primary structure and domain organization correspond to eumetazoan TGF-beta. Three of eight identified ligands can be classified as TGF-beta *sensu stricto* when next five are not fall into any of eumetazoan family of TGF-beta. Similar situation described for Wnt pathway ligands in sponges, and it shows independent involvement end lineage-specific expansion of some signalling pathways members inside Porifera phyla.

### **Regeneration in sponges (Porifera): comparative investigation**

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It is well known that sponges have unusually high regenerative capacities, which are often associated with their flexibility of tissue organization and high dynamics of cell differentiation. In order to reveal the diversity of morphogenesis and cellular mechanisms involved in the regenerative processes in Porifera, we undertook a detailed comparative study of the regeneration of a number of sponges from phylogenetically distant taxa, differing in anatomical and histological organization. The objects of this project were sponges from the classes Demospongiae, Homoscleromorpha and Calcarea, possessing leuconoid, syconoid and asconoid types of the aquiferous system, as well as different degrees of epithelial development. The main mechanism of regeneration of leuconoid Demospongiae is the epithelio-mesenchymal transformation involving the polypotent cells – archaeocytes and choanocytes. The basis for the regeneration of leuconoid Homoscleromorpha and syconoid and asconoid Calcarea is epithelial morphogenesis and transdifferentiation of cells. Regeneration of asconoid Calcarea is a rare example of "pure" morphallaxis.

We have shown that the morphogenetic processes revealed in sponges are as complex and diverse as in other higher animals. Thus, sponges can be a source of important information that will allow us to better understand the early evolution of the molecular and cellular mechanisms of morphogenesis in animals.

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## On Dinophilid neurogenesis

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Dinophilidae is a unique group of Polychaeta the representatives of which combine morphological features of different lophotrochozoan taxa. Moreover, adult dinophilids demonstrate morphological properties of a trochophore larva. Such peculiarities may be associated with either archaic origin of this group or neoteny trait.

We investigated early events in the neurogenesis of two dinophilids (*Dinophilus taeniatus* and *Dinophilus gyrotiliatus*) using immunocytochemical staining and LCSM. External ciliation was used for embryo staging.

In both species the first neural elements revealed by anti-tubulin antibodies are solitary neurons located in the hyposphere at the early trochophore stage. Neurites of these early neurons surround the stomadeum and constitute the anlage of a head neuropil. During the development the number of neurites increases and they form compact head neuropil, paired ventro-lateral and lateral longitudinal bundles, unpaired medial longitudinal bundle, and transverse commissures in the ventral hyposphere.

Serotonin and FMRFamide immunoreactive neurons differentiate adjacent to ventro-lateral bundles and head neuropil, respectively, after the establishment of main structures of the nervous system at the middle and late trochophore stages. Tyrosine hydroxylase immunopositive neurons differentiate at periphery at late trochophore stage.

Processes of serotonin, FMRFamide, and tyrosine hydroxylase immunopositive neurons constitute the small portion of tubulin immunopositive neuropil. No elements constituting apical and/or aboral organ, or specific pioneer neurons were found.

Our results demonstrate that early neurogenesis is similar in two *Dinophilus* species, but different significantly from that of other investigated lophotrochozoans. Based on the described scenario of early neurogenesis we speculate that Dinophilidae represents an archetypical Polychaeta group.

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## **The ability of calcareous sponges (Calcarea, Porifera) to develop from dissociated cells**

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Sponges are the most ancient aquatic multicellular animals, which can be characterized by the peculiar histological structure, which causes high plasticity and mobility of the cellular elements of the sponges. One of the forms of manifestation of such plasticity is cell reaggregation – the ability of sponges to recover from dissociated cells. The aim of this study was to analyze the process of reaggregation in calcareous sponges (Porifera, Calcarea) of the White Sea: *Leucosolenia* cf. *variabilis*, *Sycon* sp., *Sycettusa murmanensis* and *Clathrina arnesenae*. The process of reaggregation occurs in a similarly in all the species studied. At 24 hours after dissociation, the formation of primary multicellular aggregates was observed in

cultures. Primary aggregates have a round or irregular shape and are characterized by loose packing of cells. After 72-96 hours early primmorphs form in cultures. They have a rounded shape with more even surface. Cells in the early primmorphs are packed denser than in primary aggregates. This stage is final in the process of reaggregation in the species studied. Rearrangements and transdifferentiation of cells were observed throughout the reaggregation process. During this study the methods of obtaining and cultivating multicellular aggregates of calcareous sponges were elaborated, and optimal conditions for cultivation were determined for some species. A primary description of the structure of aggregates and cell transformations during the reaggregation at histological and ultrastructural levels was carried.

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## **10 Years dispute about our most distant metazoan relatives - status quo and novel data from sponges and comb jellies**

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More than a decade ago phylogenomics, the use of large molecular datasets to reveal phylogenetic relationships, revolutionized our understanding of animal relationships. One of the most debated relationships since is the position of the ctenophores (Comb Jellies) in the animal tree of life. Morphologists have placed these animals as sister group to Cnidaria ("Coelenterata"), sister group to Bilateria ("Acrosomata") or even within Deuterostomia. Molecular data however currently place them as one of the earliest animal lineages which challenges the previous ideas about the evolution of ctenophore characters. The two competing hypotheses "Pori-sis" or "Cteno-sis" are tackled by all means of molecular approaches that often remains obscure to non-specialists. I will aim to explain the current status of the methodological issues of solving the question with molecular data, but also discuss morphological character evolution that is impacted by the different results. I will present new data of the transcriptomic characterization of cells of sponges and comb jellies and use them to discuss the problem from a morphological perspective.

### **Regeneration of White Sea sponge *Halichondria sitiens***

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It is well known that sponges have a pronounced ability to restore lost body parts and heal wounds after injuries of various kinds. However, to date, a detailed description of the regeneration process using modern research methods has been given only for a few representatives of the Porifera type. We have carried out a study of reparative regeneration of papillae of a representative of the class Demospongiae - *Halichondria sitiens* using light and transmission electron microscopy. Wound healing is accompanied by rounding of its edges, smoothing the wound surface and reducing the number of cellular debris in the area of damage.

These processes are carried out at the expense of various cells of the mesochil, which migrate to the amputation zone, where they synthesize collagen, and also phagocytize the remnants of dead cells in the area located below the wound surface. The restoration of the apical regions of the papillae takes place with the participation of exopinacocytes surrounding the wound surface due to their flattening and spreading to the wound surface.

**How to build a polychaete larva? Natural history of the development and metamorphosis of  
*Alitta virens* (Annelida: Nereididae)**

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The larval period of ontogenesis plays a pivotal role in life history of marine organisms. Primary planktonic larvae with ciliary locomotion are believed to be an evolutionarily ancient feature of all Metazoa. These immature forms serve for dispersal and thus, encompass an adaptive potential, especially in sessile animals. Polychaetes evolved diverse developmental modes, including free-swimming planktotrophic, lecithotrophic, and hidden larval types with an amazing variety of their morphology, behavior and longevity. As a rule, an overall organization of the trochophore larva undergoes fundamental changes during metamorphosis. Exactly at the end of larval life major definitive traits of the organism originate, creating the prerequisites for further growth and development. Moreover, metamorphosis should be considered as a change of the genetic developmental program that implies activation of new genes and uses new morphogeneses involved in transformation of the entire body. Aiming to identify the cellular and molecular mechanisms of the body plan formation in polychaetes we analyzed postembryonic development of the nereid worm *Alitta virens*. Being a wide-spread representative of the Arctic macrozoobenthos, it develops through a non-feeding planktonic larva. On the one hand, lecithotrophy is a derived trait, inhibiting the development of many organ systems. On the other hand, the lack of specialization helps to unravel more clearly the features of recapitulative nature. Here, we present the spatiotemporal patterns of cell proliferation, muscle differentiation, and expression of regulatory genes, involved in specification of different body parts. These data indicate a hidden metameric organization of the early trochophore larva, as well as sequential antero-to-posterior segmentation of the trochophore body. We found a relatively late differentiation of mesodermal and endodermal primordia. The revealed profound similarity of segments formation in the larval and post-larval regions improves our understanding of the annelid body heteronomy. We believe these equivalent morphogeneses in *A. virens* are just separated in time, being realized in cell populations of different origins: the larval body is constructed in embryogenesis, and the growth zone is established much later, presumably, via local induction and dedifferentiation.

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## **Regeneration in calcareous sponges (Calcarea, Porifera) of the White Sea**

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Sponges are the most ancient multicellular animals. They demonstrate broad recovery abilities after various wounds, and due to their phylogenetic position, studies of repair processes in sponges are required for understanding the evolution of the regeneration mechanisms in animals. We studied the reparative regeneration in two widely distributed species of the White Sea calcareous sponges with an asconoid aquiferous system - *Leucosolenia sp.* and *Clathrina arnesenae*. In both species, regeneration occurs due to the reconstruction of intact tissues adjacent to the wound. Epithelial morphogeneses (stretching, flattening and fusion of epithelial layers, exopinacoderm and choanoderm) play a central role in this process. Another important part of the regeneration is temporary transdifferentiation of the choanocytes into endopinocytes. At the same time, cell proliferation is not affected by the regenerative processes and does not contribute to the restoration of lost structures. Thus, the regeneration in *Leucosolenia sp.* and *C. arnesenae* is a rare example of "pure" morphallaxis, and the mechanisms used in regeneration are similar to those of Eumetazoa.

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## **New data on the formation, growth and segmentation of the regenerative bud of nereid polychaetes (Annelida: Errantia)**

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Nereid polychaetes are quite popular objects for evolutionary development biology, and regenerative biology in particular. A new emerging model species, *Platynereis dumerilii*, and closely related *Alitta virens*, which is one of the dominant and widespread species of polychaetes in coastal communities of the White Sea, both have the ability to quickly and repeatedly repair lost segments of the posterior body end. The objects of our study possess a few specialized (cenogenetic) traits in physiology, anatomy, development and genome architecture that infers relatively low rate of evolution in this lineage. Thus, the ancestral state of numerous life-history traits makes nereids a convenient model for comparative research. Nevertheless, the regulatory mechanisms of reparative morphogenesis in annelids, including molecular profile of metameric pattern formation, cell proliferation dynamics, and neurohormonal control, remains to be enigmatic.

The aim of this work is to explore the molecular and cellular aspects of the regenerative bud development in the promising nereid model. We used two types of experiment: posterior amputation of juvenile worms, as well as double amputation of the posterior and anterior body segments, which removed the cerebral ganglion as potential regulatory center. The obtained results suggest that the formation of the regenerative bud in *A. virens* is based on dedifferentiation and local proliferation of cells originated from the adjacent old segment. The initial steps of regeneration accompanied by activation of the homeobox genes seem to be independent of the cerebral brain. At later stages, the formation of new segments differs significantly in posterior regenerates and decapitated (“headless”) fragments. Also, the results indicate involvement of the canonical Wnt signaling pathway in the process, including regulation of mitotic activity and determination of segment boundaries. As a far-going perspective of our research we announce the RNA-seq survey on different stages of the nereid regeneration. This complex approach is of great importance for integrating experimental, morphological, and molecular data on regeneration in diverse animals.

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### **Placental nourishment in cyclostome bryozoans**

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Our study was focused on the sexual reproduction of Cyclostomata, one of the most ancient bryozoan taxa, that is still diverse and abundant in modern seas. Unique combination of their reproductive traits includes intracoelomic incubation of embryos (viviparity), matrotrophic nourishment (via placentation) and polyembryony (multiple clonal development of embryos from a single fertilized egg). This reproductive pattern could play a key role in their past explosive radiation and longevity in marine ecosystems, thus making the group a unique model system for studying role of reproductive mode in evolutionary success. Till now, cyclostome sexual reproduction has been studied using only light microscopy, however.

Colonies of four common boreal cyclostomes from three distant families: Crisiidae, Tubuliporidae and Lichenoporidae were collected in the Kandalaksha Bay, White Sea. Detailed study of the anatomy and ultrastructure of gonozooids with embryos provided new data on the nutritive and developmental processes accompanying embryonic growth.

The general structure of incubation chambers, while showing basic similarities, differs in three families studied. The main distinctions concern shape, size, growth direction, origin (one or few gonozooids involved) and number of brooding chambers in a colony.

Placental analogues develop during embryonic incubation and disintegrate after larval release. They envelope the centrally placed embryonic group being surrounded by a pseudocoel. The embryos and developing larvae are directly embedded into the nutritive tissue, although, the contact is absent in some instances. Placental analogue is a complex syncytium (while also including some (presumably, totipotent) cells) of peritoneal origin which displays high synthetic activity. Besides, some cells in the pseudocoel seem to be involved in the nutrients transport being associated with both, the epithelium of

the body wall and placental syncytium. Nutrients are transferred to the embryos via exo- and endocytosis, diffusion and active transport are suggested too. Thus, cyclostome bryozoans show a combination of histotrophy and placentotrophy.

### **Functional activity of the serotonergic system in the early embryonic development of invertebrates**

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The signaling molecules of the monoamine group (serotonin, dopamine, norepinephrine) not only transmit nerve impulses at chemical synapses, but also regulate a number of cellular functions outside the nervous system. It has long been known that in various animals, serotonin is functionally active in early embryos – long before the appearance of the first nerve cells. On developing sea urchin embryos, it has been shown that serotonin is involved in the regulation of the cell cycle of cleavage divisions, affects the state of the cytoskeleton and carries out interblastomeric interactions. The functional activity of the serotonergic system in the early stages of embryonic development is shown not only in echinoderms, but also in various representatives of vertebrate animals. The aim of our work was to conduct a comparative study of the functional activity of the serotonergic system on the White Sea representatives of various groups of invertebrates - echinoderms, ringed worms, mollusks, cnidaria. All studied animals have an increase in serotonin content in blastomeres when they are incubated with exogenous serotonin or its biochemical precursor 5-hydroxytryptophan, which indicates the activity of the synthesis systems and the membrane uptake of the transmitter. The obtained data allow us to conclude that serotonergic signaling mechanisms are universal in the early embryogenesis of animals.

### **The larval development of *Ophelia limacina* (Sedentaria; Annelida)**

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We studied the body plan formation in the sedentary annelid *Ophelia limacina*. The animals burrow in the sand of the upper subtidal zone of the Great Salma Strait, the White Sea. Notably, for the first glance the sediment and hydrological conditions are the same along the beach of the Salma Strait, but *Ophelia* inhabits the very restricted area. Here, we aimed to find out peculiarities of larval morphology of *O. limacina* in order to explain its restricted habitat. In June-July 2015-2018, we collected adult worms in close vicinity of the Pertzov WSBS MSU, performed artificial fertilizations, kept cultures under 12°C degree, and salinity 25%, fed with algae *Nanochloropsis*, *Rhynomonas* and *Nitzschia*. During the 30-35 days the embryos develop to larvae, settle, and metamorphise into juveniles. We have studied external morphology with light and scanning electron microscopies, cilia beating and swimming behavior with the high speed camera, ciliogenesis and neurogenesis with the application of the immunocytochemistry combined with the confocal laser scanning microscopy, the cell proliferation in the forming segments by EdU labeling. The 30 hpf gastrulae with the prototroch start swimming. The 10-12 dpf larvae which are ready to settle have the active cell proliferation in the zone between prototroch and telotroch, they have triple ventral nerve cord, circumesophageal connectives, and one transverse commissure, set of ciliary

bands (proto-, telo-, and neurotroch) and apical tuft, capillary chaetae, gut develops (though does not function). Larvae at this stages are swimming in the water column. As larva settles, the first four segments appear simultaneously. The next segments appear in the posterior zone in front of the telotroch. Larvae start feeding and crawling on the bottom of the dishes. As a result, we hypothesize that larvae remain in the water column until they have small compact body shape. The settled larvae have the segmented and extended body. As a side result, we hypothesize the interconnection of two processes: the segment formation process triggers the mechanism of the larval settlement. We acknowledge Tatiana Belevich (Dept. of Hydrobiology, MSU) and Andreas Hejnol (Sars Center, Univ. of Bergen) for the algae package; WSBS labs for immunocytochemical and EdU labelling.

### **Cell proliferation dynamics during regeneration and larval development of the White Sea polychaete *Alitta virens*: method development and first results**

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In developmental biology, studies on cell proliferation have its importance due to the necessity of division control in cells accomplishing any morphogenesis. Mitotic regulation in various anlagen is also connected with evolutionary changes in the animal body plan. The lost control over mitotic activity may lead to tumors formation. Previously, the evaluation of various proliferation parameters was difficult and time consuming: the scientist had to produce histological sections and then count cells of interest manually. Nowadays there is software that can greatly improve the scientists' work, whether the suitable algorithm for a particular object is found. Thus, the goal of the work was to develop such algorithm for automated calculation of proliferation parameters in *Alitta virens*, which would work for any stages of ontogenesis. Quantitative analysis of labeled nuclei, in which labelling was made using one of the DNA precursors EdU, as well as an estimation of the mitotic activity index was carried out by means of Bitplane Imaris software. Other possible methods of cell counting using ImageJ and CellProfiler were also tested, but they were considered less convenient for this study.

As a result of our work, a protocol was created and standardized for semi-automatic data acquisition and processing. For the first time in polychaetes, we estimated above-mentioned quantitative proliferation characteristics during posterior regeneration and in the process of larval development of *A. virens*. After amputation we observed epimorphic development of new terminal structures solely by division of the cells adjacent to the wound. On the 2<sup>nd</sup> and 3<sup>rd</sup> days after amputation, the ratio of cells in the S-phase of cycle remains at the level of 19-27%. By the time the first segment is formed (the 4<sup>th</sup> day of regeneration) there is a decrease in proliferative activity of the bud. On some stages of larval development, we also see a rapidly changing picture. For instance, in early metatrochophore, the index of labeled nuclei is about 30%, the mitotic index does not exceed 5%. In the subsequent stages, both parameters decrease approximately in 2-3 folds. Thus, our results indicate a lack of growth zone in early larvae and a fundamental difference in the formation of larval and post-larval segments.

