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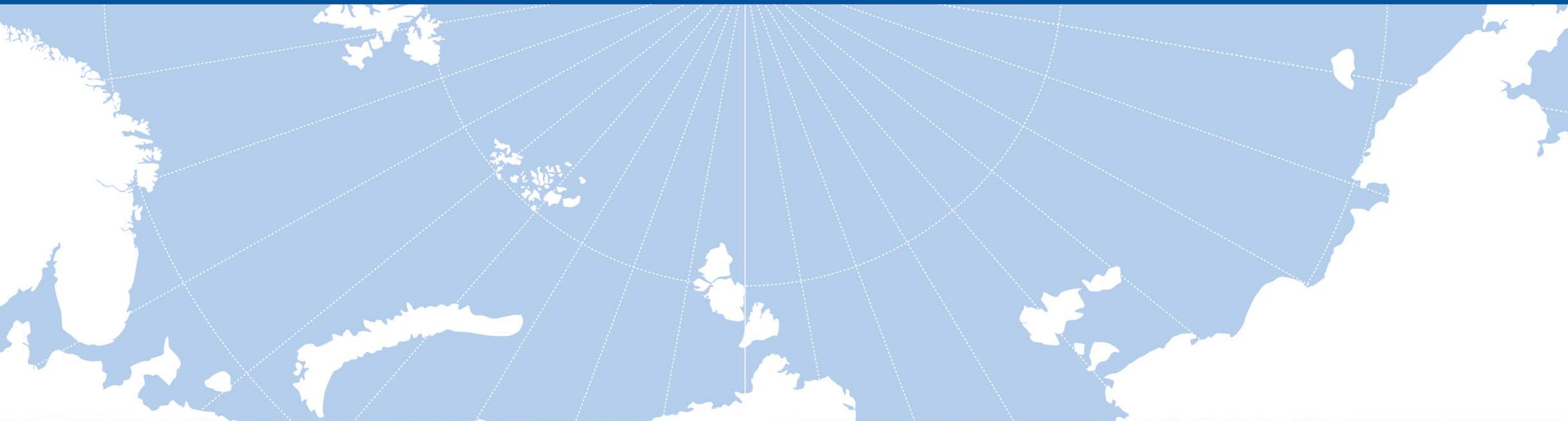
ATLAS

OF MARINE AND COASTAL BIOLOGICAL DIVERSITY OF THE RUSSIAN ARCTIC

Edited by V.A. Spiridonov, M.V. Gavrilo, E.D. Krasnova and N.G. Nikolaeva



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In this era of climate change and increasing economic activity in the Arctic, this publication, prepared by the specialists of leading scientific institutions of the Russian Academy of Sciences, universities, the Ministry of Natural Resources and Ecology of the Russian Federation, and the Federal Agency of Fishery, provides a crucial foundation for planning conservation activities in the seas and the coastal zone of the Russian Arctic. The Atlas illustrates the distribution of specially protected natural areas in the coastal zone of the Russian Arctic seas, presents schemes of physiographical and biogeographical regionalization, data on species diversity of particular taxonomic groups, biotopes and components of biological diversity which may be used for marine spatial planning in the Russian Arctic, development of protected natural areas network, establishment of fishery refuge zones and areas with special shipping regulations. A particular emphasis is given to the systems of boundary biotopes at interfaces of different environments: sea/sea ice, sea /river discharge, and sea/land and their associated biological diversity.

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ABBREVIATIONS

AARI — Arctic and Antarctic Research Institute
AMAP — Arctic Monitoring and Assessment Programme of the Arctic Council, an international regional organization aimed at promoting cooperation and sustainable development in the North Polar Regions
AO — Autonomous Okrug
CAFF — Conservation of Arctic Flora and Fauna working group of the Arctic Council
FEB RAS — Far-Eastern Branch of RAS
FSS RF — Federal Security Service of the Russian Federation
GEF — Global Environmental Fund
IBA — important bird area
IO RAS — P.P. Shirshov Institute of Oceanolology of RAS
IPEE — A.N. Severtsov Institute of Problems of Ecology and Evolution of RAS
MSU — M.V. Lomonosov Moscow State University
MMBI — Murmansk Marine Biological Institute (MMBI) of the Kola Scientific Centre of RAS
MPA — marine protected area
MSP — marine spatial planning
NGO — non-governmental organization
PAME — Protection of Arctic Marine Environment working group of the Arctic Council
PINRO — N.M. Knipovich Polar Research Institute of Fishery and Oceanography
RBCU — Russian Bird Conservation Union
RAS — Russian Academy of Sciences
Roshydromet — Federal Service for Hydrometeorology and Environmental Monitoring
SPNA — specially protected natural area
UN — United Nations
UNDP — UN Development Program
UNESCO — United Nations Education, Science and Culture Organization
IUCN — World Conservation Union
VNIIPriroda — All-Russian Research Institute for Nature Protection
VNIRO — Russian Research Institute of Fishery and Oceanography
WSBS MSU — N.A. Pertsov White Sea Biological Station of Moscow State University
WWF — WWF, The Conservation Organization
ZIN RAS — Zoological Institute of the Russian Academy of Science

PREFACE

The growing interest in the Arctic is natural. Some people view it as a treasure trove of resources waiting to be discovered, others are concerned about the Arctic's sensitivity to climate change. In 2008, the President of Russia approved the «Fundamentals of the State Policy in the Arctic for the Period Before 2020 and a Longer Perspective» [Fundamentals.., 2008], while in late 2009 the Climate Doctrine of the Russian Federation was adopted [Climate Doctrine.., 2009]. Now its implementation plan is in progress. In this document the Arctic is considered from scientific, economic, and conservation perspectives. Our knowledge of climate change is still incomplete, but there is no doubt that global processes influence the Arctic and that the condition of this region influences the Earth's climate.

After the disastrous BP Gulf of Mexico oil spill in the spring of 2010, optimism on the feasibility of environmentally safe exploitation of the hydrocarbon resources on the continental shelf began to fade. The spill revealed gaps in the industry's international regulation and cast doubts on the ability of countries and corporations to respond to such catastrophes in a timely and effective manner.

At the same time, large-scale plans of industrial development in environmentally sensitive regions, such as the Arctic seas and coasts, are still in the works. Proponents believe that changing climate conditions and sea ice regime will facilitate this development. However, before extensive intrusion into the Arctic marine ecosystems occurs, it is important to have a full understanding of the diversity, spatial structure, complexity of temporal dynamics and the value of the services that these ecosystems provide. It is important to intelligently locate industrial facilities and economic activity (e.g. shipping) on the shelf and in the coastal zone of the Arctic seas. Otherwise, all intentions to exploit the natural resources of the Arctic would bear unacceptable risks not only to countries and corporations implementing the projects, but also to their neighbors in the Arctic realm, and in some cases far beyond. One of the instruments of risk mitigation is marine spatial planning, or functional zoning. In order to design and implement this practice (and thus ensure biodiversity and ecosystem conservation), the most valuable areas must be chosen and governed by special protection and management regimes. This document — an Atlas of the biological diversity of the seas and coasts of the Russian Arctic — is an important step in this process.

We hope that this publication will be used by decision-makers in Arctic policy, participants in international consultations and symposia on Arctic issues, officials from state agencies dealing with environmental issues, natural resource use and transport development in the Arctic, managers from resource extraction and transport companies and scientists. We hope the Atlas will stimulate the interest of a wide audience of people who care about the future of one of the least developed — and most wonderful — regions of the world.

Igor Chestin,
Director of WWF Russia

SUMMARY

Today the Arctic is entering a new climatic period and a new phase of economic development. Experts believe lighter sea ice conditions will facilitate the development of large-scale industrial projects, especially hydrocarbon development and transportation. The areas slated for development will likely include those areas of the Arctic seas and coast where wildlife is concentrated — ecological «hotspots». In particular, increasing pressure is expected on flaw polynyas (stretches of open water surrounded by pack ice and fast ice) which are natural shipping lanes along the Northern Sea route. Access to previously remote corners of the Arctic is increasing, making increased tourism — often self-described «eco-tourism» — in the area, possible. No one can predict how the combination of climate change and economic activity will impact the ecosystems of the Arctic seas. However, there is a way to mitigate consequences of the climate transformation and the increasing anthropogenic impact using marine spatial planning instruments (we propose to translate this globally accepted term into the Russian language as «functional zoning of marine areas»). Marine spatial planning has its terrestrial analogy in Russia which is called «territorial planning». One of the instruments of such planning is marine protected areas (MPAs). Naturally, marine spatial planning (or functional zoning) does not restrict itself to the creation of MPAs. It comprises a broad range of instruments, some of which are already present in Russian legislation. The aim of this project organized by WWF Russia is to present biodiversity data (with particular focus on the biotope systems and related biodiversity components) which may serve as a basis for the design of MPAs and marine spatial planning. Several experts from the Russian Academy of Science institutes, Moscow University, the Arctic and Antarctic Research Institute (AARI) and the Federal Agency of Fishery contributed to the assessment. The material is presented in an Atlas form.

The Atlas includes maps demonstrating the schemes of physiographical and biogeographical regionalization, species diversity in particular taxonomic groups of the Arctic biota, and distribution of existing federal and regional specially protected natural areas. Particular attention is paid to the systems of boundary biotopes at interfaces of different environments: sea/sea ice, sea/river discharge, and sea/land and their associated biological diversity. In the concluding part of the present work recommendations are made to marine environment protection, marine biodiversity conservation and organization of marine resources use (on the basis of the adopted scheme of physiographical regionalization). These recommendations may serve as a basis for the development of an integral system of marine spatial planning for the Arctic waters under Russian jurisdiction.

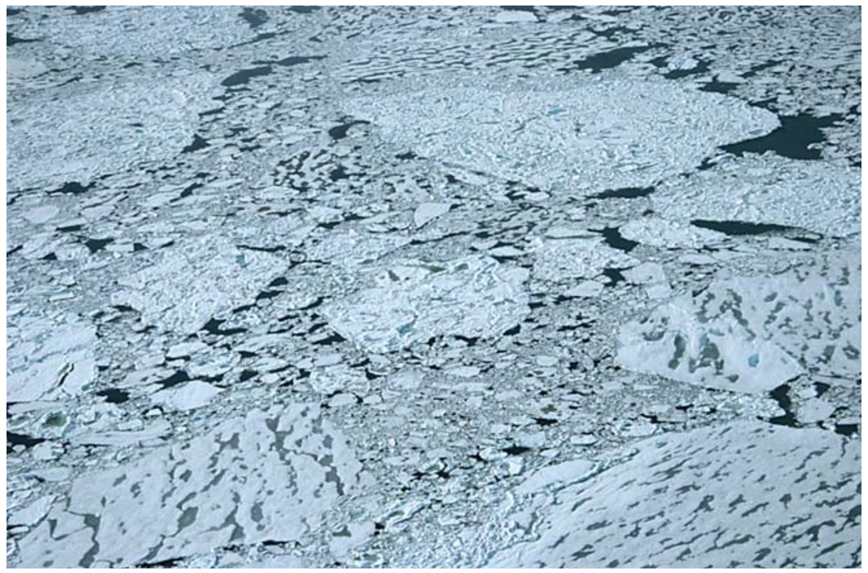
Section 1

INTRODUCTION

The Arctic has one of the most sensitive climate systems on our planet. Global anthropogenic impacts have recently caused interferences in the oscillations of the Arctic climate [Alekseev, 2004]. The report prepared by Roshydromet [Evaluation.., 2008] reviews a broad range of factors involved in climate transformation and the consequences of these changes. The cause of some effects are known, but in many cases our knowledge is insufficient [ACIA, 2005; Anisimov et al., 2007; Ramstorf, Schellnhuber, 2008; Frolov et al., 2006, 2009; Sommerkorn, Hamilton, 2008; Sommerkorn, Hassol, 2009]. Shore abrasion and the decrease of the summer sea ice cover and perennial sea ice massifs lead to significant changes in the marine and coastal Arctic ecosystems. Increasing water temperature throughout the world ocean, rising sea levels and the increasing acidification of marine waters portends larger scale changes [IPCC, 2007]. Given the present uncertainty of climate forecasts and our insufficient understanding of causal relationships, a cautious approach in Arctic activities is called for. Therefore when planning environmental protection and biodiversity conservation measures, we must factor in the possibility of unfavorable developments and adverse effects of synergies between climate transformation and anthropogenic impacts.

As the Arctic enters a new phase of economic development, many industry analysts believe that commercial activities will be facilitated by the new sea ice conditions. Further development of the extraction and transportation of hydrocarbon and mineral resources creates serious environmental problems and threats for biological diversity [Problems of the Northern Sea Route, 2006; Larcen et al., 2003; Spiridonov, 2006; Bambulyak, Frantzen, 2009]. BP's April 2010 oil rig catastrophe starkly illustrated the risk associated with offshore oil extraction and the difficulty of stemming damages. Locations likely to be developed include areas of the Arctic seas and coast where wildlife is concentrated, which may be called nodes of ecosystems and biodiversity hotspots. In particular, increasing pressure is expected on flaw polynyas (which develop in the Arctic seas in winter and spring). Polynyas are natural shipping lanes along the Northern Sea Route. No one can predict how the synergy of climate change and increased economic activity will impact the ecosystems of the Arctic seas. However, the impact may be mitigated with the use of marine spatial planning (Fig. I-1) similar to territorial planning on land. An important component of the marine spatial planning process is the establishment of marine protected natural areas (MPAs).

Climate change has always affected the inhabitants of our planet. Today, nobody can say with certainty that the mammoth was doomed to extinction when the periglacial steppe turned to tundra and taiga [Markova, 2008], but most scientists agree that man had a role in the disappearance of the giants [Tikhonov, 2005]. Imagine for a moment that 15 to 20 thousand years ago an expansive preserve for mammoths and associated organisms had been created. Perhaps in the Urals, where recent paleoecological studies [Markova, 2008] indicate the last characteristic assemblages of periglacial mammals lived; or in Chukotka and Wrangel Island, where the most recent remnants of mammoths (between 3.7 and 8 thousand years ago) [Vartanyan et al., 1993; Tikhonov, 2005] have been found. With a secure habitat and protection from hunting and wildfires, perhaps the mammoth would be here with us today. This is a fantasy, of course, but it illustrates one of the most important tasks that protected natural areas perform: **to provide places free of negative anthropogenic impact where nature is allowed to fend for itself — where species, populations and their communities can thrive and adjust to changing conditions, at times, perhaps, with the aid of humans.**



Summer sea ice in the Laptev Sea[1]

Table I-1. Anthropogenic threats to marine ecosystems and potential role of marine and coastal reserves in their mitigation and prevention (compiled by V.O. Mokievsky)

Kinds of threats		Possibility of marine reserves to mitigate a threat
Harvesting of marine organisms (fishery, hunting)	impact on harvested species	+
	impact on associated species	+ (—)
	Impact on environment	+
All kinds of pollution		— (+)
Invasions of alien species		— (?)
Direct extermination, transformation and alteration of biotopes		+
Mariculture		+ (—)
Disturbance		+
Tourism		+

\+ good possibility; — very slim possibility; ? issue requires further investigation

The adaptive potential of living organisms to climatic changes is significant. Petroglyphs from Karelia have preserved for millennia the images of beluga whales (or white whales, *Delphinapterus leucas*). The animals apparently were commonly hunted by inhabitants of the White Sea coast about 6000 years BCE, at the time of the Holocene temperature maximum [Lobanova, 2008]. At that time the Arctic and Subarctic were much warmer. During the more severe conditions of the Little Ice

