An approach to marine bioregionalization in the Russian Arctic for the purposes of planning marine protected areas and other areas in need of protection

Paper presented for the CBD Expert Workshop on Ecological criteria and Biogeographic Classification Systems for marine areas in need of protection, 2 to 4 October 2007, Azores, Portugal

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With contribution of the participants of the Petrozavodsk workshop (19-21 February 2007) on preliminary planning of specially protected marine nature areas in the Russian Arctic[•]

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Summary

The papers describes initial steps of the project on planning a system of federal nature protected areas in the Arctic which is underway in Russia. As a framework for assessment and planning physiographic regionalization has been applied to the part of the North Polar Ocean which has been traditionally studied and used by USSR/ Russia. We apply an integrative physiographical regionalization approach based on identification of integral natural systems at various hierarchic levels. It is assumed that peculiarities of the geological-geomorphological structure of the shelf and coastal zones, climate, water circulation, their physical and chemical characteristics, whereupon the identification of physiographical units is based, also determine the specificity of the marine biota and communities within identified regions that is closely linked to these factors. As a result, 33 physiographic provinces have been identified in the Russian Arctic seas and adjacent areas of the North Polar Ocean (Fig. 1; Table 2). Most of the units of the physiographic regionalization correspond to biogeographic boundaries or particular eco-geographic patterns. Although this scheme needs to be compared to other biogeographic and ecologic regionalization and classification exercises conducted at different scales and using various, including numerical methods, it may serve as a working tool for assessment of representativeness of existing MPA and designating new marine areas in need of protection. The physiographic regionalization of the North Polar Ocean adjacent to Russia may be thus further applied to assessment and strategic planning of Arctic MPAs and other measures of biodiversity conservation addressing the new climate, economic and political conditions in the Arctic. Of particular priority is the

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Introduction

USSR and Russia have a developed a system of continental specially protected nature areas, which partly covers the adjacent marine waters (Spiridonov & Mokievsky, 2003; Zabelina et al., 2006). Marine stretches of coastal protected nature areas of the Arctic and the Russian Far East form a traditional set of coastal seascapes attached to terrestrial state strictly protected nature reserves (in Russian *zapovedniks,* IUCN category I) and federal reserves (in Russian *zakazniks,* IUCN category IV or V). One should bear in mind that a considerable portion of them was established for purposes of conservation of certain species (eiders, colonial seabirds, walruses, polar bears etc.). The question, whether these marine protected areas (MPAs) can perform the designated mission and, moreover, secure conservation of the marine biological diversity in the quickly changing conditions: decreasing ice coverage of the Arctic and other manifestations of the global climate change; possible intensification of traffic along the Northern Sea Route; development of extraction and transportation of hydrocarbons in the shelf area; increasing accessibility of remote areas and development of tourism – has not been discussed in depth. However, small sizes of sea stretches of *zapovedniks* and federal *zakazniks* make these vulnerable to aggravating threats to marine ecosystems.

In order to develop a representative system of marine protected areas and meet the goals of the Convention on Biological Diversity and the Resolution 2 of the World Summit on Sustainable Development in Johanessburg the Ministry of Natural Resources of Russian Federation requested WWF Russia to prepare a proposal for establishing new federal protected nature areas including marine protected areas. As the first step to planning of marine protected areas a working bioregionalization scheme should be adopted. Until now no such scheme has been proposed. The recent update of the marine ecoregions of the World (Spalding et al., 2007) also does not bring many details in the marine regionalization of the Arctic dealing there with traditionally defined seas rather with provinces and ecoregions. The present paper describes an approach to physiographical classification of the Arctic marine regions applied to the sector of the North Polar Ocean which has been traditionally studied and used by USSR/ Russia and discusses its relevance for refinement, consolidating and developing the global biogeographical and ecologic classification systems.

Why physiographic approach?

Bioregionalization can be based on various principles. In particular, it may rely on distribution ranges of certain taxa or entire floras and faunas. This approach is sometimes called biotic biogeography (Starobogatov, 1982). Distribution of some groups of organisms in Arctic seas was studied in enough detail to allow one demarcate borders of faunal regions on the map. However, the resulting schemes comprise two or three large regions, and further subdivision of these depends on the group of organisms under consideration (Table 1).

Obviously, it is difficult to design marine reserves using this approach. Schemes of biotic biogeographical regionalization are far too general for the problem we are concerned with. The eco-geographical regionalization relies on the distribution analysis of certain communities and ecosystems. Knowledge of all the diversity of Arctic ecosystems is definitely insufficient to carry out such an approach in the required detail

Therefore, the present paper uses an integrative physiographical regionalization approach based on identification of integral natural systems at various hierarchic levels. It is assumed that peculiarities of the geological-geomorphological structure of the shelf and coastal zones, climate, water circulation, their physical and chemical characteristics, whereupon the identification of physiographical units is based, also determine the specificity of the marine biota and communities within identified regions that is closely linked to these factors. Essentially the same assumption is shared by several independent marine regionalization and ecologic classification projects: habitat classification on the Atlantic shelf of Canada (Roff et al., 2003), marine ecosystem classification for the waters around New Zealand (Snelder et al., 2006), bioregionalisation of the Southern Ocean (Grant et al., 2006). But methodologies of these and the present study differ.