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## **Regulation of oral-aboral axis specification during *Dynamena pumila* (L., 1758) development**

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Cnidaria is a large phylum comprising mostly marine animals with few freshwater species. Recent phylogenies place them as a sister group to the Bilateria. Unlike Bilateria, clade Medusozoa in the phylum Cnidaria has an evolutionary simple body plan with radial symmetry and one main oral-aboral body axis. As an outgroup to the Bilateria cnidarians have a strategic position to serve as powerful models for investigation of body plan evolution and pattern formation.

Our work is focused on molecular mechanisms of oral-aboral axis specification during development of a common White Sea colonial hydroid *Dynamena pumila* (L., 1758). Wnt signalling is required for the specification of oral pole. Wnt3 and Fzd3 are the components of canonical Wnt signalling pathway and markers of oral and aboral poles of cnidarian body, respectively. Using in situ hybridization we have shown that expression of Wnt3 and Fzd3 is became polarized from preplanula stage. Hence, our results revealed that in *Dynamena* oral-aboral axis is finally established at the late developmental stages. In contrast, in other cnidarian model organisms Wnt signaling components are localized asymmetrically already in the fertilized egg and animal pole of the egg gives rise to the oral structures. Moreover, according to our results gastrulation morphogenetic movements and expression pattern of body axis markers Wnt3 and Fzd3 appear to be uncoupled in *Dynamena* unlike in other studied cnidarian model organisms.

Furthermore, we are going to investigate the expression of Brachyury transcription factors, presumably the target genes of the canonical Wnt signalling pathway. We have already described expression patterns of these genes on gastrula-planula stages. We have shown that Bra1 is a downstream target of the canonical Wnt signalling pathway.

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## **Development of *Testudinalia tesulata* (Mollusca, Gastropoda) in the White Sea**

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Patellogastropoda is the basal group of Gastropoda, fundamentally different from other gastropods by a morphological features, one of which is a docoglossate (stereoglossate) radula. Patellogastropods have a stereoglossate feeding stroke while all other gastropod and non-gastropod outgroups are flexoglossate (Guralnik and Smith, 1999). According to the latest data, the stereoglossate condition of the radula in patellogastropods is secondary (Haszprunar 1988a; Salvini-Plawen 1988; Ponder and Lindberg 1997), and the flexoglossic state is primary for all mollusks (Colgan et al., 2003). These conclusions were based on morphological data radula of adult animals. A comparative morphological analysis of the larval radula of various gastropods can be an important addition to clarifying the basal condition of the radula

of all mollusks. Since the patellogastropods are the basal group of the Gastropoda, the establishment and synthesis of the larval radula is of particular interest.

*Testudinalia tesulata* habitats on the border of the intertidal and upper subtidal zones of the White Sea. External fertilization occurs in the water at the beginning of June. Spiral cleavage is an equal. One division at a temperature of +10 g passes every 2.5-3 hours. One day after the fertilization, an early trochophore is formed, which does not move, ciliary cells do not form prototroch. The trochophore about 30-39 hours is started to swim. It is with the apical cilia, the slit-like blastopore is almost closed, and on the dorsal side the shell gland is formed, which is still concave inward. After 10 hours (48-54 hours), the velum develops, the telotroch shifts to the ventral side, there is a foot bud and a shell begins to form. Veliger for 90 hours after fertilization has a well-developed shell, which begins to calcify, foot, well-translucent liver through the shell and the rudiments of tentacles. A radula also develops, it consists of three teeth in a row and nine rows, while at the 88-hour stage, radula have not been fined. Most likely the torsion occurs after 100 hours, while the torsion veliger has a well-developed operculum, already a white shell and rather long head tentacles. By 170 hours, the process of sedimentation begins, with the larvae floating-settling, eyes and well-developed tentacles, the test is completely calcified. It was possible to trace the development to 264 hours, the veliger only crawled, but a complete metamorphosis did not occur. There are numerous studies of the development of Patellogastropoda (for example, Smith, 1935; Crofts, 1954; Bigelaar, 1977; Wanninger et al., 2000; Kostyuchenko et al., 2013) and our data coincide with those obtained earlier. It is important to note that the development is asynchronous and in the one group were detected at different stages of development. It is also significant that when the temperature is higher on several degrees, the development takes place at least twice as fast (Kozin et al., 2013). New fact that we find is that the radula of the patellogastropods is triserial with central and lateral teeth, as well as described for polyplacophores (Minichev, Sirenko, 1974). And in the adult state of *Testudinalia tesulata*, the radula consists of four teeth in a row (with the central tooth being reduced). The information obtained rather gives rise to new questions: at what point does the central tooth reduce and add more lateral pairs, does the pattern of formation of one tooth remain in the larval and adult state or does it change, do there are common patterns in the formation of the larval radula in patellogastropods and other groups of mollusks with flexoglossate radula? To answer these questions, we need new data on the fine morphology of the larval radula and data on the tabulation and formation of the radula in other groups of mollusks.

## **INTERDISCIPLINARY RESEARCH**

### **Equipment and technology of the very high resolution seismic survey in the White Sea** ***Gainanov Valerii*<sup>1</sup>, *Tokarev Michail*<sup>1</sup>, *Birukov Eugeni*<sup>2</sup>, *Potemka Andrey*<sup>2</sup>**

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The very high resolution seismic survey in the White Sea started in 1970-s, when the Laboratory of Seismoacoustics of the Geological Faculty of the MSU was invited by A.P. Karpinsky Russian Geological

Research Institute (VSEGEI) to carry out this survey for the purpose of geological mapping, using sparker seismic source and single channel streamer (*Vladov et al, 2004*).

The Laboratory of Seismoacoustics of the Geological Faculty of the MSU was engaged in developing this technology from 1960-s. Some experimental work has been performed in the Black Sea and the Caspian Sea, in some rivers. To 1970-s the technology in general was developed and in deep Black Sea provided the penetration almost to 1-1.5 km.

In the White Sea geological conditions appeared to be very different: penetration of the seismic survey comparing with it for the Black Sea was very low, on the surface of the bedrock unexplainable for the first appearance deposits were lying. Their thickness was not very big, inner structure was very heterogeneous. Later we came to understanding that they are glacial sediments.

To the 1980-s VSEGEI completed the geological mapping in this area, seismic investigations also were finished.

The revival of seismic investigations in the White Sea happened in 2003 thanks to initiative of M.Tokarev (*Gainanov, 2016*).

What is new after 40 years pause? How changed the technology? What are results?

It may seem that technology is not much changed: the equipment and methods are similar to that from 1970-s. Thanks to digital technologies now equipment became much more compact and can be installed on small-size vessels. Digital data registration and processing provides facilities for improving the quality of seismic data acquired during rough sea conditions.

The multichannel very high resolution seismic observations are carried out using common depth point (CDP) technology with 16 channel streamer and 1000-2000 Hz boomer. Streamer and boomer are on 0.4 m depth towed. In some cases 200-400 Hz sparker is used, and the tow depth is changed to 0.8 m. Shot interval mostly is chosen equal to 1.5-2.0 m, so that CDP fold may be equal to 16.

The alternative technology – towing the source and multichannel streamer on the much bigger depth (*Tokarev et al, 2008*). This technology makes it possible that the first reflected waves may be registered without interference of the peg-leg waves, improving the vertical resolution, stability of the signal form and amplitude – the way for using signal attributes for mapping the sediments on the sea bottom.

Though such system also has some disadvantages: the towing difficulties, low profiling speed, impossibility to work on shallow water areas. We developed also the technology of very high resolution seismic profiling with slanted multichannel streamer (*Gajnanov, Tokarev, 2018*). On acquired by this technology seismic data it is also possible to suppress peg-leg reflections in receivers point, though dependence from sea conditions remains.

In 2014 we started experiments with 3D very high resolution seismic profiling (*Shmatkov, Tokarev, 2014*), in 2017-2018 experiments were continued (*Gajnanov, Tokarev, 2018*).

For a long period only reflected waves were used in very high resolution seismic profiling. Nowadays higher demands for engineering survey on marine areas and impossibility in some cases to obtain useful information using only reflected waves requires to consider using the waves of other origin too.

The first experiments with lying on bottom seismic streamers and 4 component ocean bottom stations (*Gajnanov, Tokarev, 2018*) showed possibility of using for studying of shallow sediment not only reflected waves, but of refracted and surface waves too. First, it gives possibilities for estimation of mechanical

properties of earth, second, we can use these waves for exploring the earth in cases, when it is impossible with using reflected waves.

The main goals of the geophysical investigations on the White Sea Biological Station are to apply complex of methods for solving geological and biological problems. Purchased in 2011 according to MSU development program new equipment delivers possibilities for solving these problems on higher level. The new vessels “MSU student” and “Professor Zenkevich” are very good instrumentation platforms.

*This work is done in accordance with the theme “Development of hardware and software systems for prospecting, geophysical and geochemical monitoring of the reservoir engineering, including that in difficult of access regions and complicated natural climatic conditions” by financial support of Ministry of Education and Science of Russian Federation, using the equipment, purchased according to MSU development Program. Agreement # 14.607.21.0187 about provision of funds from 26 September 2017. Unique identifier of the agreement RFMEFI607I7X0187.*

### **GIS "White Sea islands: Geology and Geomorphology"**

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At present, the northern regions attract attention of scientists and politicians all over the world. The White Sea is characterized by the ecological diversity (various sea life, fish resources and coastal landscapes, unique on beauty, which attract tourists) and complex geological history. Numerous islands of the White Sea are a good model for studying the interaction of endogenic and exogenic factors of landform (relief) formation. The irregular distribution of islands reflects also the heterogeneity of the geological and geomorphologic structure of the White Sea region. Therefore, the study of islands morphology and history of their development is one of the priorities in marine geomorphology.

Our research is directed to creation of a geographic information system "White Sea islands: Geology and Geomorphology". During the forwarding researches on islands of Kandalaksha Bay of the White Sea in 2007-2018 the following geological and geomorphological information was collected: contours of geological and geomorphological objects, the high-rise provision of objects, landscape characteristics, structure of the spreading surface, etc.

At the moment GIS "White Sea islands: Geology and Geomorphology" is developed in two directions:

- collecting, examination and preparation for input of the cartographic, literary, archival materials and new data collected and submitted by participants of the research project;
- creation of the specialized software for input, editing and storages of cartographical information, creation of digital elevation models, creations of maps of islands relief and the adjacent continental land and also a bottom landforms of the explored sites of the water area, i.e. for visualization of data.

The spatial database consisting of 10 thematic sections (blocks) reflecting the main components of the environment of the White Sea (Table 1) became a basis of our GIS-project.

**Geography.** The block contains the general information on the White Sea region, which reflected in overview maps of different scale. This maps are presented in the raster data with a spatial reference.

**Orohydrography.** Key parameters of the environment were vectored during the analysis of overview maps of the region for the further thematic and spatial analysis.

**Geology.** A series of maps of a geological structure of different scale gives detailed view of history of development and the processes, which created the water area and coasts of the White Sea and happening now.

**Tectonics.** The block contains information on a tectonic and neotectonic structure of the research regions, presented in the raster form (maps of different scale with a spatial reference) and vectored basic elements for further analyses.

**Bathymetry.** A series of navigation maps from which certain sites were transferred to a digital format became a basis of this block.

**Morphostructure.** The block represents result of the morphostructural analysis of topographic and bathymetric maps of the research region.

**Geomorphology.** The block is result of forwarding researches on White Sea islands in 2007-2018 – a series of geomorphological maps of islands of different scale.

**Paleogeomorphology.** A series of paleogeomorphological maps reflect the main elements of the islands' surface at a certain stage of the Pleistocene and Holocene periods.

**Morphometry.** A series of the maps constructed during the morphometric analysis of the topographical maps, bathymetric maps and this remote sensing became a basis of this block.

**Auxiliary materials.** This block contains information obtained from open sources – digital terrain model, geological maps, tectonic maps, etc.

Processing of materials on the research region is made in the environment of the software of ArcGIS 10 ESRI. Thus, in uniform cartographical scale it is possible to visualize collected data (interactive representation), to carry out the analysis of data by method of geoprocessing and to edit these data (creation, updating and maintenance of geospatial information). Application of modern methods of geoinformation technologies allows to conduct monitoring researches of the geological environment.

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### **The concept of factual search**

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This paper presents the concept of creating a factual search engine based on the developed tools for processing descriptive information. The need for such tools is long overdue.

The current state of science is characterized by the accumulation of a large number of descriptive information (reports, dissertations, articles and other scientific documents) of different size and purpose, digitized in various applications in tabular, text, taxon formats, as well as databases. This spontaneous digitization of information using a variety of software tools has created the problem of access to integrated information and the problem of extracting factual information from the rapidly growing flow of scientific documents, consisting, as a rule, of poorly formalized information, rather arbitrary structure.

The search for solutions to these problems has been carried out since the 70s of the last century and for objective reasons has not been developed. The emergence of the world wide web has stimulated the development of documentary search engines with a low level of relevance of the document search. Have spread fact-finding systems based on well-structured information. However, such widely used search engines do not allow researchers who have in circulation multi-format, mostly poorly formalized descriptive information to search for facts. This requires a special level of search quality: to find the necessary information and only it.

Formal analysis of the set of information resources showed that it consists of a set of finite number of subsets of the same type of digitized information. At the same time, a significant amount of scientific descriptive resources are tabular format and natural language texts.

We have developed the concept of creating an information retrieval system for the collection and storage of descriptive documents digitized in various formats with tools for finding and extracting the necessary facts within the technology of geographically distributed information system of cluster type. The developed technology is a means of processing text information, the result of which is a factual search engine. It allows you to combine disparate digitized information in unlimited volume and create a search engine based on the classifiers formed from the elements of the source text. The basis of the technology developed by us is the principle of primary information and secondary format, cluster method of its accumulation and iterative approach to information processing.

The idea of the proposed technology is that of the disordered and heterogeneous digitized information set stand out "sources of information", owning a certain amount of data. For each "source of information" within the technology, a client workstation is created to process the initial information using a set of tools.

The primary information of the client workplace, in the sense and type of digitization, is combined into clusters, defined by unique names. For each cluster, with a single type of digitization of the information contained, a transformation tool (bridge) is created, with the help of which the original digitized information is brought to a regulated structure, each record of which is a fact. This process is individual for each type of information digitization.

The transformation of the original digitized information to the regulated structure allows to solve the problem of bringing multi-format digitized information to formal uniformity, which makes it possible to further process the information in a single scheme.

The process of creating a search engine begins with the technology of structuring the information contained in the regulated structure. It is based on the use of conceptual lists created from the source text using various automation mechanisms: taking into account the presence or absence of separators in the records, the presence of keywords or concepts in the text. From fragments of a simple table formally created directories, fragmentation Technique allows you to create a hierarchical directory.

The elements of the directory are linked to the corresponding records of the regulated structure, carry out their unification and actually get a search engine for the cluster. Unification combines semantic elements of the directory and as a result simplifies the search system. Thus constructed hierarchical directory, linked to the facts of the regulated structure and the process of unification of semantic elements of the directory, makes it possible to build different types of search engines.

The proposed approach, based on the primacy of information, using the developed tools allows for each cluster to create search engines of the end user. It should be emphasized that we are not developing a search engine for the end user, but a set of end user tools, using which we can create a search engine for multi-format digitized material.

In addition, in this way, the information processing allows you to create a factographic search engine not only for the cluster, but also for a single client workstation (for a group of clusters) and for an array of information for a group of client workstations in an unlimited amount. The result of such processing

allows you to search the information array, both facts and documents containing these facts with a high degree of relevance and reliability of the information received.

An example of the practical use of the developed technology can serve as a factual search system based on text processing, carried out on the basis of historical and archival materials of the mineralogical Museum of the Ilmen reserve in order to extract facts from electronic documents according to the specified search criteria in the process of studying previously developed objects of minerals (Kuvshinova L A., 2014).

In conclusion, it should be said that the result of the above information processing is actually a knowledge base. Combining the results of the processing of thematically similar amounts of information it is possible to base knowledge on certain subjects and various fields of knowledge. In addition, by accumulating directories created by the end user, it is possible, using them and new information converted to a regulated structure, to formally determine the subject of the newly received information. Using the operation of unification of terms, it is possible to expand the knowledge base into other natural languages.

NOVEMBER, 20

## **BIOLOGY OF MARINE ANIMALS**

### **Synoptic scale volatility of flow in reference to *Delphinapterus leucas* occurrence and distribution behaviour in the Southern Laptev Sea**

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Cetacean distribution, particularly beluga whale appearance in the Laptev Sea, mainly depend on oceanographic and other conditions, distance to sea ice edge because both relate to factors such as prey distribution, predation and others.

So, we can presume, that flows characterized by maximum velocities are generally directed to the North-East–South-West for Khatanga, Lena and to North-South for those closer to the central part of the Laptev Sea (Yana, Anabar). The presence of thin peak cyclicity can be explained by wave process origin.

Beluga whale show a high degree of active and passive flow control and it physically can cope with flow variations in its migration routes, which highly depend on prey species routes, being in turn determined by flows and currents, dynamic fronts (chlorophyll and nutrients), depth, as well as the conditions of estuaries and the distance to the ice edge.

All stated above can suggest the species can be found with a high rate of probability in the south - western and south-eastern coastal waters of the Laptev Sea and can be noticed at the western shores of the Lyakhovsky, Kotelny islands. The characteristic features of inter-seasonal variations of flows are analysed.

The results of statistical analysis of currents in an ice-free period (July-October) from ADCP buoy stations installed at the bottom suggest that synoptic variability of flow greatly contributes to the character of the prevailing circulation in summer, it also determines the direction stability of currents.

Integrated science projects, combined with input from the monitoring of "educated" sampling platforms such as whales, will greatly advance our understanding of the structure of Arctic marine ecosystems and the factors that control them. These continued efforts will help us to better understand the impact of a warmer Arctic on marine mammals. New genetic and chemical analysis methods, are the most promising future research directions. These continued efforts will help us to better understand the impact of a warmer Arctic on marine mammals.