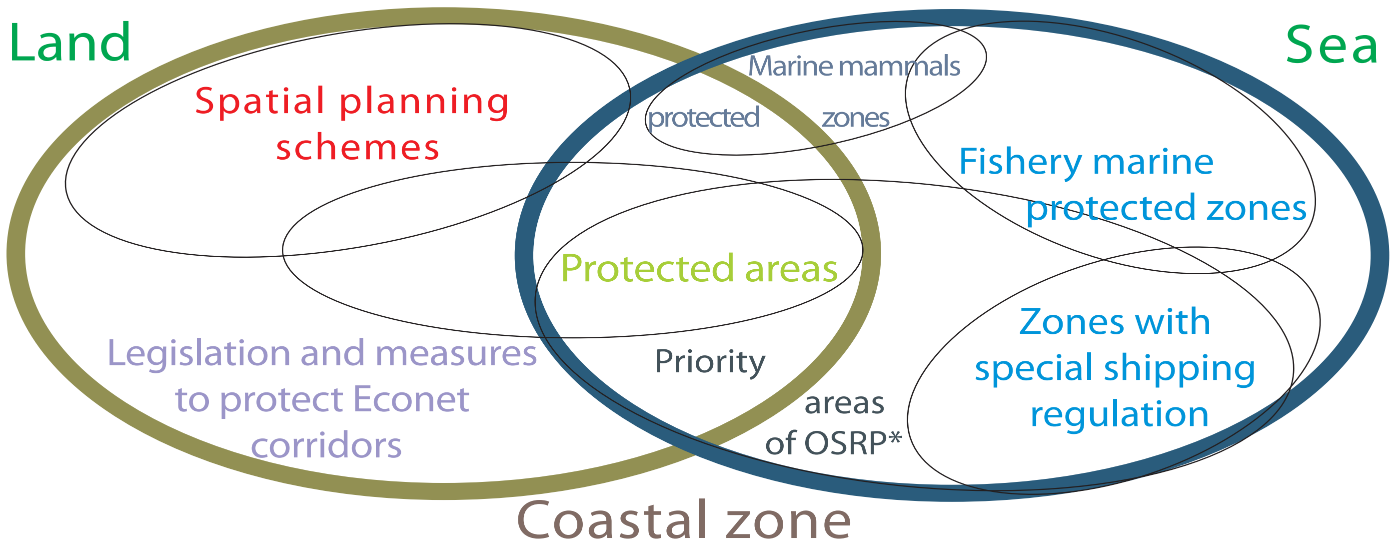


Fig. I-1. Diagram illustrating legally possible options for SPNA, territorial spatial planning and marine spatial planning in Russia. (* Oil spills response plans)

Age (140 to 400 years ago), beluga whales were again hunted, now by the Pomors. This shows that these Arctic animals, common now in the White Sea, are adaptable to different climatic regimes. To a considerable extent, this population is maintained by reproductive aggregations in Onega Bay and other areas. Specialists of the IO RAS who have studied belugas there for many years believe that the current destabilization of climate may negatively impact the population. This will be due to increasing winds and unfavorable sea ice conditions. However, the situation may turn worse due to human disturbance. Uncontrolled tourism, unregulated whale watching, wide-scale use of motor boats and the accessibility of most areas of Onega Bay to visitors may become the main risk factors for the entire beluga whale population [V.M. Belkovich, pers. comm.]. This risk can be considerably mitigated if a protection regime is introduced while beluga whales adapt to climatic changes.

Another Arctic inhabitant, the walrus (*Odobenus rosmarus*), exemplifies a second aspect of adaptive conservation. The life of these animals is greatly influenced by sea ice conditions on shallow shelves of the Arctic seas, and they respond with great sensitivity to climatic variation. Current changes in sea ice cover force walruses to change their seasonal migration routes, and their new haul-out locations are sometimes very close to human settlements. Recently a new walrus haul-out was established near the landing area of the airport in Ryrkarpiy village. Aircraft noise causes panic amongst walruses that leads to increased mortality of calves. A solution to the problem could be the designation of this haul-out site as a natural protected area and changing, if possible, the landing schedule during the walruses' hauling-out season.

Beluga whales on petroglyphs of Zalavruga, White Sea [2]

In many cases, the creation of marine and coastal reserves may be the only way to protect a unique natural system or entity [Mokievsky, 2009a]. No doubt, marine protected areas can not solve all the problems. They are unlikely to prevent such anthropogenic impacts as transboundary pollution, eutrophication, and invasions of alien species. These threats can be neutralized only at very extensive and fully protected areas at a scale of hundreds thousands square kilometers [Mokievsky, 2009a]. However, with proper monitoring, even smaller areas are useful for the early identification of the effects of pollution and the arrival of alien species. Fortunately anthropogenic pressure in the Arctic is not yet overwhelming, and there are limited activities which require regulation (Table I-1).

Types of specially protected marine and coastal natural areas in the Russian Arctic

Which kinds of protected natural areas are best suited to conserving Arctic ecosystems and species? What is the legislative basis for their creation? In the documents of many international organizations, concepts such as «marine protected areas» exist; in Russia's context this corresponds to the areas, either coastal or marine, where a protection regime is introduced in accordance with the Federal Law on «Specially Protected Natural Areas», or SNPA. As internal marine waters, the territorial sea, the exclusive economic zone (EEZ), and the continental shelf are under the federal jurisdiction in the Russian Federation, many kinds of SPNAs at sea should be established at the federal level. Regional SPNAs which aim to protect marine and coastal biodiversity may be organized on the seacoast.

The most widespread type of the federal SNPA in the Russian Arctic is a state natural zapovednik (a Russian word meaning «strictly protected reserve»). This term refers to a particular type of SPNA historically developed in Russia and therefore in the English texts we prefer to use its transliteration. Currently, there are no zapovedniks in the Russian Arctic established specifically for protection of marine ecosystems. Offshore areas of existing zapovedniks are just outposts of the terrestrial core parts. Although it is widely recognized that new Arctic zapovedniks must be created, their planning process, consultations with stakeholders, official approval, and implementation are parts of a complicated and expensive process. Thus the priority in the development of this kind of SPNA in the maritime Arctic should be best given to the institutional strengthening and expansion of pre-existing zapovedniks.

The other category of SPNA, the national park, is well suited to the goals of biological diversity conservation in those Arctic regions where tourism development is expected or is ongoing. The major difficulty associated with the development of national parks is the necessity of significant investment in infrastructure. Creation of an Arctic national park will require comprehensive planning and preparation of model management plans in the near future.

The regime of a biosphere polygon is appropriate for large marine areas. A biosphere polygon should be managed by a neighboring zapovednik which has a status of a UNESCO biosphere reserve, or has been nominated for this status. A marine biosphere reserve may encompass a large area, i.e. a large marine bay or another naturally bordered part of the sea and extend to tens of thousands square kilometers. The zones of strict protection, buffer zones with lesser restrictions, zones of various kinds of use and biosphere polygons within the reserve make possible a coverage of series of communities which replace each other along the depth gradient and in accordance to distribution of water masses and oceanographic fronts, sea ice regime, or in a more complicated pattern — if several factors are in effect simultaneously and their gradients are non-coherent [Mokievsky, 2009a]. The protected area of such a scale will be sufficient for development of all stages of benthic animals having a pelagic larva, maintenance of life cycles of coastal plankton species and providing appropriate conditions for various life history stages of migrating fishes, sea birds and marine mammals, or protection of their feeding and breeding grounds.

The category of a federal zakaznik, or nature monument, usually does not require special measures to demarcate the marine area if not considering the shore parcel. Zakazniks may include marine areas up to tens or hundreds thousands

Beluga whales, Franz Josef Land [3]

Walruses, Chukchi Sea [4]

square kilometers, as, for example, in the Franz Josef Land zakaznik. This makes them a particularly convenient method of marine biota conservation. Such an area is sufficient to protect most species within bottom communities because this scale fits the natural scale of stable populations of macrobenthic organisms and a spatial range of benthic ecosystems [Mokievsky, 2009a]. It is worth noting that these larger areas ranging from hundreds to tens thousands square kilometers are more cost effective because a correlation between the size of reserves and the expenses of their maintenance is no longer valid at this scale [Balmford et al., 2004].

A nature monument of the federal rank is a relatively rare category. However it may be particularly useful to emphasize the special status of unique marine natural entities, i.e. those which fit the criteria of the UNESCO Convention Concerning the Protection of World Cultural and Natural Heritage [UNESCO, 2008] although may not necessarily be listed in the Convention's list. The monitoring of particular marine nature monuments may be addressed by scientific institutions and universities that are conducting research there — especially if this function is delegated to them officially and necessary budget or grant funds are provided for this purpose. Finally, for the conservation of valuable natural entities in the sea/land boundary zone, regional SPNAs or their combination with other forms of spatial protection may serve as an appropriate tool.

Marine reserves cannot perform their protective function if their borders and the principal regime requirements are not shown on navigation maps and information on them is not communicated in the regular Notices to Seafarers. To control compliance with the requirements, remote observation methods should be developed, such as vessel monitoring systems and the tracking of hydrocarbon slicks on the sea surface using remote sensing and other satellite-borne and aircraft-borne methods. It is necessary to coordinate research programs and the analysis of results of scientific expeditions. This of course does not do away with the need for traditional direct inspections within an MPA using the facilities of the Coast Guard (The Border Service of the Federal Security Service), Roshydromet, shipping facilities of the Northern Sea Route, platforms of research expeditions, touristic cruises and educational projects.

Polynya's edge [5]

Marine spatial planning or functional zoning of marine areas

If done properly, spatial planning on land facilitates the sustainable development and maintenance of a region's natural resources. Specially protected natural areas often play a role of core areas in the spatial organization of the territory. The Town Planning Code of the Russian Federation (adopted in 2004) requires that a uniform system of territorial planning has to be developed in the Russian Federation by 2010, including three levels of plans, namely the federal, the regional and the municipal. General plans of municipalities, e.g. villages, towns and urban districts, are working documents of the territorial planning. They also include entities of the federal and the subfederal status, in particular specially protected natural areas, water protection zones and fish protection zones. They justify functional zoning of the territory and local land use schemes, which may include local protected areas as well. Territorial planning on land has its internationally recognized analog at sea, which international organizations and some national policies call marine spatial planning. [Ehler, Douvere, 2009]. In Russia, no such term has been officially coined for marine areas and they are largely out of the territorial planning system. We propose to translate the notion of marine spatial planning to the Russian language (not literally, but using some equivalent term) and speak about «functional zoning of marine waters». Our country is still far from the organization of marine spatial planning as an open process which is based on the ecosystem approach, recognized by the civil society and involves all stakeholders, and overcomes sectoral barriers (Table I-2). However, without developing such a process, sustainable development in Russia is not achievable. Some legislative basis for designating marine zones with particular functional specificity nevertheless exists, and we briefly discuss this below.

In Russia there are a number of regulatory measures related to aquatic biological resources, e.g. a permanent or a temporary closure (or restriction) of a fishery in particular areas introduced according to the basin-scale fishing rules. The Federal Law «On Fishery and Protection of Aquatic Bio-Resources» (# 166 FZ) contains a provision to designate fishery refuge zones, which are a relatively new form of spatial protection (Article 49). They differ from usual areas of restricted fishery by a provision to regulate not only fishing activity, but also other kinds of industrial (potentially including oil and gas development on the continental shelf), agricultural and touristic activities which may be harmful to aquatic biological resources.

Table I-2. Definition, characteristics and steps of marine spatial planning according to guidelines prepared by the International Oceanographic Commission of UNESCO (Ehler, Douvere, 2009)

DEFINITION	CHARACTERISTICS	STEPS
Marine spatial planning (MSP) is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process	Ecosystem approach: necessary balance of environmental, economical, social and cultural targets of sustainable development Integrity: breaking sectoral barriers and independence of bureaucratic hierarchy Local and regional peculiarities as a basis Adaptability Strategic orientation for tomorrow Stakeholders involvement	(1) Identifying needs and implementing organizations. (2) Obtaining financial support. (3) Preliminary planning. (4) Stakeholders involvement. (5) Identification and analysis of present conditions. (6) Identification and analysis of future conditions. (7) Preparation and approval of management plan for spatially planned marine areas. (8) Implementation of the plan and its control. (9) Monitoring and performance evaluation. (10) Adaptive change of management.

The advantages of this protection measure may be demonstrated using walruses' haul-outs as an example. Pacific walruses (Odobenus rosmarus divergens) are traditionally treated as aquatic biological resources and are managed by the federal fishery authority. In Chukotka they play a pivotal role in sustaining livelihoods of the indigenous population and maintaining a traditional hunting activity as a component of the historical and cultural heritage of our country. Areas of haul-outs and feeding grounds of walruses, other pinnipeds and cetaceans originally came under the legal coverage of the 1986 «Rules for harvesting and protection of marine mammals» approved by the Ministry of Fishery Industry of USSR. Now they still hold a protected status, but the regulatory regime has been changed. Following the adoption of the Law of the Russian Federation «On Fishery and Protection of Aquatic Bio-resources», new rules have come in force which regulate only fishery in the vicinity of haul-outs, but neither visiting them nor flights over, contrary to the previous regulations. In order to solve the problem of the protection of existing haulouts, other former marine mammal protection zones, and new haul-outs arising in the present climatic situation, the status of marine mammal protection zone should be officially re-established. In Soviet times, the protection of haul-outs as well as special measures to protect the sea ice whelping areas of the harp seal (*Pagophilus groenladicus*) from adverse impacts of shipping were adopted. In 2009, following the population decline of this species related to changes in the winter sea ice conditions in the White Sea, Russia's Ministry of Transport re-confirmed this regulation.

Fishery refuge zones are potential instruments for the protection of most important spawning grounds and feeding areas of commercial fish and invertebrate species. They are particularly needed in the estuarine areas of the Arctic rivers, where highly valuable fish stocks are exposed to various anthropogenic threats.


Atlantic walfish (*Anarchias lupus*), White Sea[6]

These zones will potentially regulate economic activities in the areas of active marine fishing where the developing infrastructure of the oil and gas sector threaten aquatic biological resources and their environment.

Special conservation measures are required for the protection of sea ice biotopes in flaw polynyas, which are critically important for maintaining marine biodiversity. The development of standards for future marine activities in the polynya areas should address guidelines for shipping, and marine geological and geophysical reconnaissance, regulation for shipping accident prevention, strict control of ship-based pollution, oil spill response plans, and the minimization of disturbance to marine mammals and sea birds. This is possible if a special law on the protection of the sea, a concept a long time in discussion, is finally adopted. All measures introduced with regard to shipping should be made in agreement with the International Maritime Organization [for details see Kalentchenko, 2008].

Federal protected natural areas at sea and regional protected areas on the coast have the potential for significant synergy and the strengthening of their capacities. Zapovedniks and national parks can form the core areas of biosphere reserves, with regional SPNAs and fishery refuge zones constituting their buffer areas. Regional legislation is fully capable of providing protection for key coastal zone biotopes such as maritime marsh massifs, sea bird colonies and marine mammal haul-outs by establishing SPNAs. Often, lack of staff is one of the disadvantages of the regional protection natural areas. This, however, can be overcome by the creation of regional directorates responsible for the protection and management of SPNAs. In some of Russia's Arctic regions, such directorates have already been organized and have been shown to be very effective. Another option is to form a partnership with NGOs, which are motivated to help protect regional SPNAs; that model is commonly used worldwide [Dudley et al., 2010]. In Russia such cases are still relatively rare, but the existing ones have proved to be effective. The NGO Sakhalin Environment Watch performs public oversight for the control of the protection of the Vostochnyi regional zakaznik on the eastern coast of Sakhalin, while the Polar Bear Patrol teams supported by WWF Russia provide stewardship of the walruses' haul-outs on Cape Vankarem (Chukotka), which has been designated a nature monument.