Despite the fact that first steps in the integral physiographical regionalization of seas and oceans in the Russian literature were made back in the 1940s, there is not any generally accepted methodology so far. Neither are there any detailed regionalization schemes of the area under consideration. An absolute majority of the existing regionalization scheme use the zonal or zonal-sectoral division of the marine environment, with numbers of zones and their borders greatly varying in different studies. Generally, there are two main methods of physiographical regionalization of the World Ocean: the deductive and the inductive. The deductive method analyses general differentiation factors of the World Ocean that rely on existing schemes of vertical, latitudinal, azonal divisions. In this, they usually apply the border overlay technique based on matching contours of special maps and high resolution seascape or habitat maps with a simultaneous analysis of a seascape-forming effect of each natural component. Special attention in this case should be given to the analysis of factors playing leading roles in partitioning of regions (determining factor technique) and factors sensitive to changes of seascape and environmental conditions (indicator factor technique). The inductive regionalization method involves a generalization of landscape map contours and, based on these, an identification of larger physiographical units. In accordance with this method, every next (higher in rank) unit is identified as a result of studying regular distributions of simpler natural units. The inductive approach extensively uses numeric techniques and multivariate analysis (Snelder et al., 2006; Grant et al., 2006)

The inductive method seems more advanced, however its application is limited by the lack of high resolution seascape data or even their surrogates or proxies. In dealing with large areas such as the North Polar Ocean this is especially critical. Therefore, in the present paper we use the deductive method as the major regionalization method. This approach is based on earlier work performed for the Russian Far Eastern seas (Ivanov, 2003).

Physiographic regionalization of Russian Arctic seas

Pgysiographic regionalization of the North Polar Ocean adjacent to Russia is based on geographic information: water circulation schemes, maps of geomorphological and climatic division, and fine-scale maps of physiographical regionalization. Partitioning was carried out based on the complexity principle, i.e. simultaneous and equal accounting of zonal and azonal factors and regularities in the partitioning of the geographic shell. Although the establishment of marine protected areas is especially urgent for coastal zones, in the present work we carried out the regionalization for the whole scope of the North Polar Ocean to provide the consistency of the results.

The Taxonomic System of Units The present scheme deals with a 5-level system of taxonomic units corresponding to: 1). Ocean Basins; 2). Megastructure of the ocean floor; 3). Sea basin; 4). Climatic zone; 5). Geomorphology of seabed and coasts. Because not any generally accepted taxonomic units of marine physiographical regionalization were available, at lower levels we used the units close to those applied to land regionalization. Let us see main diagnostic features of the regionalization units.

Level One associates with the North Polar Ocean in general. Despite its being the world's smallest ocean (which makes some foreign oceanographers consider it a sea of the Atlantic), it has traditionally been identified by Russian oceanographers as a separate entity.

Level Two of the regionalization corresponds to major megastructures of the oceanic floor within oceans. The second-order physiographical boundary in the North Polar Ocean is the divide between the underwater edge of the continent and the Arctic basin associated with the deepest central portion of the ocean.

Level Three of the regionalization corresponds to physiographic realms – azonal units associated with sea basins at underwater continental margins. Sea basins are distinguished by their sizes, depth, shape of basin, and the degree of isolation from the World Ocean. The following sea basins are distinguished in the North Polar Ocean: The Barents Sea, White Sea, Kara Sea, Chukchi Sea, and the Laptev – East Siberian Sea. The latter includes two seas that are usually considered separately. We thought it possible in our context to combine them into one sea basin due to a significant resemblance of natural features. It should be noted that these seas were indeed regarded as one is some regionalization schemes.

Level Four corresponds to physiographic regions – zonal units distinguished within sea basins by zonal climatic differences. Most researchers distinguish three climatic zones within the focal areas of the North Polar Ocean: the arctic, subarctic, and temperate cold.

The arctic zone comprises northern portions of all sea basins. The subarctic zone covers a larger area and includes southern portions of marginal seas of the North Polar Ocean. The temperate cold zone can only be traced in the White Sea and a small portion of the Barents Sea west of the Kola Bay.

Level Five of the regionalization corresponds to physiographic provinces – portions of sea basins within one climatic zone that are distinguished by their geomorphology. Characteristic of provinces are similarities of their geological structure, direction and amplitude of recent crustal motions, and combinations of underwater topographic forms that are only typical for the given province. It is assumed that, at this level, the seabed topography becomes a very important factor that affects the hydroclimate, water circulation, and distribution of the marine biota.