### **Supervision of white whales (*Delphinapterus leucus*) in Kandalaksha Bay**

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During 39-tit the summer period we studied white whales of the White Sea. White whales were studied, mainly, in daylight saving time. White whales of Dvinsky, Mezensky, Onega and Kandalaksha Gulfs were investigated. It was found out that in the White Sea the white whale adheres to local habitats. Especially it concerns females with cubs. Whereas males are inclined to migrations and transitions in adjacent to sites of dwelling of females with cubs areas. In these areas males hunt on various kinds of fishes.

Studying of a white whale spent to the period of summer seasons in 1997, 1986, 1987, 2001-2006, 2011-2013 and 2016-2018 with use of routeing (ship) and stationary supervision by a standard technique it is continuous in the daytime with use of field-glasses BPTS5 8x30M and YUKON 30x50, and also a telescope (30x50).

For the first time we observed white whales in Kandalaksha bay in the summer of 1979 when N.A.Pertsov has shown that they float aside islands Great. Two white whales floated towards top of Kandalaksha bay, cubs with them were not. A favourite delicacy of white whales - White Sea a herring. Some kinds of a herring are found in Kandalaksha bay. White whales eat also a cod, навагой, a flounder which it is a lot of in Kandalaksha bay. The white whales observed in Kandalaksha bay, are a part of Solovetsky local herd. The herd is made about 150 individuals, from which by the most part - females with cubs and a smaller part - males. Apparently, males also are observed in Kandalaksha bay. It is shown that a basis of herd of white whales family groups till 5-10 white whales. The herd of white whales consists of uneven-age groupings which consist of families. And the basis of social structure of local herd is made by the primary family including a female and its cubs - an one-year-old cub and сеголетка. Each family has the site of a child-bearing, therefore herd and is local. The males entering into local herd, carry out reproductive and protective function. Young males at the age of 3-4 years leave herd, and adult males come to herd. They co-operate with young males who find skills of gregarious behaviour: learn to hunt for jams of fishes. In Kandalaksha bay they hunt groups on 5-6 animals, the part of such group to us and could be observed.

By long-term supervision it is established that white whales in the White sea, really, live locally. From year to year certain number of white whales in this or that area is supported. Females with cubs are more adhered to local sites of dwelling whereas males make movings on adjacent sites where hunt on various kinds of fishes.

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## **Different ways of hydranth formation in thecate and athecate hydroids**

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Colonial hydrozoans (Cnidaria, Hydrozoa) are good model objects for evolutionary morphology investigation. These animals have modular organization. Most of hydrozoans from subclass Hydroidolina belong to the two main groups – athecate and thecate hydroids. These groups differ in certain features of hydranth morphology and hydranth development.

In present work we analysed the process of hydranth development (from hydranth rudiment to tentacles formation) in typical thecate species *Gonothyraea loveni* (Allman, 1859), typical athecate *Sarsia tubulosa* (M. Sars, 1835) and atypical thecate *Halecium halecinum* (Linnaeus, 1758). The latter species is characterised by reduced hydrotheca, so the hydranth can't retract into it. This morphological feature makes it similar to athecate species. The development of *Halecium* tentacles during hydranth formation display some differences from other thecate species.

Obtained data showed, that the hydranth formation of thecate and athecate hydrozoans has similar features, regardless of the hydrotheca presence or absence. But, in *Halecium* hydranth development differs from that in both groups, and these differences are greater than differences between typical thecates and typical athecates.

## **Secrets of the White Sea crustaceans**

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For a number of the White Sea crustaceans the intriguing details of their life cycle, external morphology and anatomy remain unknown. Mostly these are various parasitic taxa. Probably the most mysterious are the so-called Y-larvae of the subclass Facetotecta, found in marine plankton in all over the world. Adult stages of of Y-larvae are not discovered yet. For the first time nauplii of Facetotecta were described more than a hundred years ago (Hansen, 1899). Afterwards Y-nauplii were found in different regions of Atlantic, Pacific and Indian oceans. The body of the facetotectan nauplius consists of frontal part covered with dorsal head shield and protruding rear part. The dorsal side of nauplii ornamented with cuticular ridges forming polygonal pattern. Only many years later a post-naupliar larval stage called Y-cypris was discovered (Bresciani, 1965). Y-cypris consists of cephalon with 5-segmented antennules armed with grasping hook, labrum and modified head appendages; thorax with 6 swimming thoracopods, and 2-4-segmented abdomen with large telson terminated with furcal rami. Univalved dorsal carapace with cuticular ridges covers thoracic somites of the Y-cypris.

The position of Y-larvae among Crustacea remained uncertain for a long time. Now they are recognized as a separate subclass Facetotecta within the class Thecostraca.

The species *Hansenocaris itoi* was described from the White Sea, and the larval development was considered to be fully traced for this species, including 5 naupliar and one cypridiform stages (Kolbasov, Høeg, 2003). The facetotectan larvae were collected in plankton in April – July 2018 at the WSBS, MSU. It has been found that Facetotecta, in fact, has at least 6 naupliar stages. Additional laboratory experiments with molting hormone (20-Hydroxyecdysone) showed that induced molting of the Y-cypris leads to a peculiar worm-like juvenile stage – *ypsigon*. This stage has been described recently (Glennner et al., 2008). We have started the studies of the external morphology and anatomy of the larval stages and *ypsigon* of the Facetotecta, as well as the analysis of molecular genetics of these crustaceans.

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### **History of study, current status and practical significance of Siboglinidae as possible indicators of underwater hydrocarbon deposits.**

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The first representative of siboglinids was found by the Dutch research vessel "Syboga" in the seas of the Malay archipelago and described in 1914 under the name of *Siboglinum weberi* by French zoologist Maurice Kollari, who found that these animals had neither mouth, nor gut (Caullery, 1914). M. Collery pointed to the similarities of found worms with Chaetopteridae polychaetes and at the same time – with Hemichordata and Echinodermata. A second kind of siboglinides *Lamellisabella zachsi* was described by the Russian zoologist V. P. Ushakov in 1933 and was assigned to a special subfamily within one of the families of polychaetes – Sabellidae (Ushakov, 1933). However, after studying *L. zachsi* anatomy the Swedish zoologist K. Johansson came to the conclusion that this organism should be considered as a representative of the independent class Pogonophora (Johansson, 1937). In 1944 K. V. Beklemishev established a new type of animal Kingdom Pogonophora (see Beklemishev, 1944). In 1955 Ivanov tried to become the author of a new type, suggesting the name Brachiata for it (see Ivanov, 1955), but the rules of priority in zoology forced him to return to the name Pogonophora (see Ivanov, 1960).

In the 40-60-ies of the twentieth century the idea of pogonophores relationship with the semi-chords and other Deuterostomia (Caullery, 1944; Beklemishev, 1944, 1964; Dawydoff, 1948; Ivanov, 1960, etc.) was dominated, although some zoologists defended the belonging of pogonophors to annelids (Livanov, Porphyrieva, 1962, 1965). The annelid nature of pogonophors has not been recognized for a long time, and the reason was simple: all studied worms had the back end of the body turn off. Because of this three divisions of body composition in pogonophors was distinguished: prosoma, metasoma and mesosoma, which was compared with trunk, collar and body in Hemichordata (see Caullery, 1944, 1948; Beklemishev, 1944, 1964; Dawydoff, 1948; Ivanov, 1960, et al.). Only in 1963 the Swedish zoologist M. Webb discovered opistosoma in living pogonophors, which consists of multiple segments bearing chaetes (Webb, 1963, 1964).

In 1966 large gutless worms were found near the coast of California, which were described by Swedish zoologist M. Webb as *Lamellibrachia barhami* and assigned to the new order Vestimentifera inside the type of Pogonophora (Webb, 1969). Later the rich vestimentiferans fauna was discovered in hydrothermal oases in the Pacific ocean (Jones, 1980, 1985). M. Jones elevated Vestimentifera to the rank

of type along with the type of Pogonophora (Jones, 1985). It was soon revealed the secret power gutless worms feeding. In the cells of the special authority (trophosome) of vestimentiferans chemoautotrophic symbiotic bacteria were found that oxidize hydrogen sulfide and ensure retention of carbon dioxide in the Calvin-Benson cycle [Cavanaugh et al., 1981; Felbeck, 1981, 1985, et al.]. Symbiotic chemoautotrophic bacteria have also been found in the cells of the median celomic bag of pogonophors (Southward et al., 1981, 1986).

In 90-es of the twentieth century the taxonomic status of pogonophors and vestimentiferans began to decrease dramatically. Molecular genetic studies confirmed the identity of pogonophors and vestimentiferans to the Annelida type (see Black et al., 1997; McHugh, 1997; Rousset et al., 2004; Halanych, 2005, et al.). The taxonomic rank of pogonophors and vestimentiferans decreased from the level of independent types to the level of subfamilies within one of the polychaete families: field marshals were demoted to corporals. This is absolutely unprecedented for modern zoology, which is dominated by the tendency to increase the rank of taxa.

According to modern concepts, the Siboglinidae family includes 4 subfamilies: Vestimentifera, Pogonophora(=Frenulata), Scleroliniae and Osedacinae (Hilario et al., 2011; Karaseva et al., 2016). The subfamily Vestimentifera includes large worms, reaching the size of 1.5 m with a length of tubes up to 2.5 m or more. Vestimentiferan trophosome is inhabited by sulfide-oxidizing bacteria. Vestimentiferans live mainly in the depths of batial and abyssal in hydrothermal oases in the Pacific ocean, as well as in areas of cold hydrocarbon seeps throughout the world ocean. The composition of the subfamily Pogonophora (=Frenulata) consists of thin worms not larger than 25 cm, but their long tubes reach 1.5 m, but their diameter does not exceed 2.5 mm. They inhabit soft soils throughout the World ocean, mostly at depths of batial and abyssal, several subtidal species are known. Most species have sulfide-oxidizing symbionts, only one species (*Siboglinum poseidoni*) shows the presence of methane-oxidizing bacteria. Subfamily Scleroliniae includes the thinnest hair-like worms with a tube diameter of about 0.1-0.2 mm. They live on pieces of sunken wood, ropes, are also found on soft soils. Representatives of the subfamily Scleroliniae have sulfide-oxidizing bacteria. The subfamily Osedacinae includes worms that settle on whales skeletons and other large vertebrates. The body of representatives of a single genus *Osedax* carries tapered outgrowths that penetrate deep into bones. Worms of the genus *Osedax* have heterotrophic symbiotic bacteria that oxidize lipids remaining in bones.

Siboglinidae living on soft soils are usually associated with areas of hydrocarbon seeps in spite of the fact that the vast majority of species have sulfide-oxidizing bacteria. This is due to the microbial anaerobic oxidation of methane associated with sulfate reduction, resulting in high concentrations of hydrogen sulfide in the sediment at hydrocarbon seepage sites (Joye et al., 2004; Omeregic et al., 2009). Siboglinidae that live in hydrothermal oases absorb all dissolved gases through a well-developed tentacles. Siboglinidae of cold hydrocarbon seeps live on soft soils, their tube are emerged deeply into the sediment. They absorb hydrogen sulfide not by tentacles but directly from the sediment depth through the loose walls of the tube and body coverings (Julian et al., 1999; Freytag et al., 2001; Dattagupta et al., 2006). For this reason Siboglinidae can be considered as a possible organisms-indicators of high concentrations of hydrocarbons in the sediment accompanying underwater oil and gas fields.

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## **Hydroid “automata” - an example of self-organization of a modular organism**

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The purpose of the study is to describe the mechanisms of self-organization in colonial hydroids, which belong to modular organisms. The task is to determine the ability of the transport system to move food particles over long distances (relative to the size of the colonial organism), although the hydroplasmic currents of the intracavitary fluid are created by a plenty of disordered pulsators acting as autonomous automata.

The main research method is micro video recording of body pulsations of a colonial organism, and also a growth of stolons and the movement of particles in the gastrovascular cavity. An additional method is a simple visual scan of the movement of particles in the gastrovascular cavity of the coenosarc. Data analysis is based on a set of quantitative indicators and indices developed earlier (Marfenin, 2015) derived from three primary parameters measured every half-minute during at least 2 hours: the lumen of the stolon, the velocity of particles in the cavity of the stolon, the amplitude of the growth pulsations of the stolon apex.

The second method: visual tracking of the movement of particles through the stolon. The third method: regular registration of the direction of movement of hydroplasma in each stolon module. The fourth method: the calculation of the values of the “working volumes” of the pulsators (the difference between the maximum and minimum volumes) and the lengths of the currents derived from them, which are depending on the size of the lumen of the stolon.

A discrepancy was found between the data of direct scanning of the movement of particles and the calculated length of currents using the data of local time-lapse video recording. Using direct observations of the movement of particles, it was found that continuous flows of hydroplasm can cover up to ten modules of a stolon and extend non-stop throughout the entire length of a small colony. However, according to the results of the video recording of the pulsations and the speed of the flows, the length of unidirectional flows does not exceed two modules in the stolon.

This contradiction confirms the hypothesis that a continuous flow consists of a plenty local flows and must be due to the hydraulic interaction of quasi-independent pulsations generating flows within a modular organism. The transport system, thus, functions as a set of automata interacting with each other, and can be used as a full-scale biological model of self-organization of a decentralized system.

## **Cave colonization and morphological change: annelids as a case of study.**

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Subterranean aquatic systems are island-like habitats spread all over the world consisting of many caves linked by a common geological history but displaying different ecological parameters (e.g. distance to the sea, topography, depth). Therefore, they comprise numerous, discrete, and varied entities that facilitate independent colonization events by epigeal biota, providing many replicates of comparable evolutionary processes. The data produced over the past 100 years of research collectively indicates that subterranean aquatic systems harbor a high percentage of local endemism and disharmonic animal

communities when comparing them to surrounding epigeal environments. Whereas it is widely accepted that the study of cave communities is important for understanding the evolutionary history of numerous taxa, our knowledge on species diversity within caves is highly biased in favor of large-bodied animals, particularly crustaceans. This is an unfortunate situation not only because several animal lineages, crucial to our understanding of the Metazoan tree of life, might be waiting to be discovered within caves; but also, because they can potentially be used as a model to understand colonization, speciation, and adaptation in the ocean. Therefore, a better understanding of cave diversity might not only improve our view of the Tree of Life, but also offer a tool to better understand general evolutionary processes. We aim at illustrating that by presenting the results of our survey of cave annelids from subterranean systems scattered throughout the Caribbean, Bermuda, Bahamas, Canary Islands, Christmas Island, and the Mediterranean. Out of the 1514 species recorded in the World Register of Cave Species (WoRCS), one of the most extensive databases on cave marine fauna currently available, approximately 100 species of annelids have been cited in caves with many more remaining to be recorded. Although many of these discovered annelids represent marine species occurring near cave entrances and marine-influenced areas, detailed morphological analyses, combining various microscopy techniques including light, scanning electron, and confocal laser scanning, has revealed that approximately 50 species are exclusive to caves, never to be recorded in the ocean. Our phylogenetic analyses have also shown that while several of these new cave exclusives are sister to shallow water groups, a few newly discovered members of Polynoidae, Scalibregmatidae, and Hesionidae are unequivocally related to deep sea lineages. Even more surprising is the discovery of several cave-exclusive lineages within Nerillidae, Fauveliopsidae, Polynoidae, and Spionidae, with species restricted to caves in geographically distant areas. Finally, comparative analyses indicate that whereas some of the unique morphological features of these annelids might represent plesiomorphies, others unequivocally are secondary adaptations to novel cave habitats. Our results are evaluated in regards to their contribution to our understanding of annelid evolution, and discussed in relation to the preliminary information available from other cave groups. Our general conclusion confirms that marine cave habitats represent important sources for novel zoological discoveries, and more attention should be paid to their study.

### **Ontogenetic development of the buccal musculature and armature in nudibranch mollusc**

#### ***Eubranchus rupium* (Møller, 1842)**

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*Eubranchus rupium* is a common nudibranch species in the White Sea. The representatives of the species are drill-feeders and feed on colonial hydroids of genus *Obelia*. *E. rupium* has a planktonic larva – veliger, which settles on the *Obelia* colony then metamorphoses. The juvenile individuals may be subdivided into six categories according to their external morphology. We called these categories post-larval stages, where the first stage appears after the settlement and metamorphosis of the veliger and the sixth stage is represented by a fully matured adult individual. All the stages inhabit *Obelia* colony and

may be found together. Beginning from the first stage the juveniles switch to the drilling feeding mode, which is characteristic for adult individuals. Here, we study the morphology of the buccal complex in different post-larval stages of ontogenetic development of *Eubranchus rupium*.

The general morphology of post-larval stages' buccal complexes was studied by confocal laser scanning microscopy and scanning electron microscopy. The general morphology of adult molluscs' buccal complex was studied by confocal laser scanning microscopy, light microscopy and scanning electron microscopy. The 3D-reconstruction of the buccal complex of the adult specimen was constructed as well.

According to our data, even the first post-larval juvenile stage has similar groups of buccal muscles and the radula and the jaws of similar morphology as the adult individuals. During body growth, the size of buccal complex proportionally increases. Unlike nudibranchs of the genus *Dendronotus* young specimens of *Eubranchus rupium* have the same feeding objects and the same feeding mode as the adult ones; that is why the radula in small ones is the same as in adults. As the buccal armature in young and mature animals is identical, the buccal musculature should be the same in juvenile and adult specimens.