Development of marine conservation facilities and marine resources management into an integrative system of planning

As an Arctic country, Russia faces a serious challenge. It must protect marine biological diversity of the seas and coast in the Russian Arctic in an age of rapid and unpredictable climate change. Furthermore our country is required to fulfill its international commitments imposed by the UN Convention on the Law of the Sea (1982), the Convention on Biological Diversity (1992), the Ramsar Convention (1971) and other international agreements. In order to do this Russia needs to integrate sectoral regulations (e.g. aquatic parts of SPNAs, fishery refuge zones and zone with fishery restrictions, and regions with special shipping regulations) into a system of marine spatial planning (or functional zoning – see Fig. I-1). The objectives of this system should be the protection of the marine environment from anthropogenic degradation, the maintenance of the productive capacity of ecosystems and their services, the protection and sustainable use of biological and recreational resources, the conservation of unique natural entities in the sea and coastal zones, and the monitoring of processes in marine ecosystems. Ecosystem-based management plans similar to the one adopted several years ago by the Parliament of Norway for the Norwegian part of the Barents Sea [Report of the Government to the Storting, 2006] are expected to arise from this integration. The integrative planning system will facilitate the development of strategies and plans for the conservation and rehabilitation of particular species, communities and biotopes.

Biological diversity and the foundations of marine conservation planning

In order to plan the usage of the marine space and resources in the Russian Arctic wisely, basic information on the environment, key elements of biological diversity and the historically developed network of protected areas is badly needed. The present Atlas, which we introduce to the readers, is an attempt to merge necessary data. Until now, these biodiversity data have been either scattered in various publications (often inaccessible, especially to the non-Russian audience), or unpublished. We aim to present this in a convenient form that most readers can access.

The material presented in the Atlas supports the view that an existing network of marine protected areas in the Russian Arctic does not systematically cover the polar marine biodiversity. This network was built up historically without an attempt to include the diversity of marine biotopes and ecosystems in a larger scale, and MPAs are very unevenly distributed throughout the entire Russian Arctic sector (see 4.1). The sizes of coastal and marine protected areas only to small extent correspond to the criteria of spatial scale of protection [Mokievsky, 2009a]. Planning and evaluation of the representativeness of MPAs should take into account biogeographical regionalization. A combination of distribution ranges of particular taxonomic groups living in the Arctic seas and the coastal zone makes it possible to draw boundaries of the large floral and faunal regions on the map (see 2.2; 2.6). This may help to identify particular seas where MPAs should be designated, but for planning networks of marine reserves within particular seas these biogeographical regions are too extensive. Thus, smaller biogeographical subdivisions (of the scale of tens and hundreds thousands of square kilometers), which are inhabited by faunal and biotic complexes [Mironov, 1990] fit better to this purpose [Mokievsky, 2009a]. Another possible way of regionalizing and designating representative MPAs incorporates the data on taxonomic diversity, e.g. the number of species and higher rank taxa. Unfortunately our knowledge of species composition and taxonomic diversity is insufficient for most of the Arctic seas. Reliable inventories of animal and plant species (not to mention fungi and micro-organisms) are only available at the scale of particular seas, not smaller areas. The third direction of regionalization, eco-geographical, should take into account the data on the distribution of particular communities and ecosystems.

A well-known scheme of eco-geographical regionalization of the world Ocean [Longhurst, 1998] places all the Russian Arctic seas into a Boreal Polar province that masks significant differences between their ecosystems. The specificity of marine biological diversity is tightly connected to the shelf and the coastal geomorphology, climate, water circulation, and the physical and chemical properties of the water column. Using these factors, we propose a new version of physiographical regionalization which forms the basis of the present Atlas. Such schemes may be further developed into eco-geographical classification and regionalization systems.

Marine lake Mogilnoe, the nature monument[7]

Priority biotopes

Marine biodiversity is unevenly distributed. Some components of landscapes/seascapes, for example large river mouths, frontal zones, marine shallows and underwater banks, create particularly favorable conditions for marine organisms. As a result, key areas which greatly contribute to general biodiversity (sometimes called «biodiversity hotspots») are formed. The structure of marine biodiversity in the Russian Arctic is to greater extent determined by the systems of marine and coastal biotopes. We use here a broadened interpretation of the «biotope» notion that integrates various environmental factors of abiotic and biotic environment — [Olenin, 2004; Olenin, Ducrotoy, 2006]. Table I-3 demonstrates inter-relations of the biotopic and biological diversity components.

In the Arctic seas, a considerable part of important biotopes and, consequently components of biodiversity, is linked to the contact zones: sea/ land (coastal zone), sea/continental waters (river mouths/estuaries), water/ice (polynyas, marginal ice zone), and the contact points between water masses of different origin (oceanographic fronts).

Sensitive boundary zones

Laidas and marshes. Climate change first and foremost affects boundary zones, where interaction between contrasting physical elements is most pronounced — especially the boundary between land and sea. With the rhythm of the tides, the coastline of seas and oceans rise and fall twice daily. Laidas – zones mostly covered with expansive swampy meadows (marshes) periodically flooded by the tide or pileup and whose vegetation is well adapted to excesses of salt — are characteristic along the coasts of the northern seas. They are associated with built up accumulated, silty or sandy banks with extensive drainage, where a wide variety of conditions can be observed. Coastal laidas are unique transitional zones between the sea and the coastal tundra and the communities built on permafrost. Massifs of maritime marshes support an important canal of the carbon extraction from the atmosphere [Dudley et al., 2010] and its burial, and thus has the potential to lessen the greenhouse effect. Many ecosystem services of salt marshes in the Arctic are not yet studied in detail. This biotope contains the breeding habitats of shore birds and waterfowl and provides shelter for their migration stopover and molting aggregations (more details in 3.9 – 3.10). The laida zone includes lagoons, marshes, dunes and marginal parts of the tundra which are influenced by the tides and surge/pileups. The dynamics of maritime marsh communities are governed by the processes of shore formation and abrasion [Sergienko, 2008]. In a time of climate change and increasing winds, laida shores are washed out. A concurrent alteration of the Chukchi Sea shores is a spectacular example. A further rise in sea levels will accelerate that process, and may lead to the salinization of the lagoons, the destruction of some of the spits, which serve as important habitats for birds and marine mammals, and the eventual washout of the barriers. As a result lagoons may be transformed into open inlets, while aquatic birds and marine mammals may lose their habitats. Thus, the formation of communities of coastal vegetation will regress to earlier stages, which may have far reaching and as yet unpredictable consequences for the entire ecosystem of the coastal zone.

Steller's eiders (*Polysticta stelleri*) [8]

Oil and gas development in the Arctic may create another problem. If oil spills at sea (caused by tanker or oil rig accidents) reach the laida shore, or oil from smaller leaks accumulates, it will stay in the laida zone for years. Even worse, oil can spread into the tundra along the network of laida canals. However, the adaptive potential of ecosystems of the land/sea interface may be strengthened if protected natural areas are established in the most important laida massifs and human impact is thus minimized -- or even removed.

Table I-3. Valued biodiversity objects associated with particular biotopes

BIOTOPES / VALUED BIOLOGICAL OBJECTS	1	2	3	4	5	6	7	8	9	10	11	12
"Watten" coasts	X										X	X
Marsh massifs	X	X	X	X					X	X	X	X
Tombolo and spits					X	X			X		X	X
Insular coasts						X						
Coastal cliffs									X			X
Mouth areas, estuaries of rivers	X	X	X	X	?		X		X	X	X	X
Highly productive shallows, lagoons and inlets	X	X	X	X	X			X	X	X	X	X
Meromictic lakes and other relict waterbodies											?	X
Flaw polynyas	?	X	X	X		X	X	X			X	X
Marginal ice zone	X	X	X	X			X	X			X	X
Sea ice massifs						X				X		
Zones of oceanographical fronts	X	X	X	X				X			X	X
Upwelling zones	X	X	X	X							X	X
Underwater mountains and banks	X	X	X	X			?					X

1 — aggregations, colonies of benthic animals; 2 — patches of high biomass of benthic organisms; 3 — breeding and spawning grounds of vertebrates; 4 — feeding grounds of aquatic organisms; 5 — haul-outs of marine mammals; 6 — whelping areas of marine mammals; 7 — wintering aggregations of aquatic organisms and sea birds; 8 — wintering places of sea birds and waterfowl; 9 — breeding aggregations of marine and aquatic birds (colonies); 10 — moulting aggregations of sea birds and marine mammals; 11 — migration routes and stopovers; 12 — habitats of rare and endangered / specially protected species.

Sign X — indicates that these biological phenomena are associated with particular biotope or landscape.

Sign ? — association is possible but not investigated

River mouths areas. River mouth areas and estuaries of large Arctic rivers are very important wetlands, hosting unique habitats of anadromous and semi-anadromous fishes and providing areas where shore birds and waterfowl aggregate in huge numbers (for details see 3.11). Ecosystems of river deltas and estuaries in the river/sea contact zone are highly sensitive to climate changes. This impacts first of all regimes of discharge, timing of ice freeze up and ice drift, and the strength of floods. The contact zone between riverine and marine environments are also very sensitive to human impact, including dam construction and river discharge regulation, watershed pollution and the extraction of water and biological resources.

Flaw polynyas. Another boundary biotope is the polynya, where the level of interaction between ocean and atmosphere is highest. Polynyas are sustained areas of open water among or bordering stationary bodies of ice. They have unique features, and are of great significance to the biological and physical processes of the Arctic seas, serving as a kind of a «window» for marine organisms (more details in 3.2 – 3.7).

Climate change may influence the size of polynyas, but they will persist until the winter sea cover is developed in the Arctic. In today's warming environment, more accessible ice conditions makes flaw polynas attractive for navigation and commercial development of the Arctic. A high priority for marine spatial planning and organization of marine use in the Arctic should be the establishment of special rules for environmental and biodiversity conservation in the use of polynyas.

The above three boundary biotopes systems will be considered in the section 3 of the Atlas. Another contact zone, the system of oceanographic fronts, is very dynamic — a fact that complicates mapping for the entire Russian Arctic seas. While the study of Arctic frontal systems is in progress, presentation of general schemes and maps of the fronts with high ecosystem significance may be expected in the future.

Objects of natural-cultural heritage

In the context of the general problems of marine spatial planning, objects of natural-cultural heritage make up an important category which should not be overlooked. These are, first of all, the remnants of the marine cultural landscape/seascape which are still possible to find in Chukotka [Bogoslovskaya et al., 2007], on the White Sea coast [Bernshtam, 1978; Plyusnin, 2003; Loginov, 2008] and in some other places. Areas which have been investigated by marine scientists for many years, e.g. areas of marine research stations, need special attention. These include Dalnie Zelentsy on the Murmansk Coast, and the biological stations of the Moscow, St. Petersburg and the Kazan' Universities and the Zoological Institute of the Russian Academy of Sciences on the White Sea coast [Fokin et al., 2006; Khlebovich, 2007; Krasnova, 2008].

How we define the Arctic?

Which polar and sub-polar areas should and should not be included in the Arctic is to a large extent agreed upon. The Arctic Council and associated scientific committees and groups (CAFF, AMAP, PAME) draw the Arctic boundary generally along the Arctic Circle, adding the coasts of the Norwegian and the Bering Seas, and Iceland with surrounding seas to the Arctic — most of them being located south of the Arctic Circle. When adopting this approach in Russia, a significant portion of the White Sea falls out of the Arctic. The national oceanographic and geographical traditions consider the White Sea as a marginal sea of the Arctic Ocean. In the present Atlas we consider this basin as a part of the Arctic as it has numerous oceanographic, biogeographical, and ecological links to the polar seas and coasts. It is also tightly connected to the Arctic in historical, economical and socio-cultural aspects. The Bering Sea also belongs to a huge region of the North Pacific which is adjacent to the Arctic. Generally agreeing with the Arctic Council regarding the inclusion of the Bering Sea into Arctic, we discuss in the present Atlas only the Bering Sea waters of the Chukotka Peninsula, and mention the Gulf of Anadyr, the Karaginsky and Olyutorsky Bays only in some aspects.

Previous projects and sources of data

When preparing this Atlas we were not the first who tried to outline the foundations of the marine conservation planning in the Russian Arctic. A number of maps related to biological diversity were included in the Atlas of the Arctic [1985]. In the early 1990s the Atlas «Oceanographic conditions and biological productivity of the White Sea» [Atlas, 1991] was published. This work was an important step towards developing standards for generalization of spatial data with the final purpose of achieving ecosystem based management. Unfortunately, due to the small number of printed copies and the political upheaval at the time, this atlas has not received the attention it deserved. Since that time none of the Russian Arctic seas has been analyzed in such a way while «The Conservation Atlas of the Russian part of the Gulf of Finland» [Pogrebov, Sagitov, 2006] came to press: this publication is structured similarly to the White Sea Atlas [1991]. Another publication, «Dynamic environmental Atlas of the Northern Sea Route» [Brude et al., 1998] prepared by a group of Russian and Norwegian experts, presented the data on marine biological diversity of this part of the Arctic. In 2001 WWF organized the process of the biodiversity assessment of the Barents Sea ecoregion; in the final report experts identified priority regions for introducing conservation and special management regimes [Larsen et al., 2003]. The most updated multidisciplinary review of the Barents Sea environment and ecosystems was prepared by a large group of experts from Russia and Norway [Ardeberg et al., 2009; Stiansen et al., 2009]. Working on the present Atlas, we relied on the wealth of data in previous publications. However the scale of this assessment is broader than its predecessors — this work covers the entire Russian Arctic. Furthermore we consistently focus our attention on the systems of boundary biotopes and interfaces such as the sea ice biotopes, the sea/land transitional zone and the estuarine systems. Because of this concept, the reader does not find maps reflecting experts' assessment of marine mammals distribution, similar to those presented in the Atlas of the Northern Sea Route, although their elaborated electronic versions will be available in the near future. Also we intentionally are not concentrating on those components of biological diversity of the Barents Sea that are associated with pelagic biological productivity, plankton and fishery resources — they are comprehensively treated in a series of reviews and atlases [Matishov et al., 2000; Larsen et al., 2003; Stiansen, Filin,2008; Arneberg et al., 2009; Stiansen et al., 2009]. Finally, this project only indirectly refers to such important component of the Arctic coastal biodiversity as waterbirds that are assessed in several important publications [Important Bird Areas, 2000, 2006; Krivenko, Vinogradov, 2001].

For characterization of the Russian Arctic seas the most important publications such as «Soviet Arctic» [1970] and «The seas» [Zalogin, Kosarev, 1999] were extensively used. The physiographical regionalization scheme was developed specially for this publication by A.N. Ivanov, while the schemes of biogeographical regionalization proposed by several authors were combined and briefly summarized. The species diversity assessments for the Russian Arctic seas were provided by the current publications of the Zoologizal Institute of RAS [Sirenko, 1998, 2001, 2010; and some data of the other institutions].

Sea ice biotopes were described on the basis of extensive datasets collected over several decades of the Arctic and Antarctic Research Institute. Recognition of the flaw polynyas as one of the phenomena critically important for the Arctic marine biodiversity was to a large extent inspired by observations, ideas, and concepts by V.N. Kupetsky [1958, 1959] and V.F. Zakharov [1996] arising from the legendary presatellite era of the sea ice aerial reconnaissance.

Information on the sea bird colonies, areas of their molting aggregations, wintering grounds and migration stopover comes from the extensive data sets resulted from Kandalakshskiy State Zapovednik, MMBI, and the AARI [Bianki, 1991; Krasnov et al., 2004, 2006, 2007; Gavrilo et al., 1998; Gavrilo, Bakken, 2000 and others]. The distribution of morphogenetic shore types was adopted from the classic general works of the national school of coastal geomorphology [Kaplin et al., 1991]. The maritime marsh vegetation data are part of the current general work conducted by L.A. Sergienko [2008].

The data on specially protected natural areas are based predominately on the review produced by the VNIIPriroda [Zabelina et al., 2006]; the borders of SPNAs were digitized by the Biodiversity Conservation Center, the Transparent World Non-commercial Partnership and WWF Russia using the material provided by the Russian Ministry of Natural Resources and Environment [Cartographic base.., 2002–2010]. Other sources of information are referred to in the respective sections of the work.