All provinces related to geomorphologic factors can be tentatively divided to two groups. The first group of provinces is located in the coastal zone of sea basins or large islands. The coast type and its connection to the open sea are the main components of the geomorphologic factor. Therefore, large bays and coast stretches that differ by shore type (coasts unaffected by seaside processes, abrasion coasts, abrasion-accumulative coasts, accumulative coasts etc.) are considered provinces.

The second group of provinces is found in open stretches of sea basins. There, due to a singularly broad shelf, provinces of central portions of sea basins are distinguished, with significant depths of the seabed and a lack of processes / properties of natural aquatic complexes characteristic of coastal zones.

More detailed regionalization and identification subprovinces would require GIS-based approach and statistical techniques (Roff et al., 2003; Snelder et al., 2006). This calls for a comprehensive assessment of dataset required for the Arctic biodiversity assessment, selection and mapping of indicators. This was the core of the Arctic Coastal Biodiversity Assessment (ACBio) Science Plan endorsed by the International Arctic Science Committee (Cogan, 2006) but hardly implemented because of the lack of financial and organizational support. However, subprovinces are optional units that need to be distinguished for case studies. In accordance with the above-mentioned criteria, 33 physiographic provinces have been identified in the Russian Arctic seas (Fig. 1; Table 2, coastal provinces are tinted).

Comparison of physiographic regionalization to biogeographic regions

When comparing the physiographical provinces to biogeographic ones [as presented by Jirkov (2001)] correspondence can be noticed (Table 2). All deep water high Arctic physiographic regions coincide with the Deep Water High Arctic biogeographic region. It extends somewhat beyond the continental slope of the North Polar Ocean and includes the northern parts of the Laptev – East Siberian offshore and North Chuckchi physiographical provinces (Table 2). This is not surprising as many Arctic marine species have rather extensive bathymetric ranges and particular deep water species may penetrate to the shelf thus shifting towards the shore the boundary between deep water and shelf biogeographic regions.

Most of physiographic provinces in the Siberian Arctic seas correspond to the Shelf Arctic Biogeographic region. Furthermore, the White Sea (provinces 12-14, Fig. 1) is also referred by Jirkov (2001) and other authors as to belonging to the Shelf Arctic Biogeographic province. This may seem unexpected taking into account its isolated from the Siberian shelf location and belonging at most to the cold temperate climate zone. The White Sea with its Holocene-aged biota was colonized by taxa belonging to both Boreal or the Arctic Realms (and the latter mostly originating from the Siberian shelf). These two different biotic components are now separated in the White Sea. In the benthic environment the boreal species are generally confined to depth range occupied by the surface water mass, which undergoes summer warming while the Arctic taxa live either within the circulation range of the bottom water mass (with round year negative temperature) or in the deep semi-isolated fjords and inlets with a shallow sill (Naumov, 2001).

The Waranger – Kola and the East Kola coastal physiographic provinces correspond well to the part of the Peri-Atlantic shelf coastal biogeographic region. Most of the Barents Sea area with several physiographic provinces fall over a broad transitional biogeographic zone. The reason for this is a strong but changing from year to year impact of the North Atlantic waters and respective shifts of distribution boundaries of the species belonging to either Arctic or North Atlantic faunas (Galkin, 1986).

The Chuckchi physiographic provinces mostly correspond to the Peri-Pacific biogeographic province. This is not surprising since many Pacific species enter the Chuckchi Sea and makes its biota different from other Arctic Sea (Jirkov, 2001)

In general one can conclude that certain combinations of physiographic provinces coincide well with usually larger biogeographic regions. It also appears that no single physiographic province of the present scheme corresponds to the provinces of the Marine Ecoregions of the World Ocean (MEOW) scheme (Spalding et al., 2007). The latter hold some level of endemism, principally at the species level. By their size the physiographic provinces of the present scheme correspond to the MEOW ecoregions. The latter are defined as areas of relatively homogenous species composition clearly distinct from adjacent systems. "The species composition is likely to be determined by the predominance of a small number of ecosystems and/ or a distinct suite if oceanographic and topographic features" (Spalding et al., 2007: 575). It must be noted, however, that assessment of this relative homogeneity for most MEOW ecoregions is based on limited number of taxonomic groups and usually does not take into account the entire biota. There are not many places at the scale lesser than a sea basin for which inventories of entire biotas have been published. They are usually restricted to the areas adjacent to marine biological stations or institutes in Europe, North America, Japan, Australia and New Zealand. For the Russian Arctic in general the best available knowledge of species composition of the invertebrate fauna is presented only for the level of sea basins (List of species, 2001). At lesser scale (leveling to physiographic provinces or their parts) few updated faunal lists have been prepared and all of them are confined to coastal waters (Grishankov et al., 2000; Golikov et al., 2004; Kaliakina, Tschesunov, in press.). A notable exception is the faunal list compiled for the deep part of the Laptev Sea and adjacent part of the continental slope and abyssal plain of the Arctic Basin as a result of old Russian and modern expedition using a research ice-breaker (Sirenko et al., 2004). As complete species inventories are rare no sound measure for homogeneity of species composition in the extensive marine areas can be suggested. At the same time the system of nested physiographical regions may serve as a framework for compiling species inventories and testing various hypotheses regarding spatial patterns of species richness.