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### **Habitat characteristics of tropical Christmas tree worms, *Spirobranchus corniculatus* from Pulau Bidong, South China Sea**

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Christmas tree worms (CTW) from genus *Spirobranchus* is one of the iconic coral reef species and popular in the aquarium trade. The worms are believed to live mainly on massive coral species in shallow waters. However, information on CTW habitat in the south-east of the South China Sea is insufficient. Hence, the study is intended to determine habitat characteristics of tropical CTW, *Spirobranchus corniculatus* at Pantai Pasir Cina of Pulau Bidong, South China Sea. Observations were done using belt transect technique by SCUBA divers in three depth ranges, i.e. <3 m, 6-4m, and 10-7m during low tide. Number of *S. corniculatus* per coral colony, coral species were recorded. A total of 446 *S. corniculatus* were found inhabiting coral reef of Pantai Pasir Cina during observation with 58.5% of massive corals observed have *S. corniculatus* as symbionts. Majority of *S. corniculatus* were found in depth less than 6 m and live on coral from genus *Porites*. Nevertheless, several individuals were found living on other coral genera including *Astreopora* spp, *Montastrea* spp and *Montipora* species. Results from this study could be beneficial for determining the coral reef status using CTW as indicator species.

### **Visualization of locomotion of sedimentary invertebrates of the Kandalaksha Bay of the White Sea** ***Naduvaeva Elizaveta V., Vorsepneva Elena***

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The progress of technology over the past decades has allowed us to observe animals in natural

surroundings not only on the land, but also under the water. Due to the amateur and professional photography and video, the secrets of relationships within the populations, between different species of animals have been discovered, the processes of reproduction, hunting, feeding and much more have been visualized. Most often, underwater photography and video is used in popular-science films, however, the visualization of some processes can be key for understanding the biology of various species. Most of all large vertebrates and invertebrates that inhabit the pelagial and inhabit the surface of the bottom are removed, which is due to the easy accessibility of the habitat, but it is impossible to understand how an animal lives inside the sediment in natural conditions. However, a convenient visualization method is the replacement of muddy soil with gelatin and the subsequent observation of bottom dwellers in the laboratory. For video recording of fast-moving animals, you can use video, and for slower ones, you can use TimeLapse, which allows you to take photos with a specified period. This research presents a visualization of the process of digging up for: Annelida (Polychaeta): *Arenicola marina*, *Ophelia limacina*, *Nereis virens*, *Nephtys sp.*; Hemihordata: *Saccoglossus mereschkowskii*; Cnidaria: *Halcapa duodecimcirrata*; Cephalorhyncha: *Priapulus caudatus*; Mollusca (Bivalvia): *Portlandia arctica*, *Macoma balthica*, *Yoldia hyperborea*; (Chaetodermatidae): *Chaetoderma nitidulum*. Based on the results obtained, a conclusion was made about the types of movement of animals depending on the types of soils in which they inhabit. Thus, the wave-like movement occurs in invertebrates that live in sandy soils, and direct peristalsis has been observed in species found in silty soils. Such types of movement are characteristic of polychaetes and worm-like animals examined in this study - *Saccoglossus mereschkowskii*, *Priapulus caudatus*, *Chaetoderma nitidulum* and *Halcapa duodecimcirrata*. As for bivalve mollusks, their characteristic movement occurs due to two-core system, which also differs in detail for bivalves living in different types of substrates.

### **Spicules networks of the dorid mollusks (Gastropoda, Nudibranchia)**

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Nudibranch mollusks is the order of soft-bodied gastropods. For protection, different nudibranch mollusks have adapted in their own way. For example, species from the group Aeolidioidea embed cnidocytes stolen from various Cnidaria which they feed upon. Cnidocytes get into the special bags (cnidosac) at the tips of the papillae through the system of overgrown digestive gland. Species of another group (Doridacea) are characterized by spicules, which are in the integuments. Even though the spicules in the Doris integuments have been described for a long time, the structure of the spicular apparatus has been studied extremely fragmentary. This paper presents the results of the study of the spicular apparatus of three species from the *Onchidoridae* family (*Acanthodoris pilosa* (Abildgaard in Müller, 1789), *Adalaria proxima* (Alder & Hancock, 1854), *Onchidoris muricata* (O.F. Müller, 1776)).

The collection of material was carried out in the summer period 2016-2018. in the Kandalaksha Bay of the White Sea in the vicinity of BBS them. NA Pertsova divers, as well as manually on the littoral. We used classical methods of light and scanning electron microscopy.

Onchidorid spicules are not randomly arranged but are assembled in tracts (vertical in papillae and horizontal across the rest of the mollusk). At the first time was noted the special structure of the transition

zone between the vertical and horizontal tracts (star tract). Spicules of various shapes are involved in the formation of paths. It is noted that the method of packing spicules affects the density of the integument. Thus, the four-axis form of spicules allows *O. muricata* to form extremely dense clusters in the notation, due to the special arrangement of the spicules — the secondary axes of the spicules lie according to the key-lock principle. Spicules with a monolithic, mixed, as well as concentric internal structure are characteristic of this. Onchidorida, while the internal structure of spicules does not affect its shape.

The spicular tracts of the studied species, significant differences were found. So, *A. pilosa* has no vertical tract in the form of spicules located in papillae rosette, but at the same time, the presence of spherical spicules, which are not characteristic of *A. proxima* and *O. muricata*, is noted. The structure of horizontal tract is similar, but it has a number of specific features. *A. pilosa* has extremely thick integuments in the central part, and spicules are completely absent, whereas for *A. proxima* and *O. muricata* the thickness of the spiculae exceeds the thickness of the integument by about 3 times. Thus, we can conclude that the thickness of the integuments is correlated with the packaging and the shape of the spicules. The method of packing spicules depends on their shape and affects the density of integuments.

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### **The role of crustaceans of the genus *Daphnia* in the zooplankton communities of the rock baths of the Keretsky islands (White Sea)**

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The rock pools ecosystems are characterized by extreme conditions, determined by the small size of water bodies and sharp fluctuations in physicochemical characteristics. Since 1990, the members of the Department of Ichthyology and Hydrobiology of St. Petersburg State University investigated more than 150 rock pools with a wide range of mineralization, from freshwater to hypergalin ones.

In freshwater pools, out of 33 zooplankton taxa, more than half are crustaceans. These are 12 species of Cladocera and 6 of Copepoda. According to our research, it has been shown that in freshwater baths the season mean number of planktonic invertebrates was 10–900 ind / l, varying from a few to 10 thousand ind./l. Biomass in some pools changed from 0.1 to 220 mg / l, reaching sometimes 900 mg / l. due to the mass development of *Daphnia* species. In general, a freshwater complex, including *Daphnia* species, is common at salinities up to 3‰. We paid special attention to two pools with low salinity (1-3‰) on Medyanka island where *Daphnia (C.) magna* and *D. pulex* reached a high abundance. At the same time, when seawater enters and the salinity increases to 5‰, the community may completely eliminated.

At total, *D. longispina*, *Daphnia (C.) magna* and *D. pulex* were noted in the pools of differetn islands. Moreover, the distribution of various species directly depends on the chemical indicators of water bodies — the pH and the concentration of biogenic elements. At the same time, the presence of two species of *Daphnia* was noted simultaneously in 20% of the studied ponds,. In 2017, about. Medyanka indicated the presence of another species of *Daphnia* - *D. curvirostris*. Since we have not noted this species before, the materials of past years require a thorough revision. In 2017, the number of *Daphnia* in the baths studied averaged  $11.2 \pm 4.4$  ind / l.

Thus, it is shown that Cladocera play the main role in the communities of freshwater rockpools, and accounts for more than 70% of the total number and biomass in most water bodies. This can be

explained by their high capacity to adaptations to high fluctuations of abiotic factors. The large cladocerans *Daphnia (C.) magna* and *D.pulex* are dominated in community biomass, and generas *Bosmina* and *Chydorus* in common number.

### **The kinetid of *Ministeria vibrans* and its importance for the reconstruction of the ancestor of Metazoa**

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The kinetid (flagellar apparatus) of *Ministeria vibrans* (Opisthokonta, Filasterea) has been studied in this work. This research has been carried out within the framework of comparative-morphological studies in order to reconstruct the traits of the unicellular ancestor of Metazoa. *Ministeria vibrans* is of great interest for comparative analysis, since the Filasterea group is the next lineage related to Metazoa after the choanoflagellates. Besides *Ministeria vibrans* is one of the few organisms in the Opisthokonta group that have a flagellum at vegetative rather than distributional stages. Detailed images of the main elements of the kinetid (transition zone, microtubule and fibrillar bodies associated with the kinetosome, the relative positions of the kinetosome and centriole, as well as the kinetosome and nucleus) were obtained and the general scheme of the flagellar apparatus was produced. The kinetid structure of *Ministeria vibrans* was compared with the previously reconstructed choanocyte kinetid structure of the common ancestor of Porifera, as well as with the kinetid structure of the choanoflagellates. The similarities in the kinetids of the Filasterea representative and the ancestral choanocyte of Porifera were noted. Some conclusions about possible evolutionary transformations of the kinetids within the Filasterea + Metazoa + Choanoflagellata lineage were drawn out. The obtained results can be used in the reconstruction of the structure of the unicellular ancestor of Metazoa and the choice of an evolutionary scenario for the appearing of multicellularity.

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### **New data on organization of White Sea phoronid *Phoronis ovalis***

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*Phoronis ovalis* is a single phoronid species discovered in the White Sea. Specimens from White Sea have body length about 1 mm. The lophophore bears 20-24 tentacles. The body is subdivided into anterior and posterior body parts. The terminal ampulla is not expressed as distinct body part. The anus is located on the prominent large anal hill. The lophophore base is surrounded by muscle cylinder that is formed by radial bundles of outer muscles; middle layer is represented by separated bundles of longitudinal muscles; the inner layer is formed by numerous transversal muscles. Anterior portion of the body in *P. ovalis* lacks radial muscles, which was described in *Phoronopsis harmeri* and apparently provides rotation of the lophophore accordingly to local water currents. In *P. ovalis*, separated longitudinal muscles of the muscular cylinder of the lophophore base provide the complex movements of the lophophore. The circular muscle of the lophophore extends along the inner perimeter of the lophophore, at the tentacle bases. In

each tentacle, two longitudinal bundles of muscles pass along the frontal and abfrontal sides of the tentacle. At the base of each tentacle, there are two bundles of radial muscles, which contact each other on the medial line of the tentacle. The frontal muscle of tentacle starts from the circular muscle of the lophophore, whereas abfrontal muscle is not evident in the tentacle bases. “Flick-like” movements of each tentacle are created by longitudinal tentacular muscles, whereas the radial muscles of the tentacle base provide the wave movements of tentacles. The musculature of the anterior portion of the body consists of transversal and longitudinal muscles. The latest is represented by 23-25 large bundles. Numerous radial muscles pass from the body wall and intestine. In the posterior body part, the musculature looks like a net of thin inner longitudinal and outer transversal muscles. The musculature of terminal end of the body is represented thick net of muscles, in which the longitudinal muscles form outer layer, whereas transversal muscles form inner layer. Organization of musculature allows to conclude that *P. ovalis* has real ampulla. The inversion of the muscular layer, which was previously discovered in *P. harmeri* and is also present in *P. ovalis*, is probably characteristic of all phoronids. The specificity of organization of musculature in terminal end of the body correlates with that great role which the ampulla plays in digging into substratum.

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### **Localization of the p48 protein from the morular blood cells *Styela rustica* (family Styelidae) in the tissues of the ascidians of the White and Japanese Seas**

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In the ascidian *Styela rustica* morular blood cells contain two major proteins the function of which is still unknown, one of them is a protein with a molecular mass 48 kD - p48.

The aim of the present study was to find possible homologues of the p48 in the ascidians *Styela coriacea* (family Styelidae), *Molgula citrina* (family Molgulidae), *Boltenia echinata*, *Halocynthia aurantium* (family Pyuridae) and to determine p48 tissue specificity.

In order to show the presence of p48 in the tissues of sea squirts we used indirect immunolabeling method on paraffin sections.

Our results showed the antibodies binding to morular blood cells, test cells and tunic matrix. The most prominent binding of antibodies was observed in the strongly tanned peripheral layers of the tunics. It was also shown that the antibodies marked test cells the hypothetical function of which is the formation of larval tunic. Those findings support the hypothesis that p48 is a component of the tunic extracellular matrix and takes part in its sclerotization being a possible substrate of phenol oxidase system.

### **Tubes and other constructions of marine worms**

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Marine Annelides make up about half of the benthic biomass living on the bottom of the world ocean. Most of the worms are active builders. They build tubes, constructions and labyrinth-like passage systems in the upper sediment layer, which form a system of microbiotopes, significantly change the

macro and microstructure of the upper sediment layer, oxygen distribution, porosity and many other parameters that determine the possibility of colonization of the sediment layer by small animals, fungi and specific microflora. The fine structure of the tubes of sea worms was studied in representatives of more than 13 families and more than 25 species of annelids. In addition to the annelids, the structure of the tubes of several species of phoronids and the constructions of some marine amphipods were studied. The obtained data showed that the tubes of polychaetes differ in a number of ultrastructural characters. The thin structure of the tube allow us to determine the owner of the tube to the family, and in some cases to the genus or species level. The main characters of agglutinated tubes are the mutual orientation of the layers in the inner cylinder of the tube, as well as the details of the packing and fixing of sediment particles in its outer layer. The microstructure of the amphipod constructions differs significantly from that of annelid. An analysis of a number of fossil materials – remnants of tubes (supposedly belonging to marine annelids) showed that the microstructure characteristic of polychaete tubes is rarely preserved, since the grain of the rock replaces the material of the tube usually larger than the elements of the microstructure. At the same time, some types of especially characteristic tubes could be identified in the fossil state. The study of the structure of the tubes in many cases will allow answering questions about the lifestyle of animals living in the midst of the ground and inaccessible for direct observation. This concerns questions about how animals increase the tube size (length and diameter of the tube) as they grow, whether animals are able to dissolve the walls of the tube. How animals build branching tubes. The ability of the worms to soften or dissolve the organic material of the tube allows us to ask in what degree, the tubes can protect their owners from predators.

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## **PHYSIOLOGY OF MARINE ANIMALS**

### **Renaissance of physiological research at White Sea Biological Station of MSU in 2007-2018**

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Despite important achievements have been reached by Soviet physiologists working at White Sea Biological Station (WSBS MSU) in the middle of twentieth century, physiological research was completely stopped in 90s. However, during the last decade (2007-2018) Department of human and animal physiology of MSU has managed to establish a new electrophysiological lab at WSBS and conduct several projects in the field of comparative cardiac physiology. The report will focus on the major results of these studies together with experience of 3 International summer schools on comparative physiology held at WSBS MSU during the last decade. The perspectives of further physiological research development at WSBS will be discussed.

### **Comparative analysis of motor innervation in axial musculature of vertebrates**

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The report will cover structural-functional peculiarities of motor innervation of the fast axial skeletal musculature in the different groups of fish (Chondrichthyes, Chondrostei, Teleostei) and

cyclostomes. Own and literary data concerning the nature of “double” innervation phenomenon in fast skeletal muscle fibers will be discussed by virtue of comparative electrophysiological and morphological analysis of neuromuscular junction organization in muscle fibers from river lamprey (*Lampetra fluviatilis*) and White Sea subspecies of atlantic cod (*Gadus morhua marisalbi*).

### **Adaptations of ectothermic animals dwelling at high latitudes**

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Ectothermic animals of high latitudes face great temperature changes during a year. Some of them are able to adjust their physiological functions to low temperatures to maintain activity in winter period. Most of the studies of thermal acclimation are based on artificially modelled cold acclimation, but some of the recent researches focused on acclimatization in natural conditions allow to suggest that its effects are much stronger. Thus, the aim of the present study was to compare the effects of these two acclimation models on heart electrophysiological phenotype in European shorthorn sculpin (*Myoxocephalus scorpio* L.), a eurythermal fish dwelling at temperatures from -1,5°C to 16°C. The animals were divided into three groups according to their acclimation protocol: 1) summer-acclimated (SumAcz, caught in summer, acclimatized to 12°C); 2) cold-acclimated (ColdAcl, caught in summer, artificially acclimated to 3°C) and 3) winter-acclimatized (WinAcz, caught in March, acclimatized to 2-3°C) fishes. APs and ionic currents were recorded from enzymatically isolated cardiomyocytes of sculpin using standard whole-cell patch-clamp method.

Action potential duration at the levels of repolarization 50% and 90% was significantly decreased in ventricular cells from WinAcz sculpins if compared to the cells from SumAcz group; no differences were found between SumAcz and ColdAcl groups. Such changes in AP configuration can be explained by changes in repolarizing currents densities: potassium currents  $I_{Kr}$  and  $I_{K1}$  both in ventricle and atrium were profoundly upregulated by naturally occurring acclimatization. Low temperature adaptation did not change steady-state activation of  $I_{Kr}$  current and its time-dependent inactivation. Calcium L-type current peak amplitude and charge transfer were also larger in atrial and ventricular myocytes from WinAcz animals, but time-dependent inactivation was slowed by winter acclimatization, and steady-state activation curve was shifted to the right. Surprisingly, but fast sodium current was significantly downregulated in myocytes from WinAcz group in comparison to the animals caught in summer. In atrial cells seasonal acclimatization also affected activation and inactivation of  $I_{Na}$ : the steady-state activation curve was shifted to the left and the fast time inactivation constant was significantly increased.

Thus, naturally occurring seasonal acclimatization profoundly alters the electrical activity of sculpins myocardium while artificial thermal acclimation fails to do the same. Most of the changes in electrophysiological phenotype of sculpin cardiomyocytes are due to changes in channels density, but some of the described changes can be explained by a shift in channel's isoforms ratio.

## **The role of the types of ontogeny, the formation of endothermy and acoustic stimulation in the development of hearing and behavior in birds**

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Endothermy, a high level of organization, the development in the egg make birds a convenient model for studying behavior in early ontogenesis. A variety of ontogeny types in birds form a series that allows for a comparative study of the development of sensory systems, in particular, hearing, and acoustically guided behavior. Hearing sensitivity develops early than vision in endothermic animals. Feeding behavior forms first in the ontogeny of birds and mammals, then defensive behavior formed as freezing reaction, which followed by escape reaction. The defensive behavior appears in altricial nestlings at the time of opening the eyes as a response to a parent alarm call. The defensive behavior appears in altricial nestlings at the time of opening the eyes as an answer to parent alarm call.