Horned puffins (*Fratercula corniculata*), Chukotka [9]

The Arctic coast of Russia is bordered by the Barents, Kara, Laptev, East-Siberian and Chukchi shelf seas, and by the semi-landlocked White Sea. All these seas are part of the Arctic Ocean (Map 1.1; Table 1-1). The Bering Sea is part of the Pacific Ocean. To the north, these seas are influenced by the Arctic Ocean, while the westernmost Barents Sea is closely connected to the Atlantic (via the Norwegian Sea) and the easternmost Chukchi Sea waters mingle with the Pacific Ocean. The boundaries of the Eurasian Arctic Seas are delineated by conventional borders or by the islands and archipelagos. To the north of the Eurasian Arctic Seas is the Arctic Basin, a deep sea divided into a series of secondary basins by underwater ridges. All the Eurasian Arctic seas have similar origins: they were created by flooding of the continental margins during the modern post-glacial geological era. The mountains and ridges that were not submerged became the islands and peninsulas that rise above the surface of the waters. Most of the Eurasian sea area (and in some cases entire seas) is located on the continental shelf where the water depth rarely exceeds 200 m.

Most of the waters that make up the Shelf Seas are Arctic surface waters, which sources include rivers flowing from the land into the sea mixed with oceanic waters from the Atlantic, Pacific and the Arctic Oceans [Zalogin, Kosarev, 1999]. The northern areas of all the Eurasian Arctic seas are dominated by the cold waters of the Arctic Ocean. Relatively warm saline Atlantic waters, spread by surface currents, cover the whole of the Barents Sea and sink to depths of 200–400 m as they spread out along the shelf trenches to the Kara, Laptev and East-Siberian seas. Pacific waters are present at lower depths in the Chukchi Sea and, partly, in the East-Siberian Sea. Most of the relatively warm and fresh water of riverine origin spreads out over the subsurface layers of the Kara, Laptev and East-Siberian seas; in all these seas, freshwater can be observed at relatively long distances from the river mouths. From the Kara to the East-Siberian Sea, surface waters spread out in an easterly direction along the continental coast, while in the northern part of the seas, water circulates in the opposite direction. Water circulation patterns in the Barents and White Seas are more complex. Because of global water circulation patterns, the westernmost Barents Sea and the easternmost Chukchi Sea are fed by higher salinity warmer waters than the central Arctic seas. In the shallow coastal zone the water column is homogenous; in most regions of the Arctic seas the waters are stratified in summer, while in the winter there is mixing at greater depths and towards to bottom of the seas. The Kara and the Laptev seas have the most severe sea ice regimes, with the Barents Sea affected to a lesser extent.

Sea level variations in the coastal areas of the Arctic seas are the result of the combined effects of tides, swash and river discharge [Zalogin, Kosarev, 1999]. Tides are highest in the Barents and White Seas (magnitudes of up to 3–4 m and 7–8 m respectively), while in the Kara Sea, tidal magnitude never exceeds 1m. In the other seas tidal variations are usually less than 0.3–0.5 m. Sea level variations

White Sea in winter [10]

Table. 1-1. Some characteristics of the Russian Arctic seas

Sea	Area* km²	Average depth* m	Continental coastline length** km	Area within state maritime border and EEZ of Russian Federation**, km²	Share of water (%) within state maritime border and EEZ of Russian Federation
Barents	1 424 000	222	3 735,57	1 042 647,33	73,2
White	90 100	67	3 117,38	91 012,17	100,0
Kara	883 000	111	9 220,13	887 398,39	100,0
Laptev	662 000	533	6 029,12	639 891,40	96,7
East-Siberian	913 000	54	1 826,02	821 389,72	90,0
Chukchi	595 000	71	1 402,32	350 382,37	58,9

* after Zalogin, Kosarev, 1999
** original calculations using ArcGIS

caused by winds and surge are significant and often exceed (to the east of the Barents Sea) tidal variations. Sea level changes caused by river discharge are particularly pronounced in the White Sea and near the mouths of large rivers.

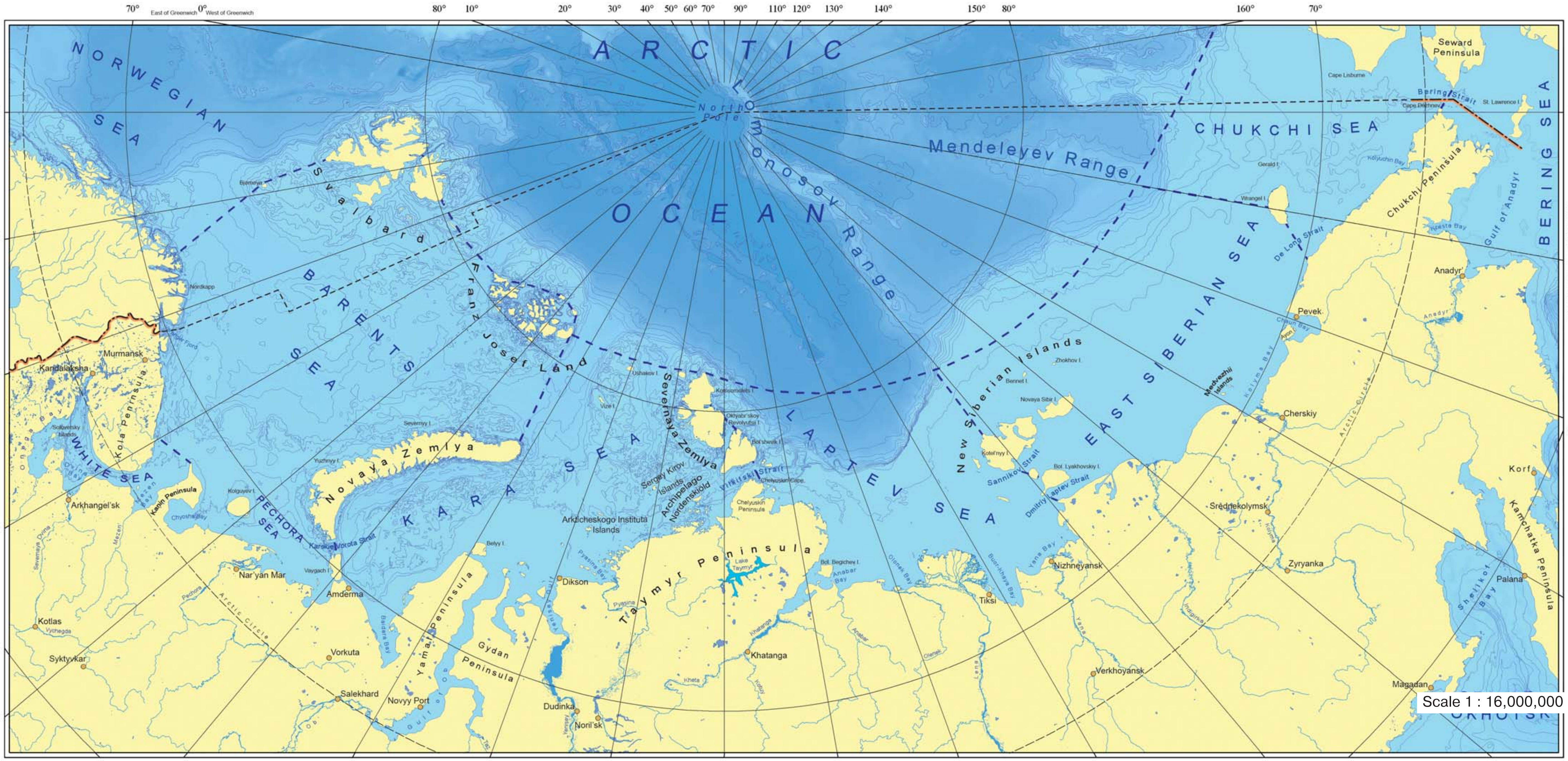
The oceanographic regime which is a feature of the large, deep, land-penetrating bays [Varanger Fjord, Kola Bay, Chyosha Bay (Chyoshskaya Guba), Pechora Bay (Pechorskaya Guba), and Kaipudyr Bay (Khaipudyrskaya Guba) in the Barents Sea; Kandalaksha, Onega, Dvina and Mezen Bays in the White Sea; Baidara Bay (Baidaratskaya Guba), Gulf of Ob (Obskaya Guba) and the Gulf of Yenisei in the Kara Sea; Khatanga and Anabar Bays in the Laptev Sea; Chaun Bay (Chaunskaya Guba) in the East-Siberian Sea; Kolyuchin Bay (Kolyuchinskaya Guba) in the Chukchi Sea; and the Gulf of Anadyr in the Bering Sea] has high specificity and is in some cases unique.

Interaction of the seabed topography and sediments, the water masses of the seas, and the Arctic Ocean, along with the coastal landscapes have resulted in a hierarchical system of biotopes which are home to communities of organisms and provide the basis for the life and function of these ecosystems. The composition of species, along with the abundance and productive potential of their populations, are to large extent determined by the properties of the marine and coastal biotopes.

The islands of the Russian Arctic seas are exclusively of the continental shelf type. Arctic deserts and subarctic tundra dominate in the insular landscapes [Litvin, Lymarev, 2003]. However the geomorphology and location of the islands in particular climate zones and subzones, the oceanographic regime of the adjacent waters and the history of human exploitation have combined to create specific conditions which make insular systems valuable for biodiversity conservation in the Arctic.

The total area of Arctic marine waters under Russian jurisdiction (excluding the Bering Sea) amounts to about 3,832,700 km² and includes internal marine waters (for example the White Sea), the territorial sea and the Exclusive Economic Zone (EEZ). The Russian Federation has a sovereign right to introduce or propose various spatial planning measures for nature conservation in all these zones and on the legally demarcated continental shelf (see Introduction for details).

Russia has prepared an application to the UN Commission on Limits of Continental Shelf to extend its sovereignty over the seabed of the Lomonosov and the Mendeleev underwater ranges and extending to the foot of the ridges. As part of this application to extend its sovereignty over this Arctic marine area, it has to outline special commitments for environmental protection in the Arctic Ocean Basin and pledge to carry out regular work aimed at monitoring the marine environment in the deep sea areas, which are essential for the health and livelihoods of marine Arctic ecosystems..



State border of the Russian Federation

Boundary of the polar domains of the Russian Federation

Boundary of the Arctic seas

Depth scale (metres): 7000 2000 200 0

Settlements

Compiled by *A.V. Makarov*
Source: National Atlas of Russia, Roskartographia [2004–2009]

Section 2

REGIONALIZATION AND BIOLOGICAL DIVERSITY OF SEAS AND COASTS OF THE RUSSIAN ARCTIC

2.1. PHYSIOGRAPHICAL REGIONALIZATION OF THE ARCTIC OCEAN SECTOR ADJACENT TO RUSSIA *A.N. Ivanov*

Maps or schemes for physiographical and biogeographical regionalization provide a basis for assessing the representativeness and biological diversity of the seascape within existing and proposed protected areas. For the purposes of this study we have used a scheme for physiographical regionalization originally developed for the Arctic Ocean.

There are two main methods for undertaking physiographical regionalization of the world's oceans. The first, the deductive method, analyses general differentiation factors of the world's oceans relying on existing schemes of vertical, latitudinal and azonal divisions. To do so, it usually applies the border overlay technique. This involves superimposing a series of maps with matching contours over one another. Special attention is given to the analysis of factors that play a leading role in the partitioning of regions and factors sensitive to changes in environmental conditions.

The second, the inductive regionalization method, involves using existing landscape contours as they have been mapped and, based on these, identifying the larger physiographical units. Using this method, every next (higher in rank) unit is identified by studying the regular distribution patterns of simpler natural units. The inductive approach makes extensive use of geostatistical analysis [Grant et al., 2006; Snelder et al., 2006] and appears to be a more advanced methodology; however its application is limited by the lack of existing high resolution seascape data. For this reason, in this study, we use the deductive method as the chosen method of regionalization. Our approach is based on earlier work performed for the seas of the Russian Far East [Ivanov, 2003].

The physiographical regionalization of the Arctic Ocean adjacent to Russia is based on geographical information: schemes of water circulation, geomorphological and climatic division, and fine-scale maps of physiographical regionalization. The divisions have been arrived at simultaneous and equal accounting of zonal and azonal factors and regularities in the partitioning of the geographic space (Map 2.1).

Levels of classification. A 5-level system of taxonomic units is used and corresponds to: (1) ocean basins, (2) megastructure of the ocean floor, (3) sea basin, (4) climatic zone, and (5) geomorphology of seabed and coasts.

Level One refers to the Arctic Ocean in general. Despite being the world's smallest ocean (which leads some oceanographers to categorize it as a sea of the Atlantic, i.e., the Arctic Mediterranean), it has traditionally been considered by Russian oceanographers as a separate entity.

Level Two of the regionalization corresponds to major megastructures of the oceanic floor. The secondorder physiographical boundary in the Arctic Ocean is the division between the underwater edge of the continent and the Arctic Basin associated with the deepest central portion of the ocean.

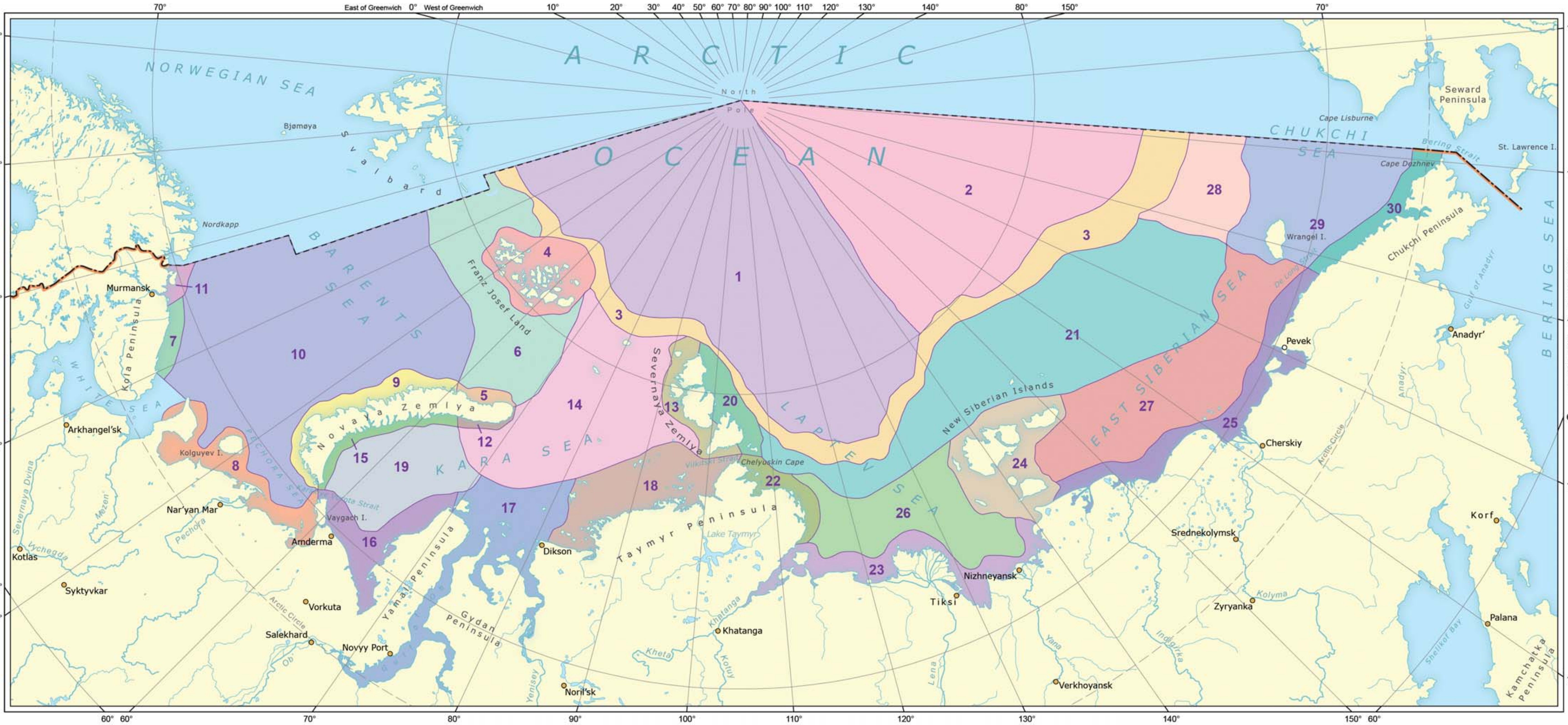
Level Three of the regionalization corresponds to physiographic realms – azonal units associated with sea basins at underwater continental margins. Sea basins are distinguished by their sizes, depth, shape of basin, and the degree of isolation from the world's oceans. The following basins have been identified: Barents Sea, White Sea, Kara Sea, Chukchi Sea, and the Laptev-East Siberian Sea. The latter includes two seas that are usually considered separately. For the purposes of this study we have considered them as a single sea basin. It is worth noting that some regionalization schemes also do consider the two as a single sea [Geomorphological regionalization, 1980; Lymarev, 2002].