Comparison of the physiographic regionalization to eco-geographic patterns

The areas showing uniformity with regard to occurrence of particular taxa (i.e. biotic biogeography regions) may be indeed different with regard to eco-geographic patterns, i.e. distribution of various biodiversity components. The structure of the Arctic marine biodiversity is largely determined by a number of vital marine and coastal habitat elements and systems, and biological objects. Participants of the Petrozavodsk workshop determined these components of the habitat and biological diversity in the following way:
Habitat elements and systems:
- extensive salt marshes
- wadden shores
- tombolo
- big river estuaries
- shore cliffs
- highly productive lagoons and bays
- relic water bodies (including refugia)
- stationary polynyas
- marginal ice zones
- frontal zones
- upwelling zones
- underwater mountains and bank
- cold seeps and hydrothermalism spots on seabed

Biological objects:
- mass settlements of bentic organisms, including biogenic reefs and banks
- sites with a greater biomass of bentic organisms
- breeding and spawning sites
- feeding areas of aquatic organisms, in particular seabirds and marine mammals
- rookeries of marine mammals
- wintering aggregations of aquatic organisms, for example eiders wintering in polynyas
- breeding colonies of sea and water birds
- moulting aggregations of sea and water birds
- stopover sites of migration
- populations of rare species

A preliminary testing of the physiographic regionalization against the listed above biodiversity components indicated that each province may be characterized by a unique combination of these features. Furthermore the published data on the distribution of Arctic top predators shows a good correspondence with particular physiographic provinces. For example sightings of grey, bowhead and other whales are confined to provinces 33 and 32 and bowhead, humpback and minke whales to provinces 4 and 6 (Fig. 1). Beluga whales occur rather broadly but are nearly absent in the provinces 1, 2, 3, 24, 30 (Belikov et al., 2004). In the Kara and the Barents Sea the sightings of Polar bear were mostly confined to the provinces 5, 20, 22 (see Fig. 1), those of walrus to the areas 8, 19, 22 and maximum abundance of bearded seal was observed in the area 20 (Matishov et al., 2005). However, comprehensive assessment of the biodiversity components even in the coastal zone of the Arctic is by far not completed and needs a consolidated international effort using a multi-disciplinary and multi-scale approach as proposed by ACBio (Cogan, 2006).

MPAs in relation to physiographic provinces

The first assessment showed that existing MPA represent only a limited fraction of the provinces (Table 2). As mentioned above, most of Russia's MPAs in the Arctic and elsewhere are offshore stretches of the terrestrial *zapovedniks* and *zakazniks*. Some of them are small areas adjacent to protected islands, for example the waters of the clusters of the Kandalaksha *zapovednik* in the coastal regions of the Barents and the White Seas, Nenets zapovednik in the south-eastern Barents Sea (Kanin – Pechora coastal province), the Severnaya Zemlya *zakaznik* (Kara – Severnaya Zemlya coastal province), the buffer zones of the Taymyr *zapovednik* (East Taymyr coastal province) and Ust'-Lena *zapovednik* (Khatanga – Yana coastal province). For locations of the reserve one can refer to Spiridonov & Mokievsky (2003).The size of these protected areas is usually not great and ranges from several hundreds to 1800 km^2 (Zabelina et al., 2006) A unique for the Arctic (but not for Russia's Pacific seas) characteristics of the Chuckchi coastal province is the presence of extensive areas around marine mammals haulouts and colonies which are closed for fiheries related activities according to the fishery regulation ("Fishing Rules"). In USSR there was a special regulation on these marine mammal protection zones which restricted also other activities. A notable exception from usually small size of marine protected areas is the Franz-Josef Land *zakaznik* (26000 km^2 of marine area), Great Arctic *zapovednik* (9809 km^2; West Taymyr coastal province), and the Wrangel Island *zapovednik* [37453 km^2; South Chuckchi province Zabelina et al., 2006)]. The participants of the Petrozavodsk workshop identified several candidate areas to be designated as MPAs under Russia's regulation within the national Exclusive Economic zone (Spiridonov et al., report in preparation). It is recognized also that since most of these areas fall within the zone of the internationally used Northern Sea Route special regulatory measures should be adopted also at the international level.
It is not surprising that no areas in need of protection has been designated or even proposed so far in the Deep Water High Arctic physiographical provinces and the provinces of northern parts of Siberian seas. Few years ago this seemed to be non-actual. But the situation is changing rapidly. With decreasing summer ice cover and raising interest to recoinassance of hydrocarbon and mineral resources on the seafloor of the Arctic Basin it is time to begin the process of assessment and selection of areas which represent the principal ecosystems of the Deep Water High Arctic. Following the suggestion by Thiel (2001; see also in Gjerde, 2003) they can be designated as unique scientific reference areas and protected from the adverse impact of other human activities within the framework of regional international agreements, for example OSPAR Convention for the Atlantic sector of Arctic (Gjerde, 2003). However, we are still far away from understanding the principles of selection such areas in the deep North Polar Ocean. In spite of more than hundred years history of research the biodiversity of the Arctic Basin is poorly known and the more scientists learned about the life in the deep Arctic the more mosaic distribution of habitat and communities appears (Sirenko et al., 2004).