Three stages stand out in the development of hearing in all birds. The duration of the stages are determined by the type of ontogenesis. Stage II is characterized by the rapid development of auditory sensitivity and is a sensitive period when acoustic stimulation allows one to adjust hearing to species-specific acoustic signals. The moment of establishing effective thermoregulation occurs when the nestling or the chick can maintain body temperature above 37 ° C at an ambient temperature equal to the lower critical temperature of the adult thermo-neutral zone. The transition to the III stage of development coincides with the moment of establishing effective thermoregulation. The boundaries between stages I and II are also characterized by certain qualitative changes in the development of endothermy and metabolic rate.

The nature of changes and fluctuations in RR intervals of ECG (HVR variability) adequately reflects the general functional state of the pied flycatcher (*Ficedula hypoleuca*) nestlings and the main pattern of behavior, feeding and defense reactions. In the feeding-sleep-activity cycle, the RR rhythmogram is characterized by relatively regular fluctuations with a period of 7–20 s. The feeding reaction is always accompanied by a sharp decrease in the RR intervals, the wave structure of the rhythmogram is usually preserved. When chicks are cooled, oscillations with a period of 7–20 s disappear, the amplitude of respiratory oscillations sharply decreases, and changes in RR intervals are ensured by their linear dependence on body temperature. Defensive behavior in response to the acoustic alarm of parents in nestlings aged 6–9 days (period II of hearing development) is characterized by sinusoidal oscillations of the RR rhythmogram with a period of about 33 s.

## **Significance of electrical excitability in thermal tolerance of fish heart**

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Electrical excitability is defined as the ease with which an all-or-none action potential (AP) is generated by the interaction of ion channels in the plasma membrane of the cell. Rate and rhythm of the vertebrate heart is controlled by electrical excitation (EE) in the form of cardiac AP, which propagates from the site of origin in the sinoatrial node through the cardiac syncytium. At high temperatures

approaching the upper thermal tolerance of the fish, EE may fail due to thermal deterioration of ion channel function. In particular, ventricular excitation seems to be sensitive to heat-induced failure, which appears as missing ventricular beats, short periods of ventricular tachycardia, bradycardia and asystole. Ventricular failure may be due to temperature-dependent mismatch between depolarizing and repolarizing ion currents of ventricular myocytes. Initiation of ventricular AP is dependent on two antagonistic currents: the inward sodium current (INa) enhances excitability and the outward potassium current (IK1) decreases excitability. These currents are differently affected by high temperature: INa starts to decline well below the upper thermal tolerance limit of the fish, while IK1 continues to increase beyond this limit, i.e. when INa decreases IK1 still continues to increase. As a consequence a mismatch between current source (depolarizing INa) and current sink (repolarizing IK1) develops and INa fails to depolarize the membrane to the threshold voltage of the cardiac AP. Ventricle is expected to be particularly sensitive to high temperature due to the high density of IK1 in ventricular myocytes.

**The agreement between physiological and “mitochondrial” sex of blue mussels *Mytilus edulis* and *M. trossulus* under effects of hybridization and introgression in northern Europe**

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Blue mussels *Mytilus* sp. have distinct gender-associated mitochondrial genomes due to particular type of inheritance - doubly uniparental inheritance (DUI). In case of hybridization and introgression DUI can be disrupted. In this paper we identify histologically physiological sex and “mitochondrial” sex of *Mytilus edulis*, *M. trossulus* and their hybrids from Scotland, Norway, the White and the Barents Sea. The rate of agreement between physiological and “mitochondrial” sex is quite high. However we identify some anomalous mitochondrial haplotypes. In contrast to Baltic *M. trossulus*, mitochondrial introgression is restricted in studied mixed populations of *M. edulis* and *M. trossulus*.

**Depolarization and repolarization of the ventricular myocardium in Atlantic cod (*Gadus morhua*)**

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The study aimed at investigation into the depolarization and the repolarization pattern in the myocardium of the ventricle of the heart of Atlantic cod (*Gadus morhua*, n = 11) at 12C. The heart rate of the heart of cod is 34 ± 5 bpm. The first foci of myocardial activation appear in the subendocardium near the atrioventricular orifice, and late - in the subepicardium of the apex. The activation wave in the myocardium of the ventricle of the cod moves from the zone of the atrioventricular aperture to the region of the apex (p <0.05), and from the endocardium to the epicardium (p <0.05). The early repolarization zone is located on the subendocardium of the apex, and the late one on the subepicardium in the region of the atrioventricular orifice. In the basal part and at the top of the ventricle, the repolarization sequence from the endocardium to the epicardium (p <0.05) coincides with the direction of movement of the

activation wave. The activation-restoration intervals in the apex region are significantly less than in the region of the atrioventricular orifice.

## MARINE MYCOLOGY, MICROBIOLOGY AND ALGOLOGY

### Luminous bacteria from the White Sea

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Luminous bacteria are widely distributed in the world ocean in the form of plankton and symbiotic forms of the White Sea, as the habitat of luminous bacteria, little studied. For several years, we have isolated and studied the morphological, physiological, bioluminescent characteristics of psychrophilic strains of photobacteria (which corresponded to the species *P. phosphoreum*) - symbionts of the internal organs of fish from the Kandalaksha Bay area of the White Sea. The main source of the isolation of strains is the bottom Kerchak European *Myoxocephalus scorpius* fish.

The emission spectrum of all isolated strains is characterized by a maximum at about 478 nm. The spectral pattern corresponds to Photobacterium phosphoreum-specific luminescence spectra with so-called luciferase and so on. BFP emitters.

The specific activity of cells reaches  $10^5$  kV/s · cell in optimized conditions, the duration of the glow is more than 100 hours. During the cultivation of isolated strains of *P. phosphoreum*, the change in pH of the medium does not exceed 0.3 units. pH and occurs in the logarithmic growth phase. From transitions to the stationary phase, the pH of the medium stabilizes. The emission manifests itself in the range of NaCl concentrations of 0.5–4%, with maximum values at 2.5%. At concentrations below 0.5% and above 4% salt, a sharp suppression of cell luminescence occurs. The pH dependence of the luminescence of intact cells has shown that the strain to be analyzed has pronounced alkaline tolerance. In a wide range of pH (7.0–9.0), the bioluminescent activity is maintained at the maximum level. The temperature dependence of the luminescence showed a maximum of emission activity at 15°C. The results showed that keeping the cells at 30°C for 30 minutes causes irreversible loss of luminescence.

The bioluminescent activity and the ATP pool in growing culture, resting, and polyvinyl alcohol (PVA) cryogel (PVA) cells of photobacteria were studied. The results of the work show that these bacteria throughout the luminescent cycle (more than 100 hours) the ATP pool remains almost at a constant level of cells ( $1.0-2.0 \times 10^{-18}$  mol/cell). A quantitative assessment was made of the integral yield of photons and the ATP pool, on the basis of which it was concluded that the luminescence decay in a growing culture or resting cells is not a consequence of the limiting of luciferase reaction by energy substrates. The most important property of the photobacteria of the White Sea is increased, compared with the described strains, the duration and stability of the emission of the deep culture. These bacteria are effectively used to create various test systems for toxicology, environmental protection, medicine and pharmacology.

Technological operations for the immobilization of photobacteria in polyvinyl alcohol cryogel (PVA), procedures for storage and use of drugs in discrete and continuous biomonitoring of various classes of toxins have been developed. The physical and geometrical parameters of the biosensor for discrete and continuous biomonitoring of ecotoxicants with minimal restrictions for the diffusion of toxins have been

optimized. It has been established that the intensity and duration of the emission of cells in the immobilized state are comprehensively controlled: 1) by the duration and intensity of the luminescent cycle of the selected strain of photobacteria; 2) the composition of the medium for the formation of the gel; 3) cryogenic immobilization and reactivation technology; 4) physical and chemical conditions of storage and use of toxins.

### **Assessment of biological safety of the bacterial strains as potential probiotics of the Far East sea cucumber *Apostichopus japonicus***

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Probiotic microorganisms are quite often used in world practice in farming of many species of fish, mollusks, crustacean because of high efficiency of these biological products in decline of hydrobionts' mortality and possibility to refuse of antibiotics application. Search of biologically active strains with probiotic properties is conducted also for the Far East sea cucumber *Apostichopus japonicus*. However, despite the commercial and biological importance of this species and existence of several tens aquafarms on reproduction of Far Eastern sea cucumber in Russia, domestic works on search of probiotics for this animal are not present. During our previous researches from a gastrointestinal tract of the wild *Apostichopus japonicus* 134 strains of the cultivated heterotrophic bacteria were isolated and identified. Their ability to synthesize various digestive enzymes and to inhibit growth of pathogenic and opportunistic microflora was studied. Based on received data 11 strains of bacteria – potential probiotics of *Apostichopus japonicus* were selected. Assessment of biological safety of the chosen microorganisms on studying of their hyaluronidase, lecithinase, plasma coagulase and hemolytic activity was the purpose of the current work. Due to obtained results, all studied strains are recommended for further *in vivo* experiments with farmed sea cucumbers.

### **What we know about the fungi of the Arctic seas**

**Bubnova Ekaterina, Grum-Grzhimailo Olga**

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Research of fungi in the Arctic seas began in the late 19th century. There have been a little over 30 articles on this topic. And by 2017, only 100 species of fungi were known from the Arctic seas. Substrates such as sediments, water, wood and plant residues were investigated. The largest number of works was carried out in the Barents and White seas. The best studied areas are the Svalbard archipelago in the Barents and Kandalaksha Bay in the White Sea. In the other Arctic seas, studies are either single (Kara, Chukchi Seas), or have not been conducted. While we still know very little about the mycobiota of the Arctic seas. But researches in the arctic marine fungi has been actively developing in the last 15-20 years.

**Fungi of the littoral sediments of the Shokalsky island in the Kara Sea**  
**Bubnova Ekaterina, Grum-Grzhimailo Olga, Maximova Irina, Nikitin Dmitry**

*Lomonosov Moscow State University.*

This is the first study of the mycobiota of the littoral sediments of the Arctic Shokalsky Island. The diversity of fungi (by morphological-cultural and molecular-genetic methods), as well as the composition and structure of fungal biomass (by direct microscopic methods) were studied. Total 119 colonies of mycelial fungi and 8 yeast colonies were isolated from all the samples (from 1 to 26 colonies per gram of dry weight of a single sample). It is not enough. But the diversity of fungi is surprisingly high: 7 yeast morphotypes, 13 species of mycelial fungi (all – anamorphs of Ascomycota), 76 unidentified morphotypes of mycelial fungi (mostly non-sporulating cultures). Such a high proportion of sterile cultures was noted for the first time in culture studies of marine sediments. Molecular studies of these cultures have shown that only 10 sterile isolates belong to Basidiomycota, and all other cultures belong to Ascomycota. In general, Ascomycota (in particular – Leotiomycetes) predominate in the species diversity of mycobiota. Fungal biomass is small (average 0.196 mg / g of dry sediments), and is represented mainly by spores (average 86%). The share of living biomass averaged 47%.

**Diversity of the luminous bacteria in the White Sea**  
**Chekanov K.A., Kublanovskaya A.A., Ismailov Anvar, Lobakova E.S.**

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The cells of luminous bacteria are able to emit the quanta of electromagnetic irradiation from the visible range of spectra as a result of bioluminescence. These microorganisms are great of a practical value as a component of biosensors, because luminescence intensity depends on environmental conditions (temperature, pollutants, etc.). Most of them are endosymbionts of marine animals, such as fishes. Luminous bacteria of South seas have been described in details recently. There were no any data about diversity of White Sea luminous bacteria. In 2018, five species of fishes were evaluated: *Myoxocephalus scorpius* (Scorpaeniformes, Cottidae), *Agonus cataphractus* (Scorpaeniformes, Agonidae), *Liopsetta glacialis* (Pleuronectiformes, Pleuronectidae), *Gadus morhua marisalbi* (Gadiformes, Gadidae), *Clupea pallasii* (Clupeiformes, Clupeidae). Axenic cultures of luminous bacteria were isolated from the organisms of the fishes by a set of standard microbiological protocols. High salinity of the culture medium used was a key factor of successful cultures obtaining (0.3% wt/v NaCl). The colonies were selected based on their ability to bioluminescence. Total of 15 luminous bacteria were obtained. Based on 16S rRNA gene sequence analysis, they were related to four genera: *Photobacterium*, *Aliivibrio*, *Vibrio*, *Photorhabdus*, and *Shewanella*. Thus, White Sea luminous bacteria were related to a range of taxonomical groups differed from each others and represented almost whole abundance of prokaryotes with the ability to bioluminescence.

**Biotechnology potential of *Thiocapsa roseopersicina* strain BBS**  
**Gavirova L.A., Shestakov A.I.**

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The strain of purple sulfur bacteria *Thiocapsa roseopersicina* BBS was isolated from the estuary of the White Sea located in the vicinity of the White Sea Biological Station by Bogorov L.V. Today this is one of the most studied member of *Chromatiaceae*. Research has focused on genes and enzymes involved in the carbon, sulfur and hydrogen metabolism, biosynthesis of photosynthetic pigments. Nowadays this strain biotechnologically important because of its stable hydrogenase. Hydrogenases have found use in a variety of biotechnological applications. Enzyme obtained from BBS strain unlike others hydrogenases is oxygen tolerant, works in a wide range of temperatures. It's considered as promising electrocatalysts, especially in the development of biofuel cells and biosensors. In our work we used the immobilized enzyme as a sensitive element of the biosensor for hydrogen. We tested amperometric and potentiometric measurements.

### **New data on dinophyta of the Laptev Sea**

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Dinophyta is a large group of algae, representatives of which often dominate in the phytoplankton of both marine and freshwater biotopes. The northern seas of Russia, because of the great inaccessibility of this region, remain the most poorly studied in relation to this group. This report presents data on the diversity of Dinophyta obtained from the analysis of phytoplankton samples from the western part of the Laptev Sea. A total of 24 species were identified, including *Amphidinium crassum* Lohmann, *Ceratium longipes* (J.W. Bailey) Gran, *Dicroerisma psilonereiella* F.J.R.Taylor & S.A.Cattell, *Preperidinium meunieri* (Pavillard) Elbrächter. first noted in this region.

### **Alkalitolerant filamentous fungi inhabiting the coastal zone of Svalbard**

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Fungi play a crucial role in ecosystems, being destructors of a wide range of organic substrates. Recent studies have shown that filamentous fungi capable of growth at high external pH are widespread in different habitats. In this study, we investigated alkali-resistant micromycetes inhabiting the coastal zone. We demonstrated the presence of alkalitolerant fungi in the littoral soils of Svalbard with undoubted domination of *Pseudogymnoascus pannorum*. Also *Wardomyces inflatus*, *Phoma eupyrena*, sterile light and dark mycelium were present. This report discusses some ecological and ecophysiological features of isolated fungal taxa.

### **Fungi link age of the lakes in the WSBS area**

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We explored the diversity of fungi recovered from the Lakes Verkhnee, Krugloe, Ershovskoe, and Kislo-Sladkoe, and found that acremonium-like species dominate the fungal community. Phylogenetic analyses of these fungi showed their affinity mainly to the three clades: *Emericellopsis*, *Sarocladium*, and *breve*, which harbour marine and terrestrial species. We found that underwater sediments of the lakes were rich in acremonium-like fungi, when compared to peat around these lakes. Interestingly, the Lake Kislo-Sladkoe, the only lake that is still connected to the sea during high tides, had the highest frequency of acremonium-like fungi in all parts of the lake, except in forest soil at the rim. The majority of the fungal isolates recovered from this “sea-connected” lake fell into clades with marine species. Our results suggest that acremonium-like fungi in the studied lakes have marine origin. The growth tests with various conditions (temperature, pH, salinity, carbon source) showed these fungi are capable of growing in a wide range of abiotic conditions, which match fluctuating ecology of these lakes. We showed that the diversity of these fungi depletes with the age of the lakes as they slowly traverse away from the sea due to glaciostatic movements of the earth crust. These findings were corroborated by the diatom algae analysis, as well as hydrological and geological investigations of the studied area.

#### **New method for long-term maintenance of the sponges *Halisarca dujardini* under controlled microbial conditions**

***Kozlova S.Yu.*<sup>1</sup>, *Lavrov A.I.*<sup>1,2,3</sup>, *Gavirova L.A.*<sup>1</sup>, *Shestakov A.I.*<sup>1</sup>**

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According to the type of food, most sponges are non-selective filter feeders: they can feed on both microscopic organisms (bacteria, viruses) and relatively larger organisms (ciliates, diatoms, flagellates). Due to their filtering ability, they can be considered as potential biofilters to remediate microbial contamination of water in natural or artificial conditions. We studied the White Sea sponge *Halisarca dujardini*, which feeds on microorganisms. To determine ability of the sponges for the remediation of microbial contamination we developed the method of controlled cultivation of sponges under the conditions of a flowing marine aquarium at the Nikolai Pertsov White Sea Biological Station. In this technique sponges in specially designed membrane modules were placed in a flowing aquarium block. The membrane modules were glass containers with an aperture closed by a track membrane. A pore diameter of 0.22 µm allowed water to circulate through the module, but limited the penetration of microorganisms from seawater. As a model of microbial contamination we used cell suspensions of the following microorganisms: *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Micrococcus luteus*. Suspensions with high concentrations of cells were added to the modules with sponges, the modules were placed in a flowing aquarium. Modules without sponges were used as a control. We estimated the number of microorganisms at the beginning, middle and end of the experiment. It was shown that the number of microorganisms in the controls decreased insignificantly; therefore the test cultures are stable in seawater. The number of microorganisms in membrane modules with sponges decreased by several orders of magnitude. This method allows to cultivate the sponges in conditions are

similar to natural and at the same time to control microbial profile in the modules. This method can also be used in the study of symbiotic microorganisms of sponges, since it allows to cultivate sponges without influence of the marine microbiota.