Level Four corresponds to physiographic regions — zonal units distinguished within sea basins by latitudinal climatic differences. The Arctic zone includes the northern portions of all the sea basins. The Subarctic zone covers a larger area and includes southern portions of marginal seas of the Arctic Ocean. The Cold Temperate 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 provinces – portions of sea basins within one climatic zone that are distinguished by their geomorphology. Characteristics of provinces include similarities in their geological structure, direction and amplitude of recent crustal motions, and combinations of seabed topography forms that are only typical for the given province. It is assumed that, at this level, the seabed topography becomes a very important factor affecting oceanographic conditions and distribution of the marine biota. All provinces can be tentatively divided into two groups based on geomorphologic factors. The first group of provinces is located in the coastal zone of sea basins and includes large bays and coasts of different types (3.8). The second group of provinces is found in open stretches of sea basins. In these areas, because of the singularly broad sea shelf, the defining features of the central portions of sea basins include significant depths of the seabed and a lack of processes/properties of seascapes characteristic of coastal zones.

Because of the special regime which characterizes the White Sea, including its complex and long coastline, and the presence of geomorphologically separated parts, regionalization of the White Sea has been defined according to yet another scheme (Map 2.1). It is based on two approaches: a traditional approach based on the first hydrographic descriptions of the White Sea by M.F. Reinike in 1827–1832 and the approach based on specificity of the oceanographic regime of different parts of the sea [Naumov, 2006] (3.4).

Coast of Chukchi Sea [11]



P r o v i n c e s

1 West-Polar-Arctic
2 East-Polar-Arctic
3 Continental slope
4 Franz Josef Land
5 Barents Sea-Novaya Zemlya, northern
6 Northern Barents Sea
7 Kola
8 Kanin-Pechora
9 Barents Sea-Novaya Zemlya, southern
10 Central Barents Sea
11 Norwegian-Murmansk
12 Kara Sea-Novaya Zemlya, northern
13 Kara Sea-Severnaya Zemlya
14 Northern Kara Sea
15 Kara Sea-Novaya Zemlya, southern
16 Baidaratskaya
17 Ob-Yenisey
18 Taymyr
19 Southern Kara Sea
20 Laptev Sea-Severnaya Zemlya
21 Laptev-East Siberian seas
22 Eastern Taymyr
23 Khatanga-Yana
24 New Siberian Islands
25 Indigirka-Kolyma
26 Southern Laptev Sea
27 Southern East Siberian Sea
28 Northern Chukchi Sea
29 Southern Chukchi Sea
30 Coastal Chukotka

State border of the Russian Federation

Boundary of the polar domains of the Russian Federation

Scale 1 : 16,000,000

Compiled by *A.N. Ivanov*

Bioregionalization may be based on the distribution ranges of certain taxa or entire groups of flora and fauna. This approach is called biotic biogeography [Starobogatov, 1982]. The resulting demarcated areas in the Arctic seas mainly comprise two or three large regions. These are further sub-divided and the final hierarchy depends on the group of organisms under consideration.

For example, using amphipods Caprelloidea as her reference species for biogeographical regionalization, S.V. Vassilenko [1974] defined the Arctic Area as including all the seas of the Arctic Ocean except for parts of the Barents Sea and the White Sea, which she defined as belonging to a transitional zone (Map 2.2. A: C1–C). Similarly O.G. Kussakin [1979] in his regionalization scheme based on isopod crustaceans (Map 2.2. A: I1–I2), treats most of the Russian Arctic seas as a single Arctic Subarea of the Arcto-Atlantic Area with the western/central Barents and the White Sea belonging to the separate Atlantic Boreal Subarea (Map 2.2.A). Other authors have identified other subdivisions within the boundaries of their Arctic Area, Subarea or Province (Maps 2.2. A and B). Using amphipod crustaceans as her species of reference, E.F. Gurjanova [1951] defined the south-western Barents Sea as being part of the Boreal Area, while she considered that the other Russian Arctic seas were part of the Arctic Area comprising of several provinces (Map 2.2.B: A1 – A5). Z.A. Filatova [1957], who studied the distribution of bivalve molluscs, recognized the boundary between the Arctic Area and the Boreal Area as following Norway's shelf break to Bear Island and then following the Kola Peninsula and the internal White Sea coasts: all these coastal areas host boreal fauna. In the Pacific, the Bering Strait marks the boundary between Arctic and Boreal fauna distribution.

I.A. Jirkov's [2001] approach, based on the distribution of polychaets, does not use the «Arctic vs. Boreal» opposition. However, what he defines as the Shelf Arctic Region is similar to the region defined by Z.A. Filatova as the High Arctic Sublittoral Subarea, while the region he defines as the Deep Water Arctic Region corresponds to that defined by Filatova as the Eurasian Arctic Bathyal and the Arctic Abyssal Provinces. According to I.A. Jirkov's classification, while the south-western Barents Sea belongs to the Shelf Peri-Atlantic Region, and the coastal areas of the Kola Peninsula and the White Sea are combined in the Scandinavian Shallow Water Region, most of the Barents Sea represents a transitional zone. The eastern Chukchi Sea is part of the Shelf Peri-Pacific Region [Jirkov, 2001; Map 2.2. B: P1–P6]. The central Barents Sea is considered as a large transition zone also in the biogeography of the Arctic fishes [Andriashev, Shaposhnikova, 1985].

The boundary of Bogdanov's [1990] Arctic Area (based on studies of distribution of the gastropod subfamily, the Oenopotinae) coincides in the Barents Sea with the boundary of the Arctic Subarea as defined by O.G. Kussakin [1979]. The boundary between two of Bogdanov's [1990] Arctic provinces, the West Siberian and the Chukchi-American, passes further east of the New Siberian Islands (Map 2.2.A: O1–O4). The latter province meets the Beringian Province of the Pacific Boreal Area to the north of the Bering Strait. This subdivision is similar to the scheme derived by K.N. Nesis [1982] from the distribution patters of Cephalopoda. Like Jirkov [2001] he does not use the «Arctic vs. Boreal» opposition and considers five provinces within the Russian Arctic Seas: the Celtic Province, extending to the coastal waters of the Kola Peninsula; the Peri-Atlantic province, occupying most of the Barents Sea; the West Siberian, covering the northern Barents Sea, the Kara Sea, and most of the Laptev Sea; the Chukotka–Canadian Province, including the East-Siberian, part of the Chukchi sea and the Arctic waters of North America; the Bering Strait and the adjacent waters of Chukchi and the Bering seas belong to the Peri-Pacific Province. Like Kussakin [1979], V.V. Petryashov [2009] recognizes (using benthopelagic mysids as his reference) the Arcto-Atlantic Area which includes, in particular the Arctic Province. He further divides this province into zoogeographical districts: longitudinal boundaries between them are located, in particular, in the Barents and the East-Siberian Sea (Map 2.2.A: M1–M7). Thus several latitudinal biogeographical boundaries cross the East Siberian Sea. Additionally A.B. Dilman [2009] demonstrated the presence of a broad transitional zone in this sea using the distribution of sea stars as a reference. The Kara, the Laptev and the south-eastern and the north-eastern Barents Sea are more homogenous from the faunal standpoint.

A comparison of the physiographical provinces considered in 2.1 and the biogeographical provinces reveals certain similarities. While some physiographical provinces match specific biogeographical regions identified by particular authors, it is more common to find similarities between certain combinations of physiographic provinces with larger biogeographical regions. A representative network of MPAs should cover the major biogeographical regions and the most characteristic physiographical ones. In order to establish an MPA representing a large biogeographical region it should not be placed at a transitional zone (such as most of the Barents Sea and the East Siberian Sea). Rather it should be designated within a large region not crossed by biogeographical boundaries and encompassing several physiographical provinces.

Current climate transformation may lead to rapid dispersal of marine organisms from the North Pacific [Vermej, Roopnarine, 2008] and the North Atlantic — as it has been already observed in the Barents and the northern Kara Seas [Anisimova et al., 2008; Kantor et al., 2008]. In order to monitor these possible biodiversity changes, monitoring polygons (associated with the research stations and existing or proposed MPAs) should be established within large biogeographical regions but close to some present-day biogeographical boundaries: in the Franz Josef Land area, in the vicinity of transitional zones of the Barents and the East-Siberian Seas, or within such biogeographical enclaves as the White Sea.

CONVENTIONS TO MAP 2.2 A and 2.2 B

regionalization based on the distribution of Isopoda [Kussakin, 1979]
I1 — Arctic Subarea of Arcto-Atlantic Area;
I2 — Celtic Province of Atlantic Boreal Subarea, Arcto-Atlantic Area;
I3 — Bering province of Aleutian Subarea, Pacific Boreal Area;

regionalization based on the distribution of amphipod families Caprellidae and Paracercopidae [Vassilenko, 1974]
C1 — Arctic Area;
C2 — Atlantic Boreal Bathyal Area;
C3 —Aleutian Province of Upper Boreal Aleut-Kamchatka Subarea, Pacific Boreal Area;

regionalization based on the distribution of the gastropod subfamily Oenopotinae [Bogdanov, 1990]
O1 — West Siberian Province of Arctic Area;
O2 — Chukchi-Alaska Province of Arctic Area;
O3 — Atlantic Boreal Area;
O4 — Bering Subarea of Pacific Boreal Area;

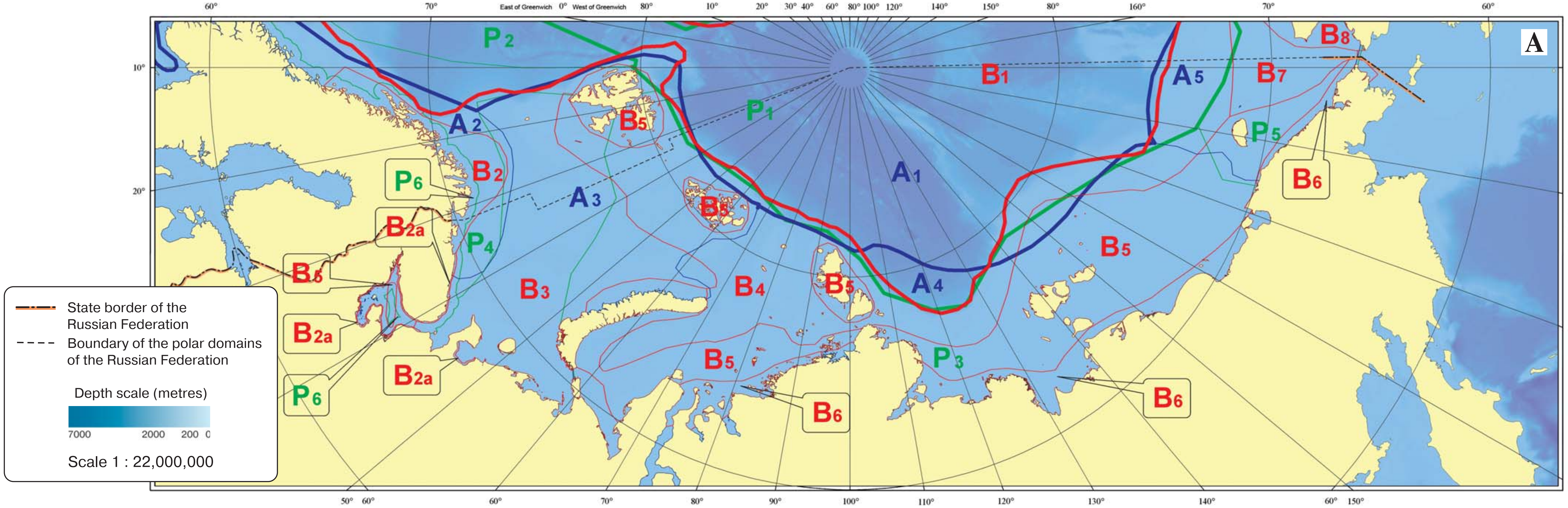
regionalization based on the distribution of the benthic and bentho-pelagic Mysidacea [Petryashov , 2009]
M1 — Eurasian District of Arctic Province of Arcto-Atlantic Area;
M2 — Amerasian District of Arctic Province of Arcto-Atlantic Area;
M3 — East-Greenland District of Arctic Province of Arcto-Atlantic Area;
M4 — White Sea-Barents District of Scandinawian Province of Arcto-Atlantic Area;
M5 — West Barents District of Scandinawian Province of Arcto-Atlantic Area;
M6 — Norwegian District of Scandinawian Province of Arcto-Atlantic Area;
M7 — Pacific Boreal Area;

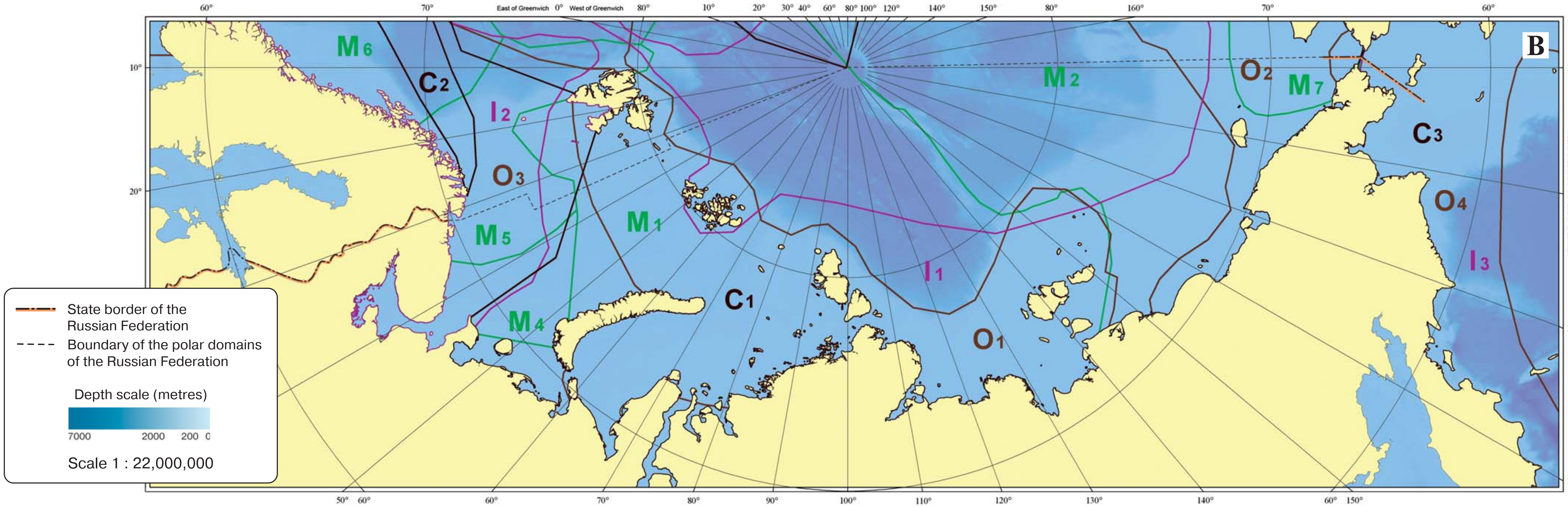
regionalization based on the distribution of the Amphipoda Gammaridea [Gurjanova, 1951]
A1 — Deep Sea Arctic Area;
A2 — Boreal Area;
A3 — White Sea-Spitsbergen (Svalbard) Province of Arctic Shelf Area;
A4 — Siberian Province of Arctic Shelf Area;
A5 — Chukchi-American Province of Arctic Shelf Area;

regionalization based on the distribution of Bivalvia [Filatova, 1957]
B1 — High Arctic Abyssal Polar-Greenland Province of Arctic Area;
B2 — Norwegian-Murmansk Province of Boreal Area;
B2a — Coastal enclave of Norwegian - Murmansk - White Sea Province of Boreal Area;
B3 — Barents Province of Arctic Area;
B4 — Eurasian Bathyal Province of Arctic Area;
B5 — Siberian- White Sea Province of Arctic Area (with enclaves);
B6 — Siberian Brackish Water province of Arctic Area;
B7 — Chukchi Sea Province of Arctic Area;
B8 — Alaska and Chuckotka-Bering Provinces of Boreal Area;

regionalization based on the distribution of Polychaeta [Jirkov, 2001]
P1 — Deep Sea High Arctic Region;
P2 — Deep Sea Norwegian Region;
P3 — Arctic Shelf Region;
P4 — Shelf Peri-Atlantic Region;
P5 — Shelf Peri-Pacific Region;
P6 — Shallow Water Scandinavian Region.