Conclusions and recommendations

The physiographic regionalization system based on four hierarchical levels (mega-structures of ocean basins and their parts; marine basins with their offshore and coastal parts and climate zones) provides a useful framework for assessment of marine biodiversity. Most of the units of the physiographic regionalization correspond to biogeographic boundaries or particular eco-geographic patterns. Although this scheme needs to be compared to other biogeographic and ecologic regionalization and classification exercises conducted at different scale and using various, including numerical methods, it may serve as a working tool for assessment of representativeness of existing MPA and designating new marine areas in need of protection. The physiographic regionalization of the North Polar Ocean adjacent to Russia may be thus further applied to assessment and strategic planning of Arctic MPAs and other measures of biodiversity conservation addressing the new climate, economic and political conditions in the Arctic. It is recommended to extend this approach to the remaining part of the Arctic seas and provide a comprehensive physiographic classification which validity for biodiversity conservation purposes should be tested against a set of biogeographic and eco-geographic criteria. Basing on the present regionalization scheme a priority at the international level should be given to designation of potential unique scientific reference areas [as first proposed by Thiel (2001] in the Deep Water High Arctic as the first step toward establishing a coordinated and manageable network of MPAs.

Acknowledgement

We acknowledge the help of Olga Stepanova who translated the original version of the description of the physiographic approach, and Anton Makarov who prepared an electronic version of the physiographic provinces map.

The present analysis is part of the WWF Russia project "A new future for the Russian Arctic" supported by WWF Netherlands and WWF Russia. The organization of the Petrozavodsk workshop was supported by the WWF Barents Sea Ecoregion project.

References

Belikov, SE, Boltunov, AN Gorbunov, YA. 2004. Distribution and migration of cetaceans in the Russian Arctc according to multiyear aerial recoinaisance of sea ice and information from 'North Pole' drift station. In: Marine Mammals Results of Research in the years 1995-1998. Marine Mammal Council, Moscow, p. 21-51 (in Russian).

Cogan, C. 2006. Arctic Coastal Biodiversity assessment. Report to IASC. Available at www.iasc.se/projects

Galkin, Yu.I. 1986. Multi-year changes of bottom fauna. In: Life and conditions of its existence in the benthal of the Barents Sea. Murmansk Marine Biological Institute of Kola Branch of Academy of Sciences of USSR, Apatity, p. 43-52 (in Russian).

Gjerde, K.M. 2003. Towards a Strategy for High Seas Marine Protected Areas. Proceedings of the IUCN, WCPA and WWF Experts Workshop on High Seas Marine Protected Areas 15-17 January 2003, Malaga, Spain, 52 p. Available at www.iucn.org/places/medoffice/documentos/ProceedingsGjerdepdf

Golikov, A.N., Gagaev, S.Yu., Galtsova, V.V., Golikov A.A., Dunton, K., Menshutkina, T.V., Novikov, O.V, Petryashev, V.V., Potin, V.V., Sirenko, B.I., Schonberg, S., Vladimirov, M.V. 2004. Ecosystems of the Chaun Bay of the East Siberian Sea. In, Golikov, A.N. (ed.). Ecosystems and the flora and the fauna of the Chaun Bay of the East Siberian Sea. Part. 1. St. Petersburg, Zoological Institute of the Russian Academy of Sciences. Exlrorations of the fauna of the seas, 47 (55): 4-111.

Grishankov, A.V., Ninburg, E.A. & Shkliarevich, G.A. 2000. Macrozoobenthos of the Kandalaksha zapovednik (strict nature reserve). Flora and fauna of zapovedniks, **83**: 1-74 (in Russian).

Grant, S., Constable, A., Raymond, B. and Doust, S. (2006) Bioregionalisation of the Southern Ocean: Report of Experts Workshop, Hobart, September 2006. WWF-Australia and ACE CRC

Ivanov, A.N. 2003 Oroblems of the organization of marine reserves in Russia. Vestnik Moskovskogo Universita, ser. Geogr. (Bulletin of the Moscow University. Series Geography), 2003, # 4: 22-27 (in Russian).