**Analysis of cyanobacterial component of the algal-bacterial consortia of the supralittoral baths on the coast of Kandalaksha Bay of the White Sea by metagenomic and microscopic methods**

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Lobakova Elena Sergeevna***

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Supralittoral rock baths of the Kandalaksha Bay of the White Sea are characterized by extreme environmental factors. A small amount of living organisms are able to survive there. Cyanobacteria are capable of enduring adverse conditions due to the presence of mucous covers and some metabolic pathways. Algal-bacterial consortia, containing green microalgae *Haematococcus lacustris* and cyanobacteria of all the subsections were found in the White Sea supralittoral zone. Qualitative and quantitative analysis of the cyanobacterial component of these consortia was carried out by the metagenomic and light microscopy methods. In four of five samples non-diazotrophic (subsection III, order Oscillatoriales) and diazotrophic (subsection IV, order Nostocales) non-branched filamentous cyanobacteria were considered as dominant and subdominant bacterial component, respectively. In one sample unicellular cyanobacteria (subsection I, order Chroococcales) are the dominant group, in the other samples they are considered as a minor cyanobacterial component. The representatives of the II (order Pleurocapsales) and V (order Stigonematales) subsections are noted in small amounts in two different samples (about 5,12% and 4,46%, respectively, from all cyanobacterial component). The taxonomical analysis of the cyanobacterial component in the samples was carried out by using two workflows: the combinations of two programs and two databases (QIIME+Greengenes and Usearch+NCBI GenBank). Similar data of the cyanobacterial taxonomy structure on the subsection level were obtained by using of the two workflows. Both sets of results were compared with microscopic data. However, the differences of the cyanobacterial representation on the genus, family and order levels were detected. Thus, the using of different data analyzing programs and reference databases affects on the results of the metagenomic data analysis. This is a first study of the taxonomic composition of cyanobacteria in the algal-bacterial consortia of rock baths at the coast of Kandalaksha Bay (White Sea), where a polyphasic approach (combined quantitative metagenomics approach, optical microscopy and environmental conditions characterization) was applied.

**Trophic interactions between bacteria, heterotrophic Protozoa and bacteriophages in epipelagial of the Sea of Japan**

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We estimated trophic interactions between the microorganisms of major ecological groups, the grazing rates of protozoa on bacteria; and the number of bacteriophages on some groups of microorganisms in plankton the epipelagial of the Sea of Japan.

### **Research of microorganisms' capability to grow and decompose hydrocarbons in marine conditions at low temperatures**

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Along with progress of development of oil reserves usage in the Arctic region, the anthropogenic pollution of the environment with hydrocarbons also increases. Snow and ice covers holding oil and low temperatures are the main obstacles during the process of the mechanical refining of the northern territories. However, now it is possible to design biological products for the purification of oil pollution using properties of microorganisms to oxidize hydrocarbons. Moreover, the search for psychotrophic microorganisms makes it possible to use such bioproducts in Arctic conditions.

There were 80 samples collected in oil-polluted coastal areas of water areas near to Murmansk city and Vaigach Island and used for our analysis. As a result, 75 stock cultures and 13 pure cultures of microorganisms were obtained, which can oxidize petroleum products under low temperature conditions. Cultivation was carried out on Tauson's nutrient medium with oil as the main carbon source at the temperature of  $-2,5\text{ }^{\circ}\text{C}$ . Based on a visual assessment of the growth rate and intensity of emulsification of oil, 6 stock and 4 pure cultures were selected for the further analysis. The pure cultures belonged to the genera of *Pseudoalteromonas*, *Rhodococcus* and *Shewanella*. A gravimetric analysis of the loss of petroleum products for the selected cultures was carried out: samples were cultivated for 30 days in with or without ice conditions. In the samples of stock and pure cultures cultivated without ice the largest decreases of  $43 \pm 3\%$  and  $20 \pm 5\%$ , respectively were obtained. In the samples of stock and pure cultures cultivated with ice the largest decreases  $17 \pm 1\%$  and  $16 \pm 5\%$ , respectively were obtained. Currently our field experiments are being conducted on the base of Nikolai Pertsov White Sea Biological Station, which will help us to assess the ability of cultures to utilize hydrocarbons in close to real conditions.

### **Study of the functional state of the photosynthetic apparatus of phytoplankton in the separated water bodies on the White Sea coast by using fluorescence methods**

***Todorenko Daria Alekseevna, Krasnova Elena Dmitrievna, Matorin Dmitry Nikolaevich***

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Chlorophyll fluorescence methods were used to study the physiological state of phytoplankton in water bodies separated from the White Sea. In order to assess the functional state of the photosynthetic apparatus of phytoplankton, we analyzed rapid light curves (RLC) and fast induction kinetics of fluorescence (OJIP curves) of phytoplankton. We showed with the use of chlorophyll fluorescence methods that high efficiency of primary photosynthesis processes, expressed through the efficiency of the

primary photochemical reaction, the activity of electron transport and the performance index, was specific for mass blooming of algae in chemocline zone, especially for cryptophyte algae.

## ECOLOGY

### **Plant size affects epibiosis on red algae *Phycodrys rubens* in Velikaya Salma strait (Kandalaksha bay, the White sea)**

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Alongside with predation and competition facilitation defines and maintains community structure. Intraspecific variation of species abundances and composition in the communities associated with strong facilitators (foundation species) is studied much less than interspecific. Coastal and intertidal macroalgae often function as foundation species in marine ecosystems, providing shelter and substrate for numerous sessile organisms. Epibiosis of red algae is underexplored in the high latitudes. We examined sessile macrobenthic assemblages associated with a foliose red algae *Phycodrys rubens* in the White Sea shallow subtidal, and the effect of individual plant properties on their structure. The blades of *P. rubens* develop annually and it is possible to tell the new blades (0+) composing the major part of the thallus from the elder part. We hypothesized that community structure 1) varies on plant parts of different age 2) depends on the size of the plant.

In September 2015 we examined 80 plants at two study sites (Site 1, N 66.33,028 E 33.9,295 and Site 2, N 66.33,276 E 33.6,470) and the results generally supported our hypotheses. Epibiosis on the old parts had higher total covers and differed in species composition compared to the young blades. Total covers on young blades decreased with plant size due to the site-specific drop of dominant bryozoans' (*Cribrilina annulata*, *Celeporella hyalina*, *Electra pilosa*) abundance. However, plant size did not affect covers of the dominant solitary species, polychaete *Circeis armoricana*. The effect revealed suggests site-specific variation in recruitment of key bryozoan species, which limits their cover on the large plants.

### **Environmental influence on the growth and transport system in colonial hydroid *Dynamena pumila* (Linnaeus, 1758)**

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The method of remote recording of pulsations in the coenosarc, despite the variability of the results, allows for two hours to adequately detect the reaction of the colony to abiotic effects, which classical methods can only be done after a few days. The reaction of growth, lateral pulsations and hydroplasmatic flows to a change in environmental factors is nonlinear. Colonies are resistant to environmental factors and do not show significant signs of depression in the studied range of temperature, salinity, air exposure and water exchange. The reaction of colonies to environmental factors allowed us to establish limits of tolerance for this species.

## **The influence of some factors of the marine environment on the formation of polycultural biofilms by saprotrophic bacteria and *Listeria monocytogenes***

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It is known that the marine environment is unfavorable for the existence of pathogenic bacteria. However, the presence and reproduction of *Listeria* in both coastal and oceanic waters is described. According to the literature, *Listeria monocytogenes* is able to maintain viability and multiply in a wide range of temperatures and pH values, withstand freezing, drying, the presence of salt. According to many researchers, microorganisms are more resistant to abiotic environmental factors precisely because they exist in the form of biofilms. The aim of our work was to study the ability of saprotrophic marine bacteria to form biofilms with pathogenic *Listeria monocytogenes* under the influence of some abiotic factors: temperature and salinity changes (according to the literature, these are the leading factors influencing the intensity of biofilm formation in the marine environment). It was found that bacteria in both mono- and polycultural biofilms retain their viability when the temperature or salinity in the medium changes. Under model environmental conditions that were close to those of natural habitat (salinity, temperature), the intensity of biofilm formation of polycultural biofilms consisting of marine saprotrophic heterotrophic bacteria and *Listeria monocytogenes* was higher.

## **Luciferase of the syllid polychaete *Odontosyllis undecimdonga***

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We opted to extract and purify the *Odontosyllis* luciferase directly from the lyophilized worms and successfully identified the luciferase gene using classic protein purification and recent whole-cDNA sequencing techniques. We then reconstructed native *Odontosyllis* bioluminescence *in vitro* using purified protein and highly purified luciferin with no additional cofactors. Lastly, we verified the identity of the *Odontosyllis* luciferase gene by showing that recombinant protein and purified luciferin in cell-lysate is luminous, in which the luminescence spectra ( $\lambda_{max}$ , near 510 nm) matches that of the *Odontosyllis in vivo* luminescence.

## **Population status of *Zostera marina* L. in the Rugozerskaya Bay area of the White Sea**

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In the ecosystem of the White Sea, the *Zostera marina* L. – the only mass species on the silted stretches of the coast serves as a place for feeding and spawning fish and feed for waterfowl. In the last third of the 20th century, the mass mortality of *Z. marina* thickets caused by Myxomycetes *Labyrinthula*

*macrocystis* Cienc was observed, which adversely affected the abundance of *Clupea pallasii marisalbi* and *Gasterosteus aculeatus* L.

The monitoring of the population of *Z. marina* was carried out in 2009-2010 and 2015 and compared with the literature data. A decrease in the number of shoots has been detected, up to the disappearance in separate bays in different years. The continuous uplift of the Karelian coast of the White Sea forces *Z. marina* populations to move down the littoral. There is either a catastrophic scenario of mass death of a population in a separate bay, or a gradual rarefaction and disappearance of individual plants. In 2009, new habitats were discovered in the area of the White Sea biological station on the average littoral, in which *Z. marina* had not previously been noted. Observations in 2015 showed that *Z. marina* increased the number of vegetative and generative shoots in these sites and is less affected by *L. mixrocystis*.

**The first record of *Thalassiosira angulata* (Bacillariophyceae) bloom in the White Sea  
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In view of the observed warming of the Arctic and Subarctic, a change in the phytoplankton community structure and, in particular, in the composition of dominated species is forecasted (Lovejoy et al., 2007). A reliable forecast of changes in the structure and functioning of Arctic marine ecosystems is difficult due to scarcity of data because of the logistical difficulties of year-round field work, high costs and shortness of the expeditionary research in the Arctic. In this regard, the examination of phytoplankton community structure in the subarctic White Sea, which combines common to Arctic and temperate seas abiotic environmental features, appears to have considerable importance. The climate trend impact on the phytoplankton of the White Sea was examined according to the long-term dynamics of chlorophyll *a* as an indicator of planktonic algae biomass. Published results are controversial. A number of authors believe that there is an increase in the chlorophyll *a* concentration (Pozdnyakov et al., 2007). According to other researchers, the concentration of chlorophyll *a* in the White sea varies within long-term changes, and climate trend does not affect phytoplankton (Kravchishina et al., 2013). The present study shows that changes in the structure of plankton algal communities already occur. In the summer of 2011, for the first time, we have recorded the bloom of the diatom *Thalassiosira angulata*, which has never been reported as dominated species during 100 years research on the White Sea phytoplankton. For the understanding of possible trends of changes in phytoplankton community in the polar regions, it is extremely important to identify factors that favor the preferential development of species that previously did not achieve a leading position in the community ("atypical" dominants). The above defined the aim of this study – analysis of the spatial distribution of diatom *Thalassiosira angulate*, dominating in a large part of the White sea in the first decade of July 2011, in relation to hydrological and hydrochemical conditions, as well as to phytoplankton biomass and community structure.

*T. angulata* is a widespread species in polar and temperate waters (Hasle, 1978, Park et al., 2016). This diatom was recorded in the White Sea plankton from spring to early winter (Rat'kova, 2000, Semina, 2003), but it was not a dominant species previously. It presumably inhabits the ice biotope (Gogorev, 1998). We associate the atypical mass development of *T. angulata* in the White Sea with climate change. Thus, the increased air temperature over the sea and its basin (Filatov et al., 2005) leads to rise in temperature of the surface layer waters, as well as to increased rainfall and runoff. This, in turn, causes a significant stratification of the water column, high temperature and low salinity in the surface water layer, which contributes to the formation of conditions favorable for the development of *T. angulata*. Therefore, due to the climatic trend, we could expect regular summer bloom of this diatom in the White sea.

*The work was performed at User Facilities Center of M.V.Lomonosov Moscow State University under financial support of Ministry of Education and Science of Russian Federation (making scanning electron microscope images). The study was performed as a part of the government task of Lomonosov MSU (topic AAAA- A16-116021660052-0, investigation of phytoplankton community structure) and supported by the Russian Science Foundation (grant no. 14-27-00114-II, chlorophyll a and nutrients determination) and by the Russian Foundation for Basic Research (grant no. 16-05-00502, samples processing).*

**The elemental composition of lichens in the vicinity of N.A. Pertsov White Sea Biological Station  
of M.V. Lomonosov Moscow State University  
(north-west coast of the Kandalaksha Bay of the White Sea)**

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Lichens, which are a symbiosis of algae and fungus, receive the necessary moisture, nutrients and trace elements mainly from the atmosphere; they have a large surface area, which makes them natural biosorbents. Therefore, the elemental composition of lichens can show the degree of accumulation of pollutants in the ecosystem as a result of atmospheric transport. The elemental composition of more than 25 samples of epiphytic, terricolous and epilithic lichens collected in the vicinity of the N.A. Pertsov White Sea Biological Station of M.V. Lomonosov Moscow State University. Lichen samples were collected in sterile plastic bags using disposable plastic gloves. Dried samples were purified from foreign matter (fragments of other plants, soil particles). Next, the samples were ground in an agate mortar and decomposed with a mixture of concentrated ultrapure H<sub>2</sub>O<sub>2</sub>, HNO<sub>3</sub> and HF in teflon containers. The elemental composition of the samples was studied by inductively coupled plasma mass spectrometry (ICP-MS). Almost all lichen samples were significantly enriched with the following elements: K, Ca, Mn, Zn, As, Rb, Sb, Pb, Bi, Cd. The enrichment of lichens by K, Ca, Mn, Rb can be explained by the fact that these elements, being biophilic, are better absorbed by lichens. Zn, As, Sb, Pb, Bi and Cd enter in the plant cover of the study region mainly due to long-range atmospheric transport from remote anthropogenic sources.

**Distribution and population structure of two co-occurring species of  
*Pseudocalanus* in the White Sea**

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Calanoid copepods of the genus *Pseudocalanus* play an important role in the pelagic communities of the White Sea, being one of the dominant groups in terms of abundance and composing a significant portion of the total zooplankton biomass. Two species co-occur in the White Sea: *P. acuspes* and *P. minutus*, although historically zooplankton studies have grouped them together due to the very insignificant morphological differences between the species, particularly at juvenile stages. In this study we examine the species-specific distribution and population structure of *Pseudocalanus* in the White Sea, based on material collected on a transect through the Kandalaksha Bay from aboard the RV “Professor Zenkevich” in August 2018. Species identification at juvenile stages was accomplished using species-specific PCR. The abundance of this group was 200-400 ind m<sup>-3</sup> and increased towards the southern end of the transect. The populations of both species were mainly composed of later copepodite stages (CIII-CV), yet the population structure of the two species was significantly different. This suggests that these species are at different stages of their life cycle, likely exploiting different production sources, which allows them to co-exist in one environment.

**NOVEMBER, 21**

**FUNCTIONAL STRUCTURE OF MARINE SPECIES DISTRIBUTION RANGES, AND  
BITOPES OF MARINE COMMUNITIES. A SESSION DEDICATED TO 90-YEARS  
ANNIVERSARIES OF C.V. BEKLEMISHEV AND N.M. VORONINA**

**Role of geographical and environmental factors in determining a regional composition  
of the World Ocean micro- and meiofauna**

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Small-sized organisms, both unicellular (“microbes”) and multicellular (e.g., microcrustaceans), are ubiquitous and play the key role in global functioning of the biosphere. However, geographical patterns of their diversity and composition are unclear, and the relative role of spatial, historical, and ecological factors in structuring their assemblages is poorly known due to lack of empirical data. We studied the global distribution patterns of the three key groups of marine benthic organisms: heterotrophic flagellates, ciliates and harpacticoid copepods, basing on the comprehensive databases compiled from many sources. Two groups of factors potentially driving these patterns were considered: 1) geographical (spatial distance and geographical isolation by landmasses, hydrological barriers etc.), and 2) environmental (average

annual sea surface temperature (SST), annual SST variation, and average salinity). There was the significant correspondence between ciliates and harpacticoids in geographical distribution patterns, while these patterns for flagellates were quite distinct from other groups, both in terms of species richness and composition similarity. For flagellates, only the environmental variables (mainly SST) were significant, while they explained as little as 7-8% of variations in taxonomic composition. For ciliates, both geographical and environmental variables were significant, explaining together 16-24% of compositional variations. Harpacticoids demonstrated the most predictable pattern, with 61% explained by geography, 9% - by environment, and 8% - by spatially structured environmental variations. Thus, protists (flagellates in particular) exhibit a stronger response to environmental factors (mainly temperature) than to geographic distance or barriers for dispersal; while the harpacticoids' global-scale distribution suggests clear geographical dispersal limitation.

### **Distribution of bivalves in the Barents Sea in the different environmental conditions**

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This research presents data on the distribution of key species of bivalves in the cold and warm periods in the Barents Sea. The analysis of the available data on water temperature, depth and biomass of mollusks was conducted to reveal the relationships between the distribution and the environment parameters. The estimation of varieties of species reactions under climate changes for key species of bivalve mollusks is given.