Schemes of biogeographical regionalization are based on distribution of different taxonomic groups of invertebrates;
A and B: schemes, which recognize (A) and those which do not recognize (B) deep-water Arctic regions





Compiled by *A.V. Makarov* and *V.A. Spiridonov.*

Different realms and biotopes may significantly differ in their «carrying capacity» for taxonomic diversity. Inventorying species and comparing the species diversity for geographical areas and biotopes is a very common method used to describe the diversity of life. Unfortunately, the biota of Russian Arctic Seas is still not clearly understood, and this method must be used with caution.

There are not many updated lists of algae species for all the Arctic Seas. Below (Table 2-1) is the most recent update for diatom algae species living in the sea ice and partly entering the water column when the ice melts [Ilyash, Zhitina, 2009]. The White Sea appears to be the most species rich, and the Kara Sea is the most species poor. That said, the sea ice diatom floras of these two seas are very similar, unlike the flora of the White and Barents Seas. East of the Barents Sea the pattern of similarity between floras generally follows the dominant directions of sea ice drift [Ilyash, Zhitina, 2009].

The diversity of animal species of the Russian Arctic Seas is better documented thanks to the longstanding efforts of the ZIN RAN [Sirenko, 1998; 2001, 2010; Petryashov et al., 2004].

Medusa *Cyanea capillata* [12]

In particular, there are not many species of metazoans (and unicellular but relatively large radiolarians) living as zooplankton. The water column fauna of the Barents Sea is the richest and most diverse; it is enriched by the presence of Atlantic species carried on the ocean currents (Map 2.3.A). The Barents Sea is one of the most widely studied areas in the Arctic. The White Sea, with its smaller surface area, decreased salinity and seasonal temperature contrasts is home to fewer planktonic species (about half as many). Further east, the number of species living in the water column also decreases in comparison to the Barents Sea, reaching its lowest levels in the East Siberian Sea. Species numbers rise again in the Chukchi Sea, as North Pacific species enter through the Bering Strait. This may be partly explained by the fact that many oceanic pelagic animals are unable to tolerate the shallow water conditions of the Siberian seas which are strongly influenced by river run-off. In the shallow waters calanoid copepods become the numerically dominant species. The plankton fauna of the deep-water Central Arctic Basin is much richer in species diversity (Map 2.3.A). Copepods also dominate there, but the species composition is different. The spaces between sediment particles and sea ice crystals are inhabited by microfauna. These are organisms of less than 100μ, mostly unicellular. The study of the diversity of microfauna is fragmentary: for example for benthic ciliates (Ciliata) the greatest species number (282) has been recorded in the White Sea. In the Barents Sea there are 260 species; in the Kara Sea, where some time ago only few species were recorded, is now known to have 125 species. No reliable data exist for other Russian Arctic seas [A.I. Azovsky et al., in press].

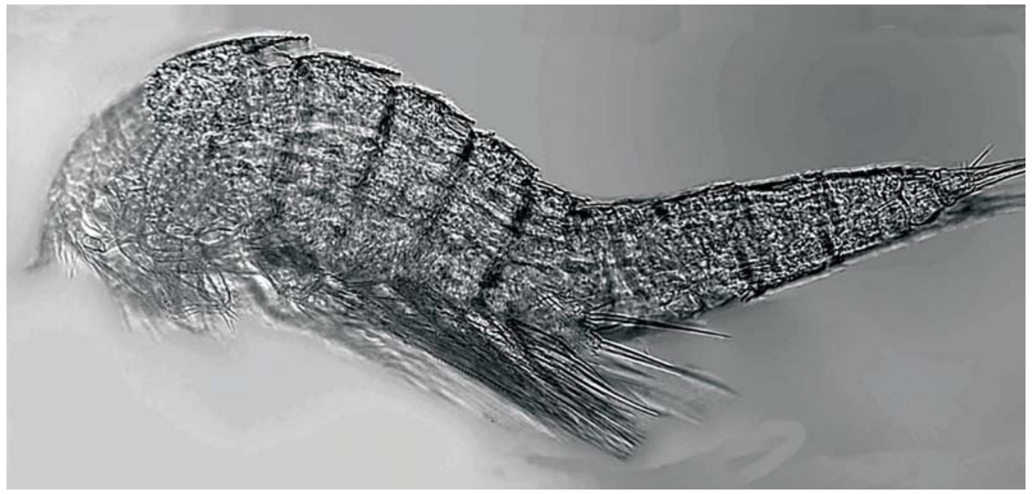
The diversity of several taxonomic groups belonging to meiofauna, i.e. animals less than 1 mm [Mokievsky, 2009], is shown in Map 2.3.B. Again, the fauna of the Barents Sea appears to be the richest. In the White Sea more seems to be known about nematodes and related taxa and harpacticoid copepods than in other parts of the Arctic seas. However, even here the inventory is far from complete. For example, at the time of publication of the check list for the Arctic Seas there were only 112 known species of harpacticoid copepods in the White Sea [Sirenko, 2001]. Following only a few years of active research by marine biological stations the number rose to more than 150 [Kornev, Chertoprud, 2008]. Now, even greater estimates are available: 185 species [A.I. Azovsky, L.A. Garlitska, E.S. Chertoprud, pers. comm.].

Table 2–1. Number of sea ice diatom species (bold), ratio-centric to pennate forms — (bold italic in brackets) in particular Arctic seas and similarity coefficients (%) between sea ice diatom floras in different seas (values above the main diagonal of the table) [Ilyash, Zhitina, 2009]

Region	White	Barents	Kara	Laptev	East Siberian	Chukchi	Arctic Basin
White Sea	**272 *(0,42)***	**0,48**	**0,71**	**0,57**	**0,49**	**0,52**	**0,55**
Barents Sea		250 ***(0,33)***	0,61	0,47	0,45	0,47	0,55
Kara Sea			57 ***(0,36)***	0,56	0,48	0,58	0,50
Laptev Sea				180 ***(0,20)***	0,73	0,73	0,52
East Siberian Sea					150 ***(0,15)***	0,84	**0**,48
Chukchi Sea						241 ***(0,19)***	0,52
Arctic Basin							209 ***(0,25)***

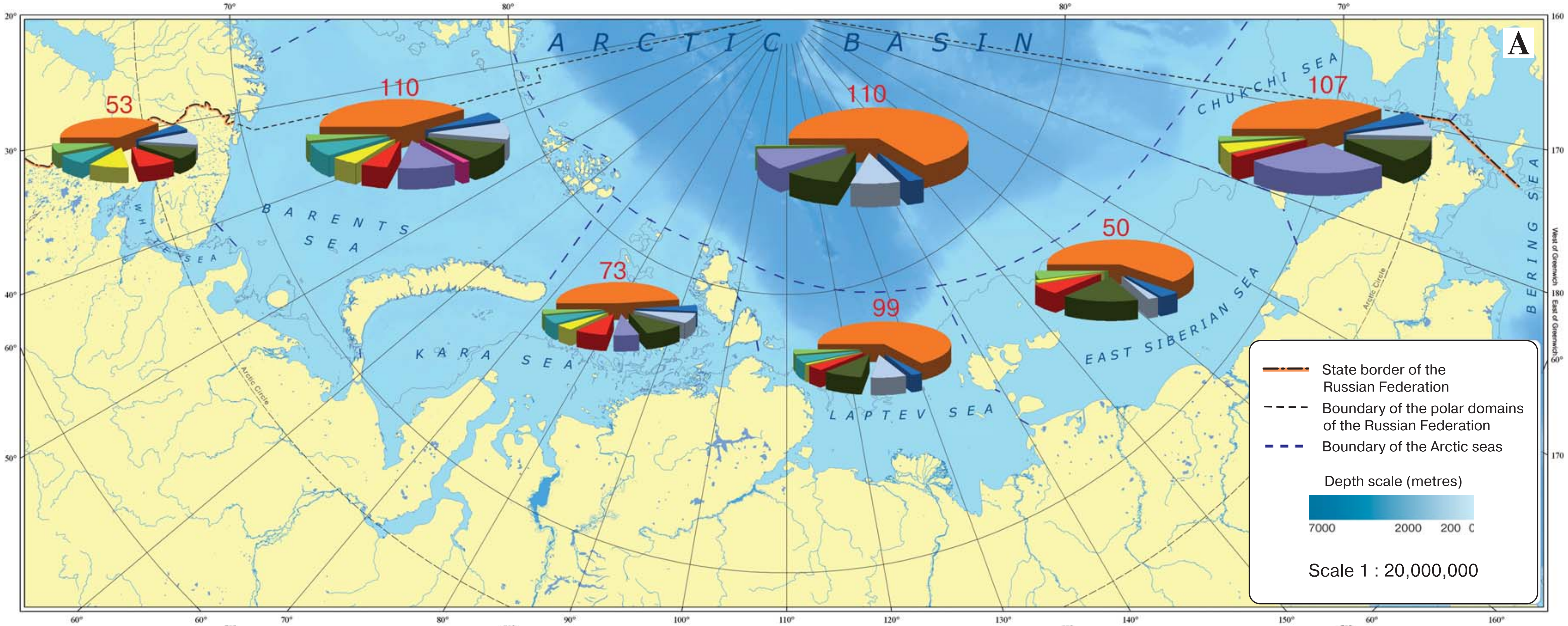
East of the Barents Sea there is a drastic decrease in the number of species from the Kara through the Laptev Sea to the East-Siberian Sea with a slight increase in the Chukchi Sea. However, while taxa composition in the Kara Sea is similar to that in the Barents Sea, in the Laptev, East-Siberian, and Chukchi Seas and in the deep Arctic Basin, certain groups (i.e. ciliates, nematodes) are practically not studied and foraminipherans are considered the most species rich group. A complete inventory of the Arctic micro- and meiofauna is still needed. In particular, it is anticipated that a new species of the deep living giant protists Komokida (related to Foraminiphera), which according to preliminary data dominate in benthos in the North Pole, will be discovered in the Arctic Basin [O.A. Kamenskaya, pers.comm.].

Harpacticoid crustacean *Ectinosoma* [13]



Compiled by
A.V. Makarov and *V.A. Spiridonov*

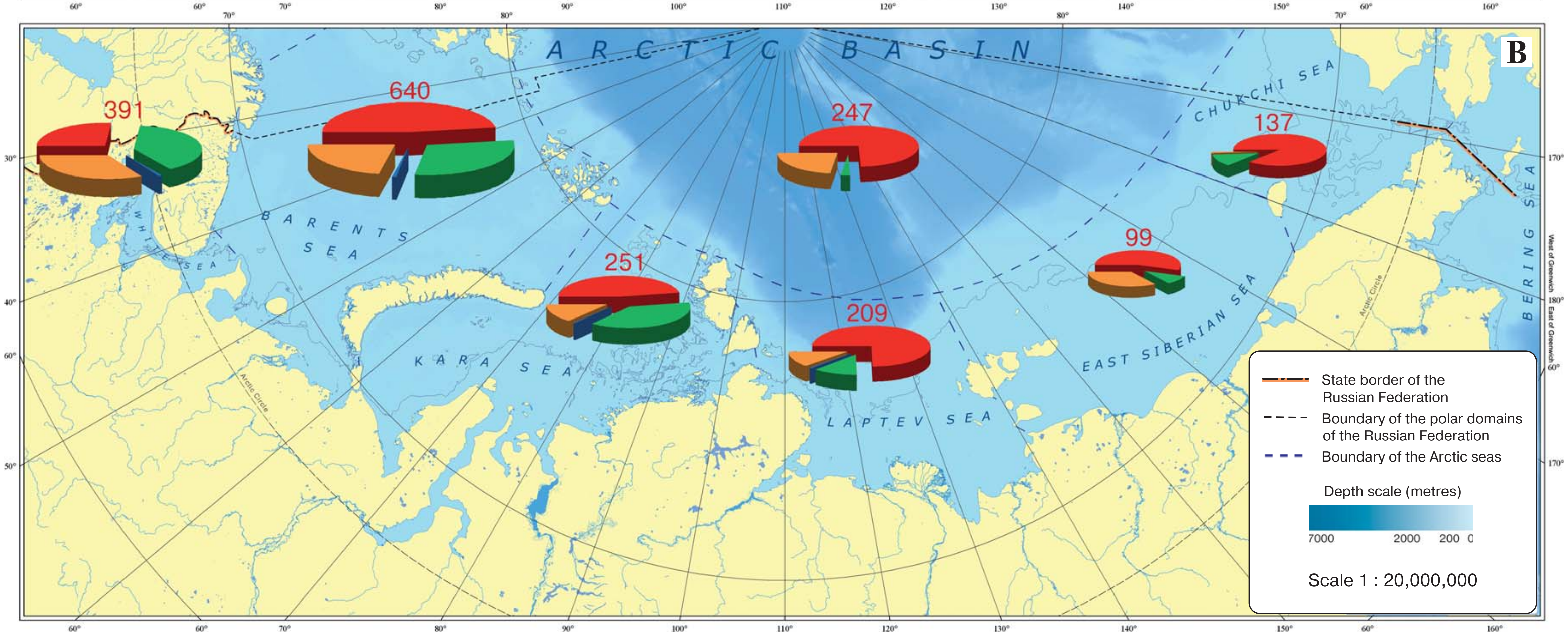
Sources:
Sirenko [2001] with additions from Petryashov et al. [2004], *Kornev, Chertoprud* [2008], *Sirenko* [2010], *A.I. Azovsky, L.A. Garlitska, E.S. Chertoprud* [pers. comm.]



99 Total number of species

Taxonomic composition

- Calanoida
- Euphausiacea
- Hyperiidea
- Chaetognata
- Appendiculariae
- Radiolaria
- Scyphozoa
- Ctenophora
- Rotifera
- Cladocera



99 Total number of species

Taxonomic composition

- Foraminifera
- Nemathelminthes
- Tardigrada
- Harpacticoida

The species of micro- and meio- and macrofauna inhabiting seabed habitats have very different life histories; it would be safe to say that they inhabit very different worlds [Mokievsky, 2009b]. Contrary to micro- and meiobenthos (2.3), which, despite their ecological importance are known only to specialists, macrobenthic species which inhabit the seabed are widely known among the public at large. They are also better studied so the data on species numbers summarized for the Arctic seas may better reflect real patterns of biodiversity distribution.