Jirkov, I.A. 2001. Polychaeta of the Arctic Ocean. Yanus-K, Moscow, 632 p. (in Russian).

List of species of free-living invertebrates of Eurasian Arctic Seas and adjacent deep waters. 2001. Explorations of the fauna of sea, Zoological Institute of Russian Academy of Sciences, St. Petersburg, 51 (59): 1-131.

Naumov A. 2001. Benthos. In: V. Berger and S. Dahle. (eds). White Sea. Ecology and Environment. Derzhavets Publisher, St. Petersburg – Tromsø, p. 41-54.

Matishov, G.G., Makarevich, P.R., Goryaev, Yu.I., Ezhov, A. V., Ishkulov, D.G., Krasnov, Yu.V., Larionov, V.V., Moiseev, D.V. Murmnsk, 2005. Hard to reach Arctic: 10 years of bioceanologic research on board of nuclear ice breakers. Murmansk Marine Biological Institute, Kola Branch of the Russian Academy of Sciences, Apatity, 146 p.

Petryashov, V.V. 2004. Mysids (Crustacea Mysidacea) of the Eurasian sub-basin of the Arctic Basin and the adjacent areas of the Barents, Kara and the Laptev Seas. In: Fauna and the ecosystems of the Laptev Sea and adjacent deep waters of the Arctic Ocean. Explorations of the fauna of sea, Zoological Institute of Russian Academy of Sciences, St. Petersburg, 54 (62): 124-140

Roff, J.C. Taylor, M.E, Laugrem, J. 2003. Geophysical approach to the classification, delineation and monitoring of marine habitats and their communities, Aquatic Conservation: Marine and Freshwater Ecosystems, 13: 77-90.

Sirenko, B., Denissenko, S., Deubel, H.,Rachor, E.2004. Deep water communities of the Laptev Sea and adjacent parts of the Arctic Ocean. In: Fauna and the ecosystems of the Laptev Sea and adjacent deep waters of the Arctic Ocean. Explorations of the fauna of sea, Zoological Institute of Russian Academy of Sciences, St. Petersburg, 54 (62): 28-73.

Spalding, M.D., Fox, H., Allen, G.R., Davidson, N., Ferdana, Z.A., Finlayson, M., Halperin, B.S., Jorge, M.A., Lombana, A, Lourie, S.A, Martin, K.D., McManus, E., Molnar, J., Recchia, C.A., Robertson, J. 2007. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas BioScience, 7: 573-583.

Snelder, T.H., Leathwik, Dey, K.L., Rowden, A.A., Weatherhead, M.A., Fenwick, G.D., Francis, M.P., Gorman, R.M., Grieve, J.M., Hadfield, M.G., Hewitt, J.E., Richardson, K.M., Uddstrom, M.J., Zeldis, J.R. 2006. Development of an ecologic marine classification in the New Zealand region. Environmental Management, 39: 12-29.

Spiridonov, V.A., Mokievsky, V.O. 2003. Marine protected areas in Russia. Map and text. WWF Russia, Moscow (in Russian and English). Available at www.wwf.ru/publ/book/53/

Starobogatov, Ya. I. 1982. On the problem of minimal subdivision in biogeography and its application to the faunistic (faunogenetical) zoogeography of the sea. In: Marine Biogeography: Subject, Method, Principles of Regioning.. Nauka,Moscow, p. 12-18 (in Russian).

Thiel, H. 2001. Unique scientific reference areas in the High Seas. Paper prepared for the symposium “Aktuelle Probleme der Meeresunterwelt” held by the Bundesamt für Seeschifffahrt und Hydrography, Hamburg, Germany, 6-7 June 2001. Available at www.biodiversity.ru/eng/publications/zpnp/archive/n57/seashtml

Zabelina, N.M., Issaeva-Petrova, L.S., Korotkov, V.N., Nazyrova, R.I., Onufrenja, I.A. Otchagov, D.M., Potapova, N.A. 2006. Marine and Coastal Protected Areas of Russia (Reference Book). ARRINP, Moscow, 72 p. (in Russian).

Table 1. Comparison of biotic biogeographical regionalization of Eurasian sector of Arctic based on different taxa (from Jirkov, 2001 with additions the data by Petryashev, 2004).