### **Long-term monitoring of physiological status of gobies and *Didacna* mollusk as indicators of the ecosystem health in the North Caspian**

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In recent years, the concept of “ecosystem health” has been actively used for the integrated environmental assessment of pollution impacts. Unlike the MPC-based evaluations, methods relying on physiological and biochemical indication can answer the most important practical question: how dangerous are the appeared pollutants for aquatic ecosystems? Therefore, monitoring of the physiological status of hydrobionts has great importance to predicting development of environmental implications in the examined water body. Hence, the stated purpose was to undertake long-term studies on changes in the physiological status of gobies and *Didacna* mollusk, as typical aquatic animals of the North Caspian. Their physiological status was evaluated by LPO level, as well as the enzymatic activity of lactate dehydrogenase and cytochrome oxidase in the liver and muscles, i.e., by the most pollution-sensitive indicators, which are the most important in the organism functioning, as well. Conducted research revealed significant fluctuations within the studied parameters in hydrobionts, both in spatial and temporal aspects. The decline in their “health” was most often registered at the aquatic areas located closer to the Volga River mouth, as compared with the more southerly areas in the North Caspian, and, most commonly, across large territories, resulting from an increased marine pollution by toxicants.

## **Cartographic integration of biotic and abiotic factors for the solution of environmental problems in the coastal zone**

**(by the example of the allocation and justification of the marine areas most vulnerable to the impacts of shipping and accidental pollution in the Bering Strait region and adjacent waters)**

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A comprehensive study of natural and anthropogenic factors determines a step-by-step approach. The spatial database makes it possible to link existing thematic information reflecting biological, geographical, environmental and economic aspects. The further development organisms living in the marine and coastal areas of the Bering Strait and adjacent waters affected by shipping and at risk of oil pollution depends on the development of the concept of integrated marine environmental management. Development of the coastal zone in all complexity of interrelations, identification of the General laws, regional features, the analysis of positive (negative) experience in world practice, economic assessment of possible options of planning of influence - the main objectives of the direction of this research.

*Key words:* biota, marine areas, Geocology of the world ocean, GEODATA, shipping, marine environmental management, planning.

## **The spatial structure of Notherneast Black Sea coast macrozoobenthos: biological traits analysis**

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Understanding the relationship between biodiversity and ecosystem functioning in the marine environment is a difficult problem (Strong et al., 2015). One of the possible approaches is the biological traits analysis (BTA) (Bremner et al., 2006). This is a relatively new approach based on the use of species functional classification instead of the classical taxonomic one, when a set of biological and environmental characteristics of species are used instead of taxa themselves. The use of this approach has shown that the regulation of ecosystems' functions and the corresponding structural features may depend on species-specific traits, but not on the species richness per se (Loreau et al., 2001; Hooper et al., 2005). At the same time, the functional structure of communities may coincide with the taxonomic one (Bolam et al., 2016), or it may differ significantly (Frid and Caswell, 2015). Thus, the aim of this paper was to compare two approaches – standard taxonomic approach and biological traits analyses – for assessing the structure of macrobenthos communities at the northerneast coast of the Black Sea.

A total of 68 species of macrozoobenthic animals were found at 8 stations. Polychaeta, Crustacea and Bivalvia played the major role in terms of the species number. The number of species was the greatest at medium depths - 20 and 40 m (Fig. 2a). The largest contribution to the abundance and biomass was

made by Bivalvia, but from a depth of 25 m Polychaeta also made a significant contribution to the abundance (20-50%) (Fig. 2b, c). ES(100), taxonomic diversity, Shannon diversity and Pielou evenness, as well as the functional diversity of communities, increased sharply with increasing depth in the range of 10-25 m (Fig. 2d, d). This was due to the decline of the role of the bivalve dominant species with depth in this range. At a depth of 10 m, *Lucinella divaricata* (Linnaeus, 1758) reached 75% of the abundance and 35% of the community biomass, at 15 m *Chamelea gallina* (Linnaeus, 1758) contributed 46% and 54%, respectively, but at depths of 20-25 m dominant positions were occupied by several species, and individual species' contribution did not exceed 30%. In the range of 30–70 m, the number of species decreased with increasing depth. ES (100), as well as the Shannon, Pielou and functional diversity indices were generally higher here than in shallow water, except for a depth of 50 m. At this station, a sharp decrease in the Shannon and Pielou indexes, as well as functional diversity was observed (Fig. 2d) with unchanged taxonomic diversity (Fig. 2e). This is explained by the high abundance (1817 spec/m<sup>2</sup>) of the dominant bivalve mollusk *Modiolula phaseolina* (Philippi, 1844) (74% of the abundance and 79% of the community biomass). Functional diversity was positively correlated with the Shannon diversity index ( $R = 0.90$ ) and Pielou evenness ( $R = 0.90$ ), as well as ES(100). However, no correlation was found either with the number of species nor with the taxonomic diversity. The index of functional redundancy generally increased with depth, that is, the number of species with the same functions decreased with increasing depth.

The MDS-ordination of the stations showed that based on the biomass, abundance, or taxonomic diversity, the communities were divided by the depth of the station (for example, Fig. 3). At the same time, the taxonomic composition of the stations at depths of 10–30 m and 40–50 m differed significantly higher than within these groups, which indicates a partial change of species composition at depths of 30–40 m. Within the range of 10–30 m, the similarity of stations in taxonomic composition, abundance and biomass comprised 25–40%. The composition of the dominant species is shown in Figure 3. Thus, at all stations, without exception, bivalve filter-feeders were dominant. However, their taxonomic composition changed at the family level with depth: Veneridae at 10-40 m and Mytilidae at 50-70 m. In addition, a significant contribution was made by an alien species of the Arcidae family (*Anadara kagoshimensis* (Tokunaga, 1906)) at depths of 20-40 m.

BTA showed that the first two axes (F1 and F2 in Fig. 4) explained 81.6% of the variability, so the selected traits sufficiently describe the structure of the communities. The main contribution to the differences in the macrozoobenthos structure at the stations was made by the feeding type, mobility, body shape and fecundity.

Stations at depths of 10–20 m were grouped very closely, as in the case of taxonomic data analysis (Fig. 4a). The main contribution to the similarity of these stations and their differences from others was made by high fecundity (> 1 million) (Bivalvia), the presence of symbiotrophic organisms (*Lucinella divaricata*) and to a lesser extent by the predominance of large-sized forms (*Chamelea gallina*). Differences between stations at 10–20 m and 25–40 m were mainly explained by the axis 1, differences between stations at 50–70 m and 25–40 m – mainly by the axis 2. At depths of 25–40 m, the greatest variety of traits' modalities was noted (Fig. 4b), which explains the increase in the FD index with depth. Stations of 50–70 m differed from others, primarily due to the presence of the largest number of sedentary forms due to the high quantitative development of *Modiolula phaseolina*.

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**Timing of gonad maturation and reproduction of two calanoid copepods *Calanus finmarchicus* and *C. glacialis* in a high-Arctic fjord**

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Seasonal changes in gonad development of adult females, males and V copepodites of two species of calanoid copepods, *Calanus finmarchicus* and *C. glacialis*, were investigated based on year-round observations in Iskjorden (the west coast of Spitsbergen). Our results indicate that the maturation of the females of these two species occurs at different seasons, and the appearance of their males also diverge by about 2-3 months. The peak of *C. glacialis* males is observed during the winter months (December-February, when abundance of *C. finmarchicus* females is very low. Differences in the reproductive phenology of the studied species indicate a low probability of potential hybridization between them.

**The development of the ideas about the frontal zones in the Barents Sea based on the concept of the ecotone biocenoses (using new examples)**

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The functioning of the Polar Front zone biota in the Barents Sea has been considered. It was attempted to associate that with the influence of the edge effect, which was the effect of the ecotone. The contribution of K. Beklemishev and other domestic scientists in the development of ideas about ecotones in the ocean is under discussion. The frontal zone in the northwestern and northern parts of the Barents Sea was called the Polar Front in the first half of the 20th century, and it was defined as a marine zone separating warm and saline Atlantic waters from cold and freshened Arctic waters, i.e., thermohaline in nature. The position of the frontal zone is relatively stable in time and space. It is known that the position of the front is determined by the bottom topography, and its small oscillations in space occur under the influence of tides. In the course of studying the problem on the example of the Barents Sea, it was shown that, due to the peculiarities of their hydrological regime, the areas of mixing of water masses were specific hydrobiocenoses, where the boundary effect was well pronounced. The area of the Polar Front is characterized by high biomass of phyto- and zooplankton, including the predatory macrozooplankton, which attract here a large number of fish plankton-eaters, mainly capelin and Arctic cod in the spring-summer period. There is also an intense vertical flow of suspended organic matter. In addition to the increased biomass of plankton, an accumulation of benthic invertebrates was observed in the zone of the Polar Front. The distribution maps of bivalves, mainly *Chlamys islandica*, *Astarte borealis* and *Ciliatocardium ciliatum* in the Barents Sea are given. It has been shown that local salinity fronts also have a noticeable effect on the distribution of *Bivalvia*. The ecology of the Polar Front zone in the Barents Sea is characterized by the accumulation of a number of pollutants here. A map shows the localization of

higher concentrations of a number of heavy metals in water in the area of the Polar Front in the Barents Sea. The main reason of the observed phenomena probably lies in the vertical flow of suspended organic matter, as a consequence of the rapid development and subsequent death of plankton organisms in the frontal zones.

### **The White Sea from pier of WSBS.**

**Pantiulin Anatoly Nikolaevich**

*Lomonosov Moscow State University.*

The principal stages of evolution the conception about the White Sea are discussed. The White Sea as a small ocean. The White Sea as a hierarchical estuarine system. The White Sea as a unique part of the unique ocean.

### **The dynamics of biotopes. Reasons and methodological consequences**

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According from the concept of K.V. Beklemishev on the biotopic basis of communities, the thesis that the soil parameters (biotope) remain unchanged from year to year is taken a priori.

For most cases, this is true, and the granulometric parameters of the soil in samples collected in different years in the same place differ from each other within statistical errors.

Specifically, the issue of changing biotope parameters is usually considered in studies on the impact of anthropogenic factors on benthos (dredging, dumping, trawling, construction of hydraulic structures, etc.), but this is a topic for special investigations.

However, there are a number of situations where the characteristics of a biotope can significantly change under the influence of natural factors, and in a very short time.

Most often this occurs under the influence of coastal hydrodynamics (waves, currents), causing changes in the distribution and sorting of the various components of loose soils. As a result - changes in the granulometric composition of the soil of a biotope and, changes in the conditions for larvae settlement and / or the very possibility of dwelling of certain organisms in new conditions.

In addition to hydrodynamics, the change in biotope parameters can be affected by the flow of suspended fine material (flood demolition of terrigenous material, sedimentation of organic detritus, wind transfer), which even in relatively small quantities can significantly change the possibility of replenishing biocenoses by new generations.

Concrete examples of short-term and long-term changes in the biotope parameters and possible methodological errors arising in the interpretation of environmental monitoring data are discussed.

### **Populations communities and biotas in changing marine environment: dynamics of the concepts of C.W. Beklemishev and N.M. Voronina**

**Spiridonov V.A.**

*Shirshov Institute of Oceanology of Russian Academy of Sciences.*

The presentation addresses the development of the concepts of natural foundations for classification of distribution patterns of marine organisms and the biotopic basis of marine communities developed by Constantin W. Beklemishev and his collaborators. A particular emphasis was also done at the application of this approach to the Antarctic ecosystem by N.V. Voronina. These concepts proved their robustness and consistency. They need to be further developed as a theoretical basis for modern marine ecology and biogeography.

### **Marine biotopes and potential biological resources of the Arctic**

**Spiridonov V.A., Zalota A.K.**

*Shirshov Institute of Oceanology of Russian Academy of Sciences.*

The issue of marine biological resources of the Arctic is discussed in the context of the biotopic structure of the Arctic marine ecosystem, in particular the areas of the Atlantic and the Pacific water inflow. Currently only inflow shelves of the Barents Sea, southwestern Greenland, and Chukchi Sea are productive enough to sustain commercial fishery (in the first two cases) or traditional marine hunting. The ongoing climatic changes and biological invasion of the snow crab, *Chionoecetes opilio* leads to the rise of harvestable (in the Barents Sea) and potentially harvestable resource in the remaining inflow shelf of the western Kara Sea.

### **Vertical distribution of macrozoobenthos in the sediments' profile at the Laptev Sea shelf**

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Multicorer samples from the Laptev Sea shelf (Transdrift-2013 and -2014 cruises) were examined. Each sample was cut in 0-5 cm and 5 cm-rest layers, a total of 55 subsamples from 11 stations were processed. 171 taxa were recorded; almost all of them (153) were present in the 0-5 cm layer, whereas the deeper layer contained only 72. The species numbers in the upper layer was, on the average, 5.6 times higher than in the deeper one; density and biomass differed in 9.5 and 12.8 times, respectively. Biomass was the most various character and in 5 samples in the deeper layer it was equal to or higher than in the 0-5 cm layer due to the large borrowing detritophages' abundance. Statistical analyses proved the reliability of between-layers' differences and showed that there were also differences in species' occurrence: in the 0-5 cm layer there wasn't any significant gap between frequent and rare species, whereas in the deeper layer only *Chaetozone* cf. *setosa* was recorded in 77% subsamples, and three taxa had occurrence about 20-30%; the rest of the species were found in 1-2 subsamples each. According to the SIMPER analyses, 90% of similarity between subsamples in the deeper layer was made up by 8 polychaete species with *Chaetozone* cf. *setosa* contributing 58% and 65% of similarity in terms of density and biomass, respectively. In the 0-5 cm layer, 31 species made up 90% of similarity in terms of density with *Micronephthys minuta* being the most significant (contributing 22% of similarity), and 18 in terms of biomass with most significant *Ophiocten serriceum* (29%). The distribution of species' contributions

to similarity between subsamples in the 0-5 cm layer was much more even than in the deeper one. Regression analyses (DistLM) explained about 60±5% of total variance of species composition, density and biomass in both layers by the effects of sediment type, location, salinity and depth, but in the deeper layer the significance of the tests was one order lower. That is because in the deeper layer at most stations the species composition and quantitative structure were randomly depleted versions of those in 0-5 cm layer. Only at few stations rich with large borrowing detritophages (mainly *Praxillura longissima*, *Maldane sarsi*, *Terebellides* sp., *Artacama proboscidea*, *Diplocirrus longisetosus*) population of the deeper layer differed significantly from that of the 0-5 cm layer and could even exceed it in terms of density and biomass.

### **Depth zonation of bottom fauna in Siberian Arctic**

**Vedenin Andrey Aleksandrovich, Galkin Sergey Vladimirovich, Mironov Alexander Nikolaevich,  
Gebruk Andery Viktorovich**

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Vertical zonation of bottom fauna is extensively studied in various regions of the World Ocean. In terms of methodology two different approaches to reveal the vertical zones exist – biocoenotic and biotic. Biocoenotic approach is based on the boundaries between different species complexes (e.g. communities), while biotic (=species) approach is based on concentrations of vertical boundaries of species ranges (Mironov et al., 2013). In the Arctic Ocean a few studies of benthic vertical zonation by using biocoenotic approach exist (Sirenko et al., 2004). However, investigations of this problem by using the biotic approach are absent in the High Arctic so far.

Here in this study we consider the depth zonation of benthic fauna using both biocoenotic and biotic approaches for the first time.

The biotic boundary revealed at 450-700 m depth corresponds with the biocoenotic boundary between the communities dominated by *Ophiopleura borealis* and *Melinnopsis arctica*, and the biotic boundary revealed at 1800-2000 m depth – with the biocoenotic boundary between communities dominated by *Melinnopsis arctica* and *Kolga hyaline* – *Elpidia heckeri*. Transition between sublittoral and bathyal fauna in the Arctic is located deeper than in other parts of the Ocean. On the contrary, the bathyal-abyssal faunal transition is revealed shallower than in the other parts of the Ocean.

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### **Impacts of bottom trawling on megabenthos communities of the Barents Sea**

**Zakharov D.V., Strelkova N.A., Manushin I.E., Nosova T.B.**

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Barents Sea is the area of extremely active bottom trawl fishery. Large sessile and slow-moving species-edificators are the most vulnerable to bottom trawling, their abundant population builds up so called «Vulnerable Marine Ecosystem» (VME). According to the classification of NAFO and NEAFC,

abundant population of certain species of colonial corals and sponges refer to indicators of the VME. At present 137 species of sponges and 45 species of anthozoans inhabit the Barents Sea, among which 41 species of sponges and 9 species of colonial corals can be classified as indicators of the VME. The paper provides information about potential indicators of VME in the Barents Sea based on analysis of the distribution of by-catches. Thus most of VME in the Barents Sea are located in far northern areas outside of the active fishery, except the south-western part of the sea where dense populations of sponges were observed.

**Study of the trophic structure of the bottom community in the subtidal zone of the Kislaya bay with the analysis of stable isotopes of nitrogen and carbon.**

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The relative contribution of different energy sources and separation or overlapping of species by source of organic matter is poorly studied in benthic ecology. The task of this work is to study the main sources and ways of organic matter transformation in a bottom community. This report presents a description of the overall trophic structure of a benthic littoral system, including all mass species of different trophic levels and food strategies using the analysis of stable isotopes of nitrogen and carbon. Guba Kislaya is a small shallow bay, with a maximum depth of about 3 m, enclosed on all sides except from the east. Macrobenthos is fairly uniform over the entire area of the bay and is represented by a community typical for the White Sea littoral. Two samples from different parts of littoral were taken to assess the sources of organic matter (detritus and microorganisms) in the soil. Bivalves, sandworms, gastropods, amphipods, shrimps, fish, marine plant material and land plants of the maritime march were collected.