Seaweed is an important component of the macrobenthos. Macrophytes grow in a very narrow range of depths ranging from 0 to a maximum of 30 m. In most Arctic seas this range is even smaller. However, the importance of the macrophyte belt as a biotope system [Zenkevich, 1963] and production zone [Romankevich, Vetrov, 2001] cannot be underestimated. The Barents and White Seas have the greatest number of seaweed species on account of the variety of seashore types and relatively milder climate conditions. These are the only seas where vascular plants, e.g. *Zostera marina*, grow. The number of macrophyte species decreases towards the Siberian seas and increases in the Chukchi Sea [Zenkevich, 1963; Vinogradova, 1990]. A continuous and species rich belt of macrophytes off the Kola coast and in the White Sea changes to isolated patches of seaweed communities further east (in some parts of the southeastern Barents Sea, the southwestern coast of Yuzhnyy Island of the Novaya Zemlya, the coastal zone of New Siberian Islands, Chaun Bay and coastal shallows of the Chukchi Sea), where a limited set of the red, brown and the green algae species is recorded (Zinova, 1985).

Amphipod *Anonyx nugax* [14]

The Barents Sea appears to have the highest diversity of taxonomic groups of macrobenthic animals and is home to about twice or more of the number of species compared to each of the other seas (Map 2.4.A). Polychaets, gastropods and amphipods are the most species-rich groups. In the White Sea, all taxa are represented by smaller numbers of species but their shares are similar to those in the Barents Sea. Thus K.M. Derjugin's [1928] early assessment that this constitutes the «negative characteristics» of the White Sea fauna makes sense. These differences can probably be explained by the relatively recent formation of the White Sea (it is about 14,000 years old) and severe conditions in the Gorlo, the strait connecting its outer and the inner parts which has existed for at least the last 6,000 years since the maximum temperatures of the Holocene era [Naumov, 2006; Solyanko et al., 2010].

The Kara Sea also has a lower number of species in comparison to the Barents Sea. The share of species-rich groups such as polychaets and amphipods among its entire fauna is higher than in the Barents Sea. This may indicate the existence of incomplete inventories of many other groups rather than a real pattern. The percentage of amphipods is even greater in the Laptev Sea which has a lower total number of species than the Kara Sea. Until recently, studies of the fauna in the Laptev Sea were limited. However in the last two decades, further studies have been conducted and the known number of species has nearly doubled [Sirenko, 1998; 2001]. The East-Siberian Sea appears now to be the poorest in terms of macrobenthic animal species numbers. This is because many species of the Atlantic origin that are moved around by deep waters do not spread far west of the Laptev / East Siberian Sea boundary [Dilman, 2009]. At the same time there are some areas, i.e. Chaun Bay, where species of Pacific origin and their communities (usually living in warmer waters) have persisted since the temperature maxima were recorded in the geological past [Golikov et al., 1994]. In the Chukchi Sea the presence of Pacific species is remarkable. According to the most recent data [Sirenko, 2010] its species richness is relatively high. One peculiar characteristic of the Chukchi Sea fauna is the increased share of species of bryozoans and other groups of sessile feeding on suspended organic matter (seston). This may be a result of the high productivity observed in the Chukchi Sea shallows (Map 2.4 A). The Central Arctic Basin appears now to be the area of the least species richness and diversity.

Benthic community dominated by ophiurans [15]

The distribution of the different types of macrobenthic communities [Sirenko, 1998] shown in Map 2.4.B demonstrates characteristic patterns which are related to different shelf zones. Areas adjacent to estuaries of big rivers in the Siberian seas are populated by estuarine species where bivalves *Portlandia aestuariorum* and *Cyrtodaria kurriana* and some crustaceans dominate. Further offshore, throughout the Russian Arctic seas, there is a range of communities dominated by the other bivalves (Map 2.4.B). At the outer shelf and upper continental slope (600–700 m) a zone of communities dominated by ophiurans can be observed (Map 2.4.B). Further north, at depths of between 700–2000 m, benthic communities are dominated mostly by polychaets from various families, in particular Maldanidae and Chaetopteridae. And at the lower depths of the continental slope (2000–2500 m) deep water Arctic species including holothurians *Kolga hyalina*, *Elpidia glacialis* and sea urchins *Pourtalesia jeffreysii* are common. Some of the differences in the distribution of benthic community types in the Barents Sea from this circumcontinental pattern can be explained by the complex topography of the seabed and the strong influence of the Atlantic waters [Sirenko, 1998].

Schemes similar to 2.4 B can be used (along with biogeographical regionalization maps, e.g. 2.2) to select representative candidate areas for monitoring and protection of marine ecosystems. Physiographical provinces (2.1) associated with archipelagos and bays (characterized by specific oceanographic regime and complex seabed topography) are of particular importance for encompassing the maximum diversity of benthic biotope within the MPA network.

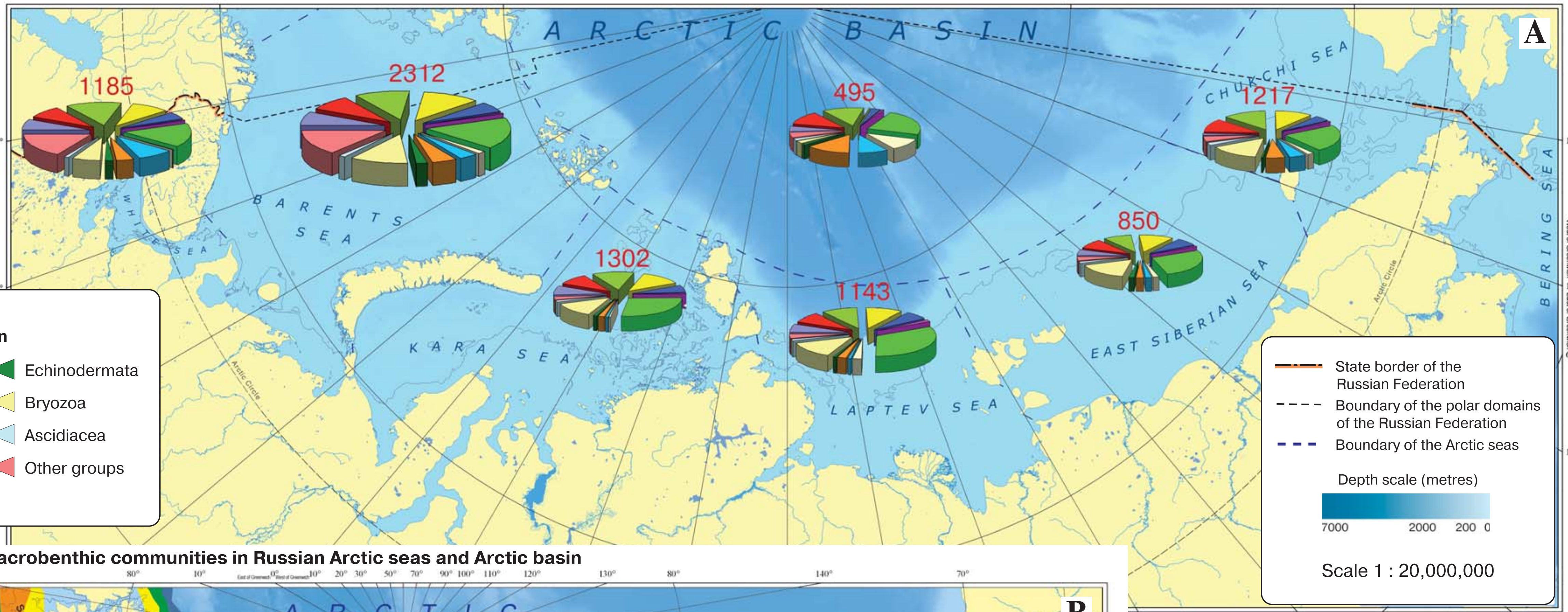
Compiled by
A.V. Makarov and *V.A. Spiridonov*

Source:

2.4 A *Sirenko* [2001] with additions from Petryashov et al. [2004], *Anisimova* et al. [2008], *Frolova* [2009], *Lyubina, Sayapin* [2009] and *Sirenko* [2010]

2.4 B *Sirenko [1998]*

2.4 A. Species diversity of principal taxonomic groups of macrobenthos

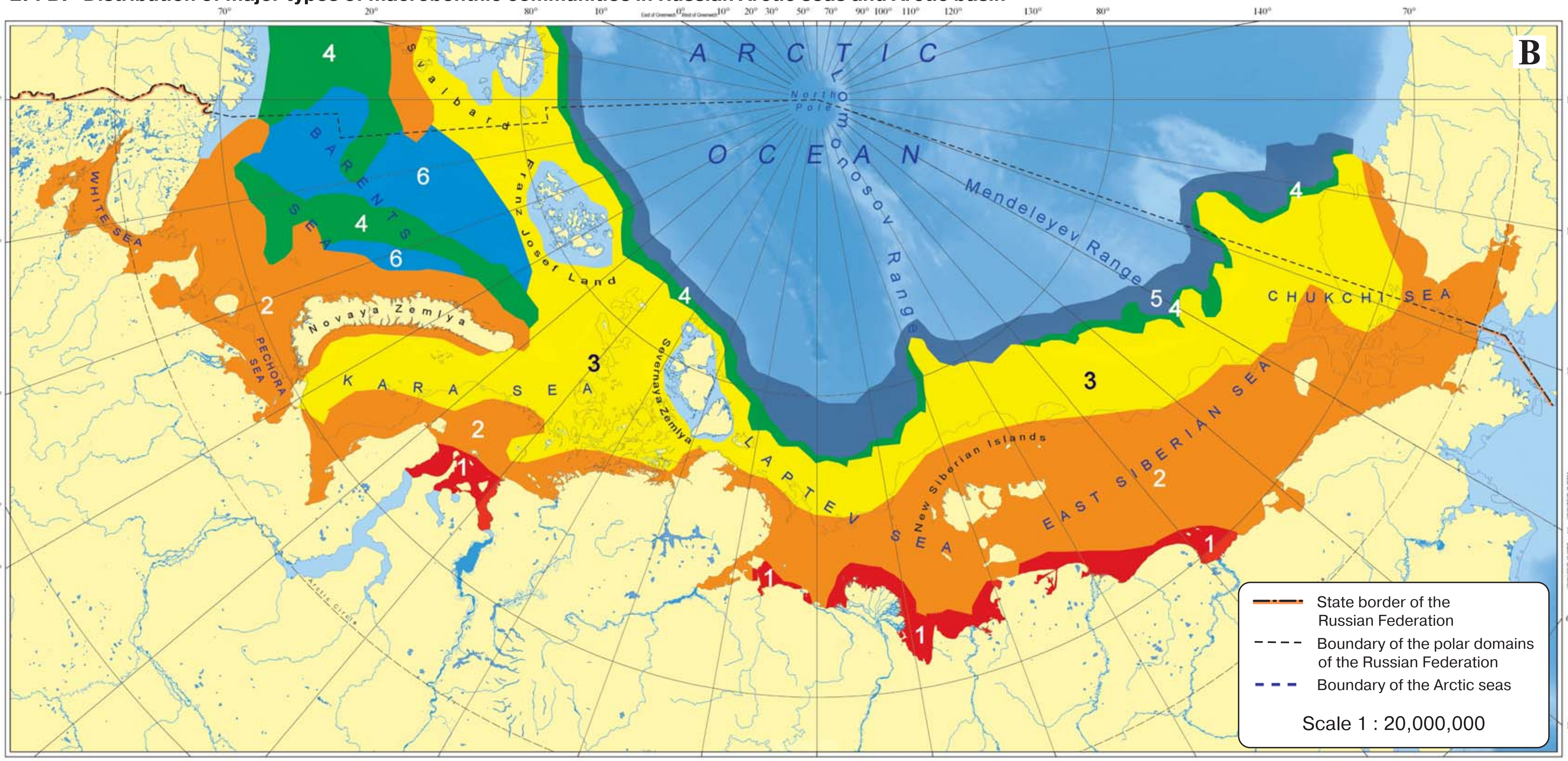


1185 Total number of species

Taxonomic composition

Porifera	Other Mollusca	Echinodermata
Cnidaria	Benthic Amphipoda	Bryozoa
Polychaeta	Isopoda	Ascidiacea
Gastropoda	Ostracoda	Other groups
Bivalvia	Other Crustacea	

2.4 B. Distribution of major types of macrobenthic communities in Russian Arctic seas and Arctic basin



Communities with domination by

1. estuarine species (*Portladia aestuariorum, Cyrtodaria kurriana, Rhizomolgula globularis, Saduria entomon*)
2. bivalves (*Tridonta borealis, T. montagui, Macoma calcarea, Nuculana pernula, N. radiata, Leionucula belotti, L. inflata, Portlandia arctica, P. siligua, Astarte crenata, Yoldia hyperborea, Ciliatocardium ciliatum*)
3. ophiurans (*Ophiocten sericeum, Ophiocantha bidentata, Ophiopleura borealis* and others)
4. polychaets (Maldanidae, Chaetopteridae and others)
5. holothurians and sea urchins (*Elpidia glacialis, Kolga hyalina, Pourtalesia jeffreisi*)
6. Sipunculida

There are significantly fewer vertebrate animal species in the Arctic seas than invertebrate species. Yet in the eyes of the public, fish, sea birds and marine mammals are the iconic species most often associated with Arctic fauna. Vertebrates are at the top of the food web and act as links between different realms. For example, polar cod (*Boreogadus saida*) juveniles feed on the organisms that inhabit the sea ice/water interface and channel organic matter and energy from the sea-ice ecosystem to the ecosystems of the water column (3.1). Anadromous fishes transfer oceanic biological production to watershed ecosystems; colonial birds feeding at sea create specific ornithogenic landscapes around their nesting places [Breslina, 1987]. In the overwhelming majority of cases, aquatic biological resources exploited by humans in the Arctic consist largely of vertebrate animals whose usage goes far beyond fisheries, hunting, and collecting sea bird fluff. For example, population composition and dynamics of colonial sea birds reflect the availability of food resources in marine ecosystems over vast areas adjacent to their colonies [Krasnov et al., 1995]. This makes them one of the best indicators for monitoring ecosystem health.

Map 2.5 A illustrates patterns of fish and cyclostomates species diversity in the Arctic seas. All these species can be divided into three ecological groups. Marine species live and reproduce in characteristically saline environments and do not usually occur in brackish water conditions — although there may be some exceptions, for example, some species of plaice enter river mouths and migrate up to tens of kilometres upstream in tidal estuarine areas. Anadromous species, such as salmon and some populations of Arctic char (*Salvelinus alpinus*) and Arctic cisco (*Coregonus autumnalis*), breed in fresh water but spend most of their lifecycle at sea often migrating over great distances. Semi-anadromous fishes, such as whitefish (Coregonidae) and smelt, *Osmerus* spp. (which also breed in fresh water) spend part of their life in estuarine and coastal marine waters of low salinity. In addition, the estuarine waters of the Arctic seas are also populated by several freshwater species (Map 2.5 A).

Species richness is at its most dense in the Barents Sea and decreases gradually as we move towards the East Siberian Sea. The East Siberian Sea is home to approximately 10 times fewer marine species than the Barents Sea. This low species count is not simply the result of a lack of investigation but reflects the harsh living conditions in the Siberian shelf waters. However, a group of anadromous and semi-anadromous fish are nonetheless flourishing in the Siberian waters where they provides up to 90% of fishery landing. That said, the East Siberian is home to a greater diversity of species that the Laptev Sea. The scorpion fishes (Cottidae) is the most species-rich group among the Eurasian seas' marine fish fauna. Among this species, the fourhorn sculpin (*Myoxocephalus quadricornis*) is a species of major ecological importance as is the Arctic cisco which preys intensively on juvenile sculpin during its summer feeding period in the coastal marine waters [Gurjanova, 1970].