Regions: 1 – Deep water high Arctic; 2 – Deep water Norwegian; 3- Shelf Eurasian Arctic; 4 – Shallow water Scandianavian; 5 – Shelf Peri-Atlantic; 6 – Faroe – Icelandic; 7 - Peri-Pacific. Minus sign (-) indicates that a particular author does not recognize certain region. Question mark (?) indicates that a particular author does not consider this region. Combining cells indicates that these regions are considered as a single one by particular authors. References to Russian biogeographic regionalization works are given by Jirkov (2001)

<table>
<tr><th rowspan="2">Taxa</th><th rowspan="2">Original number of regions</th><th rowspan="2">Corrected number of regions</th><th colspan="7">Regions</th><th rowspan="2">Number of species</th><th rowspan="2">Source</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td>Gammaridea (Crustacea Amphipoda)</td><td>6</td><td>4</td><td colspan="2">x</td><td>x</td><td colspan="3">x</td><td>-</td><td>399</td><td>Gurjanova, 1951</td></tr>
<tr><td>Isopoda (Crustacea)</td><td>4</td><td>4</td><td colspan="2">x</td><td>x</td><td colspan="2">x</td><td>x</td><td>-</td><td>68</td><td>Kussakin, 1979</td></tr>
<tr><td>Caprellidea (Crustacea Amphipoda)</td><td>3</td><td>3</td><td>-</td><td>-</td><td>x</td><td colspan="2">x</td><td>x</td><td>-</td><td>14</td><td>Vassilenko, 1974</td></tr>
<tr><td>Neptunea (Mollusca Gastropoda)</td><td>4</td><td>3</td><td>-</td><td>-</td><td>x</td><td colspan="2">x</td><td>x</td><td>-</td><td>4</td><td>Golikov, 1963</td></tr>
<tr><td>Buccininae (Mollusca Gastropoda)</td><td>4</td><td>3</td><td>-</td><td>-</td><td>x</td><td colspan="2">x</td><td>x</td><td>-</td><td>16</td><td>Golikov, 1980</td></tr>
<tr><td>Oenopotinae (Mollusca Gastropoda)</td><td>4</td><td>3</td><td>-</td><td>-</td><td>x</td><td colspan="3">x</td><td>x</td><td>31</td><td>Bogdanov, 1990</td></tr>
<tr><td>Bivalvia (Mollusca)</td><td>8</td><td>4</td><td colspan="2">x</td><td>x</td><td colspan="2">x</td><td>?</td><td>x</td><td>55</td><td>Filatova, 1957</td></tr>
<tr><td>Bivalvia</td><td>9</td><td><6</td><td>x</td><td>x</td><td>x</td><td colspan="3">x</td><td>?</td><td>55</td><td>Fedyakov & Naumov, 1987</td></tr>
<tr><td>Benthos in general</td><td></td><td>>=4</td><td>x</td><td></td><td>x</td><td>?</td><td>x</td><td>?</td><td>?</td><td></td><td>Zenkevich, 1947</td></tr>
<tr><td>Polychaeta</td><td>7</td><td>7</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>112</td><td>Jirkov, 2001</td></tr>
<tr><td>Mysidacea (Crustacea)</td><td>3</td><td>3</td><td colspan="3">x</td><td colspan="2">x</td><td>?</td><td>x</td><td>28</td><td>Petryashov, 2004</td></tr>
</table>

Table 2. Physiographic regionalization of the North Polar Ocean and its comparison to biogeographic regionalization and the existing marine protected areas in the Rusisan Arctic. Numbers corresponding to coastal provinces are tinted

Units of physiographic regionalization					Region of biotic zoogeographic regionalization based on benthic invertebrates (Table 1)	Marine protected areas
Ocean	Ocean part	Marine basin	Climate zone	Province		
NPO	Abyssal and slope area	North Polar	Arctic	1. West Polar	Deep water high Arctic	no
				2. East Polar	Deep water high Arctic	no
				3.Polar Continental Slope	Deep water high Arctic	no
	Continen-tal margin area	Barents Sea	Arctic	4.Franz-Josef Land coastal	Shelf Eurasian Arctic	Federal zakaznik “Franz-Josef Land”; national park „Russian Arctic“ planned
				5. Barents – Northern Novay Zemlya coastal	Shelf Eurasian Arctic	national park „Russian Arctic“ planned
				6. North Barents Sea	Shelf Eurasian Arctic	no
			Subarctic	7. East Kola coastal	Shallow water Scandianavian	Kandalaksha zapovednik
				8. Kanin – Pechora coastal	Transitional zone	Nenents zapovednik
				9. Barents – southern Novaya Zemlya coastal	Transitional zone	no
				10.Central Barents	Transitional zone	no
			Cold temperate	11. Waranger – Kola coasral	Shallow water Scandianavian	Kandalaksha zapovednik
		White Sea	Subarctic	12. White Sea northern	Shelf Eurasian Arctic	no
			Cold temperate	13. White Sea western-central	Shelf Eurasian Arctic	Kandalaksha zapovednik
				14. White Sea eastern	Shelf Eurasian Arctic	no
		Kara Sea	Arctic	15. northern Kara – Novay Zemlya coastal	Shelf Eurasian Arctic	no
				16. Kara – Severnaya Zemlya coastal	Shelf Eurasian Arctic	Federal zakaznik “Severnaya Zemlya”
				17. North Kara	Shelf Eurasian Arctic	no
			Subarctic	18. southern Kara – Novaya Zemlya coastal	Shelf Eurasian Arctic	no
				19. Baidara Bay	Shelf Eurasian Arctic	no
				20. Ob’ – Enissei coastal	Shelf Eurasian Arctic	no
				21. West Taymyr coastal	Shelf Eurasian Arctic	Great Arctic zapovednik