Terrestrial plants have  $\delta^{13}\text{C}$  less than -25‰. Washout from a red deposit on collected soil from the edge of the littoral is in the same range. Algae and plants have  $\delta^{13}\text{C}$  more than -21‰, as well as detritus and washout from the ground, collected from the middle of littoral. Obviously, prokaryotes and at least part of protists use substances that is produced by terrestrial plants living on the sea/ and border, as a carbon source. However, several meters below this site, terrestrial organic matter is mixed with organic matter from marine sources and is included in the total pool available to the littoral organisms. Meiobenthos is characterized by  $\delta^{15}\text{N}$  (3-5‰ higher than most plants) and  $\delta^{13}\text{C}$  (+ 0-1 ‰), which are similar to those of detritus. Obviously, the source of carbon for meiobenthic organisms is soil organic matter at its habitat. Such values of  $\delta^{13}\text{C}$  for organic matter in the soil are achieved by the influence of terrestrial organic matter, which reduces the proportion of heavy carbon isotope in the total composition of organic matter available to meiobenthos.

All analyzed animals in this area have  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values within the ranges of diets based on planktonic chain (like mussels), detritus consisting of a mixture of terrestrial and marine organic matter (meiobenthos) and direct feeding on seaweed (littorina). The upper trophic levels integrate these chains from various primary producers, and are located in the center of the range of  $\delta^{13}\text{C}$  values (shrimps, stickleback).

## **Species composition and quantitative distribution of Peracarida in the northern part of the Barents Sea**

**Zimina O.L.**

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Based on data collected during expeditions of MMBI with RV "Dalnye Zelentsy" species composition and quantitative distribution of Peracarida in little studied northern part of the Barents Sea was analysed. Main factors influenced on quantitative and qualitative characteristics were determined. Faunistic complexes of Peracarids on studied area were mapped. Biogeographical structure of Peracarid's fauna and it's changes in comparison with previous time periods was analysed.

### **STUDIES OF BIOTA AND ECOSYSTEMS OF RELICT COASTAL LAKES**

#### **Depth distribution of bacteriochlorophyll from green sulphur bacteria in the Trekhtzvetnoe, Bolshie Khruslomeny lakes and the lagoon on the cape Zeleny in September 2018**

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The work is devoted to the development of a method for determining the concentration of bacteriochlorophylls (BChl) of green sulfur bacteria (*Chlorobiaceae*), phototrophs that live in the anaerobic zone of meromictic reservoirs. The new method which uses absorption spectroscopy without extracting pigments by organic solvents was developed to simplify the procedure of determining the BChl concentration. Green-colored and brown-colored cultures of GSB were selected as samples, as well as samples taken in March 2018 from three meromictic reservoirs. The samples from the same reservoirs taken in September 2018 were used to build depth profiles. Absorption spectra were measured using a Solar PV1251 spectrophotometer. The method involves determining the concentration of chlorosomal BChl over the area under the long-wave absorption peak in the absorption spectra of living microorganisms in water. A good linear correlation was obtained between the area under the long-wavelength absorption peak in water and the concentration of BChl calculated using the Overman-Tilzer formula for extracts. From the linearity of the correlation graphs the formula for determining the concentration of BChl was obtained. Using the correlation coefficients obtained in March 2018 for the lagoon on cape Zeleny, Bolshie Khruslomeny and Trekhtzvetnoe lakes, concentrations of BChl were calculated for samples taken in September 2018. The depth distribution profiles of BChl concentrations were constructed for those three lakes.

## **Complex studies of the White Sea coast water bodies during summer practices and winter student expeditions**

***Frolova N.L.<sup>1</sup>, Krasnova E.D.<sup>1,2</sup>, Efimova L.E.<sup>1</sup>***

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The report discusses the results of complex study of small lakes on the west coast of the White Sea, made by students and staff of the geographical and biological faculties of Moscow State University in 2014-2017. During the winter expeditions of the NSO and summer hydrological practices, the geography of unique water bodies separated from the sea was expanded. The advanced results of exploration of hydrological and hydrochemical regime of lakes, their isotopic composition, the connection of coastal lakes and the sea, the spatial variability of snow cover characteristics, distribution of macrozoobenthos, phototrophic microorganisms, dissolved organic matter and protein complexes in the water column were obtained. Also a new information on the indicators of the chemical composition of water in the existing meromictic reservoir was received.

### **Bacteriochlorophylls, bacteria and ciliates in small lakes separating from the White Sea**

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The coastline of the seas and the ocean is constantly changing due to changes in ocean level and tectonic movements of the land. These lead to the permanent isolation of some parts of sea territory or, conversely, reconnection of previously isolated coastal lakes and lagoons to the sea. In particular, after melting of the Scandinavian glacial shield, the entire territory of Fennoscandia experiences glacioclastic rebound [Rosentau et al., 2012], its current speed on the coast of the Kandalaksha Bay of the White Sea is estimated at 4-8 mm per year. Therefore the process of formation of new coastal lakes by isolating fiords and bays from the main water area continues here even at present. If they have sufficient depth, long-term stable salinity stratification occurs in these newly formed reservoirs, accompanied by long-term isolation from the atmosphere of the bottom layers of water and anoxia typical for meromictic water bodies. As a result, brand new and absolutely free ecological niches with conditions that sharply contrast from those existing before are formed in a previously homogeneous reservoir. Obviously, the study of such lakes at various stages of their separation from the sea is of great interest for understanding the evolution of ecosystems of coastal waters.

In 2014 and 2015, we investigated several water bodies in the vicinity of the white sea biological station of Moscow state University, formed recently [Krasnova et al., 2015] as a result of land-level rise. In this paper we present the results of a study of the vertical distribution of individual components of the microbial community of three meromictic lakes with fresh or brackish myxolimnion in July 2014 and September 2015.

All three studied water bodies are at the meromictic stage of separation from the sea; the difference in water density between the surface and deep horizons due to the salinity gradient, quite exceeds the thermal component. In the redoxcline area of these lakes develop numerous populations of anoxygenic phototrophic bacteria of the fam.. Chlorobiaceae develop. They may be accompanied by subsurface

populations of oxygenic phytoplankton, but they tend rather to the limit of oxygen depletion, and only in the lake. Trekkhzhvetnoe in which these zones are overlap, development zones of oxygenic and oxygenic phototrophs coincide.

Preferential development of "green" or "brown" forms of Chlorobiaceae, and of certain of oxygenic phototrophs (cyanobacteria, picoeukaryote, cryptobiotic, etc.) are due to complex reasons, including the spectral characteristics of light reaching redoxcline and other abiotic factors (pH, concentration of biogenic elements, etc.). Characteristically, however, that in Lake Trekhtzvetnoe and B.Khruslameny the proportion of "brown" Bchl *e* in the upper part of the microbial plate is higher than in the maximum. This is somewhat inconsistent with the generally accepted paradigm of the development of "brown" Chlorobiaceae in deeper layers than "green" forms.

Maxima of prokaryotes in the redoxcline area are accompanied by ciliate species adapted to microaerobic and anaerobic conditions. All three lakes are characterized by a high contrast between the ciliate communities of aerobic, freshwater or low salinity, and anaerobic, more saline zones, with the main part of the number and biomass of ciliates concentrated near the microbial plates and, obviously, were associated with them by trophic relationships.

Undoubtedly, a complete and systematic characterization of the vertical structure of plankton communities of these and other similar water bodies will be important for understanding the functioning of ecosystems of meromictic reservoirs.

*We thank the staff of MSU White Sea Biological station (BBS MSU) for help in the work, and especially E.D. Krasnova and D. A. Voronov (MSU) for their invaluable cooperation in the field and laboratory works and for kindly provided data on the physical and chemical characteristics.*

### **Features of vertical stratification and distribution of Dissolved organic matter in the lake Bolshie Hkruslomeny**

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The lake Bolshie Hkruslomeny can be attributed to the meromictic reservoirs with salt water. The salinity gradient between the layers is about 9‰. The red-ox barrier can be observed at a depth of 5-6 m. After the red-ox barrier, the concentration of sulfides and hydrogen sulfide increases sharply. With the increase in concentration of sulphides observed increase in the concentration of the dissolved organic matter (DOM). Vertical stratification of the waters of lake Bolshie Hkruslomeny (S‰, pH, Eh, S<sup>2-</sup> concentration) and features of dissolved organic matter and its hydrophobic component (the sum of the hydrocarbons) distribution in summer and winter were studied.

### **New data on Lake Mogilnoe (Kildin Island, Barents Sea): results of the 2018 expeditions**

***Krasnova Elena D., Vassilenko Alexander N., Voronov Dmitry A., Efimiov Basily A., Kokryatskaya Natalya M., Kossenkov Alexey V., Patsaeva Svetlana V., Dedyk Mikhail L., Frolova Natalya L., Strelkov P.P.***

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In July and August 2018, two expeditions were organized to the relict lake Mogilnoye (Barents Sea, island Kildin) to study its current condition. Has the top fresh water layer really disappeared? Has

the position of the hydrogen sulfide distribution boundary changed? Why could this happen? Is there a pink bacterial layer that protected the aerobic zone from toxic hydrogen sulphide, and what kind of phototrophic microorganisms are responsible for its color today? The report is devoted to the results of research carried out by a joint expeditions of Moscow and St. Petersburg State Universities.

**The phenomenon of feeding of cladocers *Bosmina longirostris* on anoxygenic phototrophic bacteria from chemocline in the meromictic lake Trekhtzvetnoe (Rugozerskaya Bay, Kandalaksha Gulf, White Sea)**  
***Krasnova Elena D., Zhiltsova Anna A., Patsaeva Svetlana V.***

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In July 2017, at the time of the massive development of freshwater crustaceans *Bosmina longirostris* in the aerobic zone of the meromictic Lake Trekhtzvetnoe, green contents were found in their digestive system. The spectrum of the extract from the crustaceans revealed a narrow light absorption peak with a maximum at 655 nm corresponding to the peak of bacteriochlorophyll absorption of green sulfur bacteria living in the anaerobic part of the chemocline. This is the first evidence of nutrition of zooplankton from the aerobic zone by anoxygenic phototrophic bacteria from the anaerobic zone of the chemocline of meromictic lakes. It confirms the importance of the chemocline microbial community for the entire water body ecosystem.

**Seasonal Variations in Community Structure of Anoxygenic Phototrophic Bacteria From the Meromictic Lake Trekhtsvetnoe (Kandalaksha Bay, White Sea)**

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It is known that in the water chemocline zone of meromictic lakes a microbial community consisting of phototrophic, chemotrophic and heterotrophic microorganisms forms. If in such a community brown-colored (b/c) green sulfur bacteria (GSB) present, they usually develop at the lower boundary of the photic area.

Since 2012, we studied the microbial community of meromictic Trekhtsvetnoe Lake, which connects with Kandalaksha Bay of the White Sea. First it was shown that in water chemocline zone green-colored (g/c) GSB *Chlorobium phaeovibrioides* develop. Further studies have shown also b/c GSB in the lake developing, and in summer seasons b/c GSB localize in the upper part of the community above the green water layer.

In winter, due to the distance of water chemocline from the ice surface, the lack of surface lighting was limited g/c GSB development, and optimal conditions for b/c GSB in the upper part of the green water layer appeared. However, despite the deep adaptation to extremely low light, the amount of b/c GSB did not reach g/c GSB extent, which was probably due to low rate of b/c GSB growth in low light conditions.

After ice melting, g/c cells quickly reached an extremely large number. A dense of green water layer (not less than  $2.0\text{--}2.3 \times 10^8$  cells ml<sup>-1</sup>) did not pass surface light into the lower horizons, which prevented the development of b/c GSB there. Thus, in the summer b/c GSB locked in extremely adverse conditions between dense layer of g/c GSB and well-lit oxygen layer. There was gradual displacement of b/c cells in the oxygen zone, where they quickly lost viability, being strict anaerobes. Single viable brown cells were preserved inside the high-density green layer, which was confirmed by cultivation of water samples in agar medium.

### **Benthos of the subtidal zone of the Kislaya Bay (White Sea, Kandalaksha Bay)**

***Mardashova M.V.*<sup>1</sup>, *Lokteva V.*<sup>2</sup>, *Aphentyeva A.*<sup>2</sup>, *Agaphonov I.*<sup>2</sup>, *Smolentseva D.*<sup>2</sup>, *Ivanova A.*<sup>2</sup>, *Proensa G.A.*<sup>2</sup>, *Yakovleva E.*<sup>2</sup>, *Kilina A.*<sup>2</sup>, *Azarov A.*<sup>2</sup>, *Koschenko Y.*<sup>2</sup>, *Amisimov M.*<sup>2</sup>, *Ravinsky D.*<sup>2</sup>, *Spirichina L.*<sup>2</sup>, *Smirnov A.*<sup>2</sup>, *Menshinina L.*<sup>2</sup>, *Voronov D.A.*<sup>3,4</sup>, *Krasnova E.D.*<sup>5</sup>**

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In August 2018, macrozoobenthos of the nook part of Kislaya Bay was investigated. Its waters adjoin to two separating basins: the meromictic Lake Nizhnee Yershovskoye and saline lagoon on the Green. The study area falls within a depth range of 1.1 to 11 m. A total of 78 species of benthic invertebrates were found in the material. In general, the community can be attributed to the *Macoma balthica* biocenosis, which is characteristic of silty and sandy soils of the corresponding depths in the vicinity of the WSBS MSU. The communities of the deep-water (6-10 m), shallow-water and the community of narrow shallow-water strait separating the nook from the Kislaya Bay from its southeast part are distinguished. This paper compares the fauna of the Kislaya Bay with that of the saline lagoon on Green Cape, the bucket bay Babye More and the separating reservoirs of Son-Island. The Kislaya bay is a bucket bay with a marine hydrological structure and fauna and can serve as a backdrop for comparing reservoirs in the early stage of separation from the White Sea.

### **Observations of the population of *Ophioglossum vulgatum* L. around the Sour-Sweet lake.**

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Since August 2014, we founded a regular mapping of *Ophioglossum vulgatum* population in the territory of Kindo Peninsula and adjacent Green Cape. It has been shown that the growth spots of the Pteridophyte are confined to the separated reservoirs. The highest population density was noted along the shores of lake Kislo-Sladkoye, and some spots were found near the lake Lower Ershovskoye and lagoon on the Green Cape. For five years, the state of the population has been monitored and observations of the hydrological characteristics in the closest points of the reservoir are conducted. It is noteworthy that in the summer of 2016, Adder's tongue was not found on the northern shore of Kislo-Sladkoye lake, where its population density was the greatest previously. This event coincided with the anomalous hydrological state of Lislo-Sladkoye lake. The year of 2017 was distinguished by an unusual lag in phenophases, and the spots of the Pteridophyte were found only in a few places along the shores of the lake. At other monitoring spots it was possible to find the fern only by autumn. The summer of 2018 was abnormally dry, however, the population of the snake was fully restored around the Sour-Sweet Lake. This paper discusses changes in the spread of sporiferous shoots throughout the monitoring period.

### **Diatoms in surface sediments of Trekhtzvetnoe Lake**

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Diatom associations from surface 0-1 cm layer of bottom sediments of small meromictic lake located on Karelia Coast of White Sea were examined. High absolute numbers of diatoms valves and chrysophyte cysts were revealed for all stations. C/D index is low in shallow part of lake and significantly increase on stations localized below the boundary of anoxic bottom water. Diatom associations characterized by a good averaging over the lake area and the unity of the composition of dominants and subdominants in all samples despite the sharp environmental gradients. Benthic and meroplankton species are absolutely dominated, while holoplankton has low diversity and rare occurrence. Mass occurrence is revealed for three small colonial species of the family Fragilariaceae: *Stauroforma exiguiformis* (Lange-Bertalot) Flower & Jones, *Fragilaria sopotensis* Witkowski & Lange-Bertalot, *Pseudostaurosira* sp. Subdominants are halophilic and mesohaline species (*Ctenophora pulchella* (Ralfs ex Kützing) D.M. Williams & Round, *Amphora copulata* (Kützing) Schoeman & Archibald, *Mastogloia smithii* Thwaites, *Navicula rhynchotella* Lange-Bertalot, *Ulnaria danica* (Kützing) Compère & Bukhtiyarova and other) on all stations including shallow freshwater area of lake.

### **Studies of the small-scale distribution of microorganisms in the chemocline of coastal stratified reservoirs separated from the White Sea**

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Using the new original sampler designed by D.A. Voronov, the vertical distribution of some prokaryotic and eukaryotic microorganisms within the chemocline of several meromictic lakes on the White Sea coast, with the spatial resolution of 2.5 cm was studied. Significant differences in the abundance of infusorians, unicellular algae, cyanicatheria, and anixygenic phototrophic bacteria over the layers of small dimension were revealed.

**Seasonal changes in the spectral and physico-chemical characteristics of water from the separating lakes of the Kandalaksha Bay of the White Sea**

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The work is devoted to the investigation of seasonal variability of spectral characteristics of water with green sulfur bacteria and its relationship with the distribution of water's hydrological parameters (temperature, salinity, oxidation-reduction potential, hydrogen index). Water with microorganisms for the optical measurements was sampled from different depths in several lakes (the lagoon on cape Zeleny, Bolshie Khruslomeny, N. Ershovskoye and Trekhtzvetnoe lakes) during the expeditions carried out in the spring and winter in 2016-2018 years. In the work the optical density spectra were measured with the Solar PB 2201 spectrophotometer, and the fluorescence emission and excitation spectra were recorded by the Solar CM2203 luminescence spectrometer. The concentration of photosynthetic pigments of GSB, bacteriochlorophylls, was calculated using the Overmann-Tilzer formula for extracts of natural water samples. During the work it was shown that in the autumn-summer period the concentration of oxygen in the surface layers in all lakes was much higher than in winter. Moreover in September the water samples from different depths showed a much sharper decrease in oxygen concentration in contrast to the March samples from the same lakes. The main result of the work was the demonstration of the fluorescence quenching phenomenon in the upper layers of chemocline, which was more pronounced in summer (July) than in autumn (September) or winter (March). This fact can be explained by the high illumination of the upper layers of chemocline in the autumn-summer period and the presence of oxygen in these layers. Based on the obtained results, it can be concluded that the separated reservoirs of the White Sea are self-regulating ecosystems whose microbial community is able to adapt to environmental conditions, including changing its physiological state (its photosynthetic activity) depending on external conditions.