				22. South Kara	Shelf Eurasian Arctic	no
		Laptev – East Siberian Seas	Arctic	23. Laptev – Severnaya Zemlya coastal	Shelf Eurasian Arctic	no
				24. Laptev – East Siberian offshore	Deep water high Arctic (part); Shelf Eurasian Arctic (part)	no
			Subarctic	25.East Taimyr coastal	Shelf Eurasian Arctic	Taimyr zapovednik
				26. Khatanga – Yana coastal	Shelf Eurasian Arctic	Ust'- Lena zapovednik
				27. New Siberian Islands coastal	Shelf Eurasian Arctic	no
				28. Indigirka – Kolyna coastal	Shelf Eurasian Arctic	no
				29. South Laptev	Shelf Eurasian Arctic	no
				30. South East Siberian	Shelf Eurasian Arctic	no
		Chuckchi Sea	Arctic	31. North Chickchi	Deep water high Arctic (part); Peri-Pacific (part)	no
			Subarctic	32. South Chuckchi	Peri-Pacific	Wrangel Island zapovednik
				33. Chuckchi coastal	Peri-Pacific	marne mammal protection zones according to fishery regulation

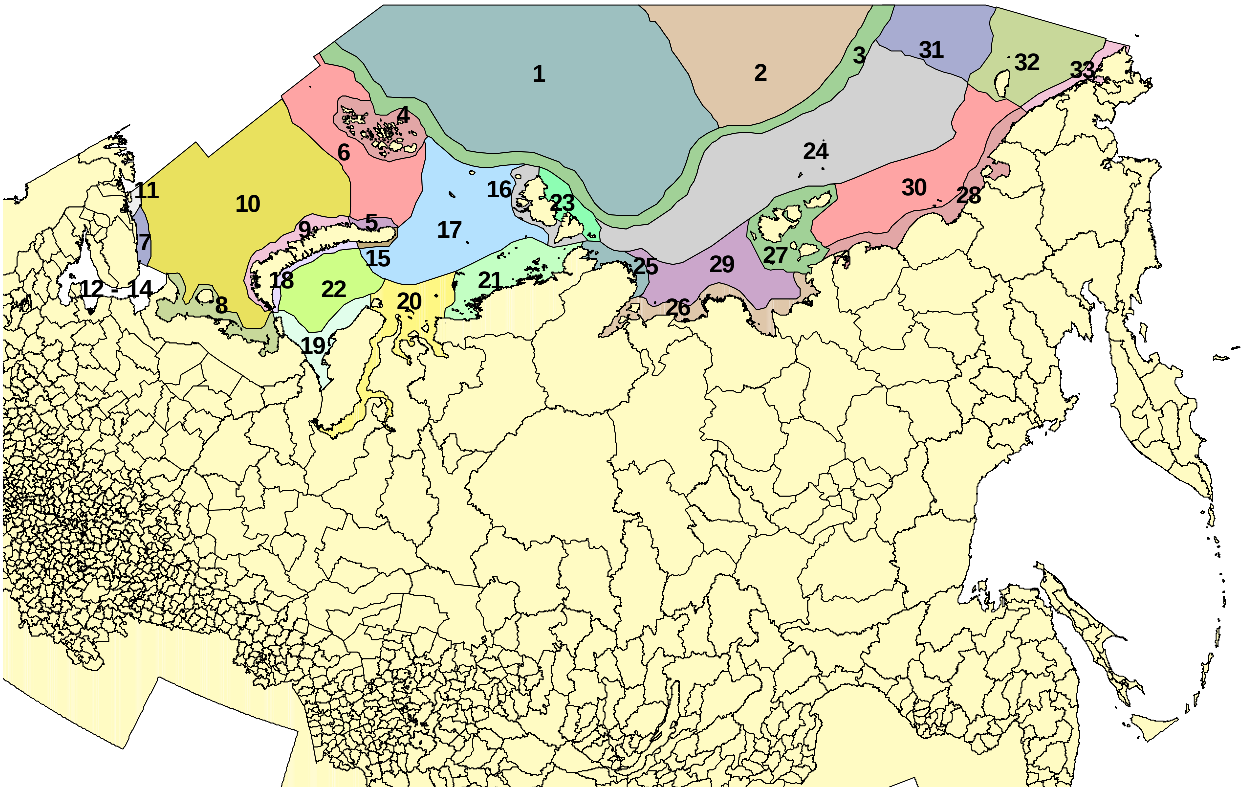

Fig. 1. Physiographic regionalization of the Eurasian Seas and the sector of North Polar Ocean traditionally studied and used by Russia. Numbers indicate provinces listed in Table 2.