Water birds constitute a large ecological group and include taxonomically and phylogenetically distant families. Marine birds include true sea birds which only forage at sea and nest primarily in colonies (obligate colonial birds including many species of the Alcidae but also from other families). There are also facultative colonial birds and an ecologically distinct group of sea ducks. The latter can be divided into two distinct groups, fish-eating species and those feeding on benthic animals. In addition to these, other waterbirds, including waders are also found in maritime coastal habitats, especially during the nonbreeding season (4.3). Map 2.5 B shows changes in species' number of marine colonial birds (mainly murres, auks, puffins, gulls, cormorants, fulmars, and gannets) and diving ducks nesting on the coasts of particular seas of the Russian Arctic. As with many other taxonomic groups, the greatest numbers are found in the Barents Sea where some Atlantic species are common: gulls, cormorants, gannets, and the northern fulmar (*Fulmarus glacialis*, the only Arctic member of the tube-nosed birds, Procellariiformes, the genuine inhabitants of the oceanic waters). The total number of species

Narwals [16]

Table 2-2. Occurrence of marine mammal species in the Russian Arctic seas and the Arctic Basin (based on *Belikov* et al., 1998; *Artukhin, Burkanov,* 1999; *Burdin* et al., 2009; *Lukin, Ognetov,* 2009; Stiansen et al., 2009).

C — common; R — rare; VR — very rare; ABS — absent.

Areas: Bar. — Barents Sea (Russian part); Wh. — White Sea; Lapt. — Laptev Sea; E-Sib. — East Siberian Sea; Chuk. — Chukchi Sea; and AB — Arctic Basin.

Species	Area						
	Bar.	Wh.	Kara	Lapt.	E-Sib.	Chuk.	AB
Cetacea							
Bowhead Whale *Balaena mysticetus*	VR	ABS	VR	VR	VR	C	ABS
Gray Whale *Eschrichtius robustus*	ABS	ABS	ABS	ABS	C	C	ABS
Humpback *Megaptera novaeangliae*	R	VR	ABS	ABS	ABS	R	ABS
Little Picked Whale *Balaenoptera acutorostrata*	C	R	VR	ABS	ABS	R	ABS
Blue Whale *Balaenoptera musculus*	VR	ABS	ABS	ABS	ABS	ABS	ABS
Finback Whale *Balaenoptera physalus*	R	VR	ABS	ABS	ABS	R	ABS
Bottle-nosed Dolphin *Tursiops truncatus*	R	ABS	ABS	ABS	ABS	ABS	ABS
White-sided Dolphin *Lagenorhynchus acutus*	R	ABS	ABS	ABS	ABS	ABS	ABS
White-beaked Dolphin *L.albirostris*	C	VR	ABS	ABS	ABS	ABS	ABS
Bottlehead *Hyperoodon ampullatus*	R	VR	ABS	ABS	ABS	ABS	ABS
Common Dolphin *Delphinus delphis*	VR	ABS	ABS	ABS	ABS	ABS	ABS
Killer Whale *Orcinus orca*	C	R	ABS	ABS	VR	R	R
Pilot Whale *Globicephala melas*	R	ABS	ABS	ABS	ABS	ABS	ABS
Phocoena phocoena	C	R	ABS	ABS	ABS	ABS	ABS
Dall's Porpoise *Phocoenoides dalli*	ABS	ABS	ABS	ABS	ABS	VR	ABS
North Pacific giant Whale *Berardius bairdi*	ABS	ABS	ABS	ABS	ABS	VR	ABS
Beluga Whale *Delphinapterus leucas*	C	C	C	C	C	C	R
Narwhale *Monodon monoceros*	R	ABS	R	VR	R	VR	ОБ
Cachalot *Physeter macrocephalus*	R	ABS	ABS	ABS	ABS	ABS	ABS
Pinnipedia							
Walrus *Odobenus rosmarus*	C	R	C	C	C	C	R
Harp (Greenland) Seal *Pagophilus groenlandicus*	C	C	R	ABS	ABS	ABS	ABS
Ringed Seal *Phoca hispida**	C	C	C	C	C	C	R
Bearded Seal *Erignathus barbatus*	C	C	C	C	C	C	ABS
Ribbon Seal *Histriophoca fasciata*	ABS	ABS	ABS	ABS	ABS	R	ABS
Common Seal *Phoca vitullina*	C	R	ABS	ABS	ABS	ABS	ABS
Spotted Seal *Phoca largha*	ABS	ABS	ABS	ABS	ABS	C	ABS
Gray Seal *Halichoerus gripus*	R	R	ABS	ABS	ABS	ABS	ABS
Crested Seal *Cystophora cristata*	C	VR	VR	VR	VR	ABS	ABS
Carnivora							
Polar Bear *Ursus maritimus*	C**	ABS	C	C	C	C	R

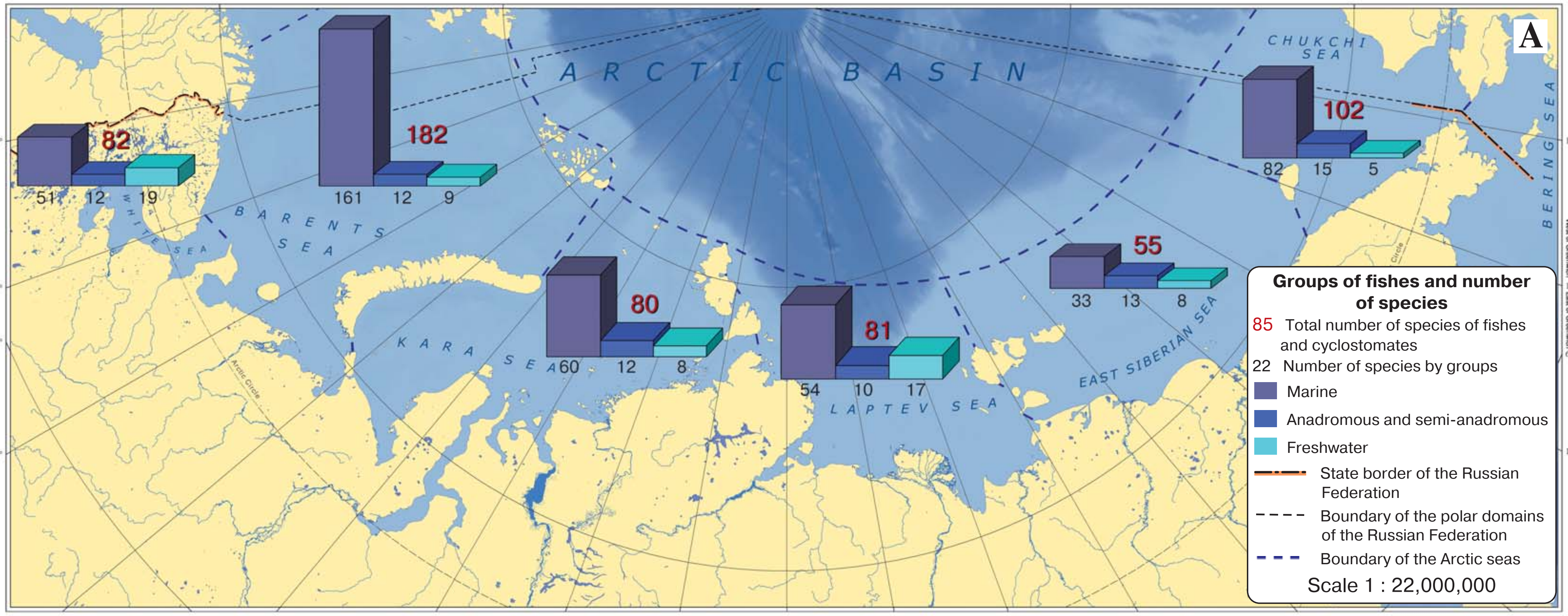
* sometimes this species is referred as *Pusa hispida*;
** in the northern part of the sea

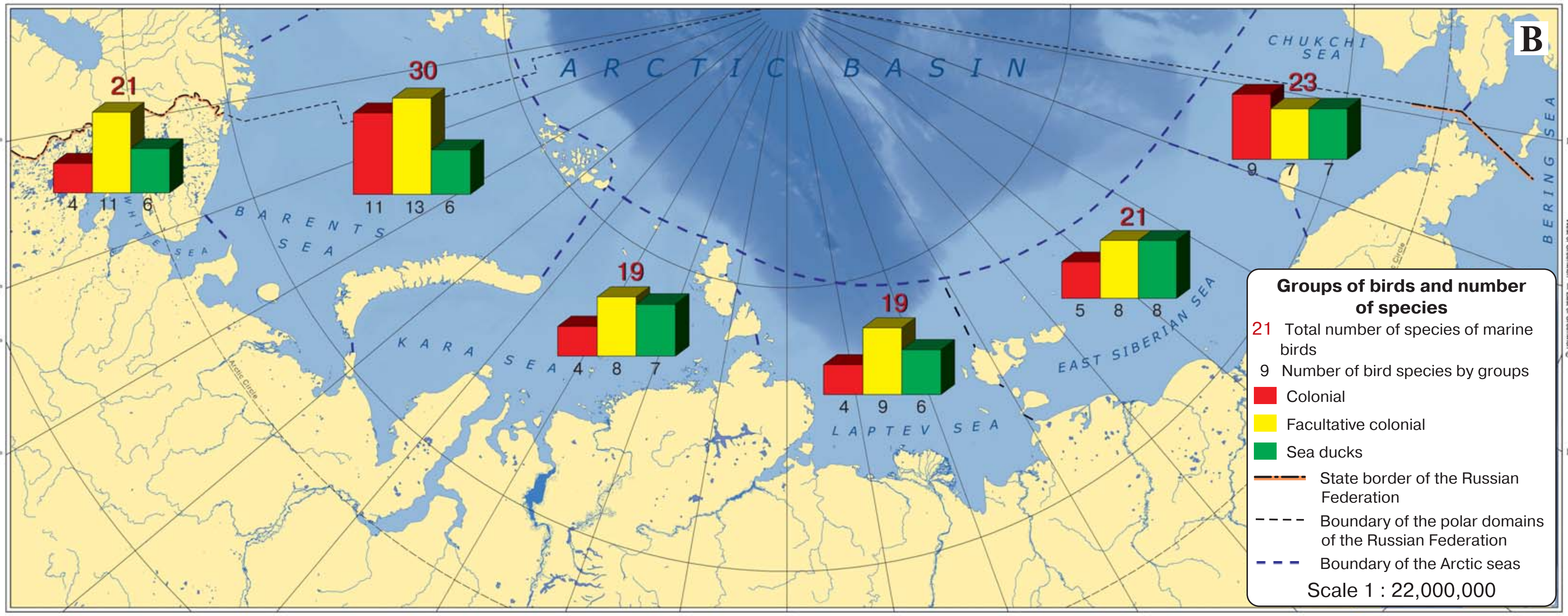
decreases in the White and the Kara Seas and remains low in the Laptev and East Siberian Seas; it increases then in the Chukchi Sea where some Pacific Alcids nest (see 3.3).

Among sea ducks, only eiders are genuine sea birds. All eiders use land for nesting and rearing broods only; the common eider (*Somateria mollissima*) then moves immediately to the sea with its brood. Eiders prey mainly on benthic invertebrates and use coastal shallows for summer feeding. Chukotka is known for the diversity of its eiders. All four species of eider can be found in Chukotka: the Pacific subspecies of the common eider (*Somateria mollissima v-nigrum*), the king eider (*S. spectabilis*), the spectacled eider (*S. fischeri*), and the Steller's eider (*Polysticta stelleri*).

Two main orders of marine mammals that can be observed in the Arctic are pinnipeds and cetaceans. The polar bear (*Ursus maritimus*), the iconic symbol of the Arctic, can also be considered a marine animal as it spends most of its life wandering on the drifting ice and obtaining its prey from the sea. Most pinnipeds maintain a connection to the shore where they breed, nurse pups and moult; however some seal species, i.e. harp seal (*Pagophilus groenlandicus*) and ribbon seal (*Histriophoca fasciata*), use sea-ice biotopes for these important functions. Although cetaceans live permanently in the marine environment, some species also maintain close connections to the shore. For example, beluga whales (*Delphinapterus leucas*) form reproductive aggregations close to the shore where they give birth to calves, nurse juveniles, socialize and mate. The migration routes of the East Pacific population of grey whales (*Eschrichtius robustus*) follow the shores: these animals migrate over distances of thousands of kilometres from their wintering grounds off the California coast to the feeding grounds in the Chukchi and the East Siberian seas.

The Barents Sea is the richest in marine mammal species; their numbers then decrease towards the White Sea and further east (especially the number of cetaceans) and increase again in the Chukchi Sea (Table 2-2). The Arctic Basin is the most species poor. That said, it is nonetheless home to important populations of narwhal (*Monodon monoceros*), a unique marine mammal species found in the Arctic. Its separate taxonomic identity and exclusive occurrence in the high-latitude Arctic region points to a long evolutionary history in the polar environment.





Compiled by: **2.5 A** — *V.A. Spiridonov* and *A.V. Makarov*
2.5 B — *M.V. Gavrilo*

Sources of data: **2.5 A** — *Andriashev, Chernova,* 1994; *Reshetnikov,* 2002; *Karamushko,* 2007, 2009;
2.5 B — number of species nesting on the coasts of particular seas summarized by *M.V. Gavrilo* using the data of different authors

The strategy of Arctic biodiversity conservation should take into account floral diversity and floral regionalization. Currently, B.A. Yurtsev's et al. [1978] scheme of regionalization is viewed as the most developed one. The data on the distribution of plant species, including endemics and edificators (environmentally transforming species, «ecosystem engineers») made it possible to recognize the Arctic Floral Area as an entity. By applying the universal criterion of relationships between plant species and summer temperatures, the authors defined the longitudinal sectors of the Arctic on the unified basis (Map 2.6). In Yurtsev's scheme, floral and geobotanical approaches are synthesized [but see a critique for such approach by Yu. I. Chernov, 1984]; thanks to this, the regionalization scheme can be applied to the Arctic maritime marsh zone.

The coastal zone is the area where the land and sea meet and interact. The middle part of this zone, i.e. the surf and the tidal zone, is alternately covered by water and then exposed to the air. Large accumulative formations, i.e. bars and spits, create shoreward barriers against which fine suspended material sediments are deposited thereby creating mudflats. These mudflats transform into salt marshes structured by complex systems of tidal stream beds and inhabited by specific plant communities.

Plant species associated with the coastal marshes and growing on salty maritime soils constitute the littoral-halophytic floral assemblage. An important characteristic of the floral assemblages of Arctic salt marshes is the lack of latitudinal pattern in their distribution (azonality): plant species occurring on the Arctic shores to a greater extent respond to the absence or presence of specific environmental conditions rather than to summer temperatures [Sergienko, 2008]. Only small numbers of circumpolar species occur on marshes throughout the entire Arctic. These are mostly grasses and sedges which rapidly build up a dense turf, i.e. creeping alkali grass (*Puccinellia phryganodes*), Ramensk's sedge (*Carex ramenskii*), Hoppner's sedge (*Carex subspathacea*), slender spike-rush (*Eleocharis uniglumis*), and dicotyledons producing rapidly growing sprouts or with pillow-like modes of the growth, i.e. Pacific silverweed (*Potentilla egedii*), salt marsh starwort (*Stellaria humifusa*), sea sandwort (*Honckenya peploides*), oyster plant (*Mertensia maritima*) [Shamsutdinov et al., 2000; Elven, 2007; Sergienko, 2008].

Taxonomic composition of the marsh flora differs between the sectors of the Russian Arctic and the provinces of the Arctic Floral Area. The formation of the core of the halophilic flora is the result of specific phases in the Holocene development of the Arctic coastline. Given that the sectoral division of Arctic Floral Area presented in Map 2.6 also takes into account the temperature regime, it would not be surprising to observe that warmer sectors, i.e. the near-Atlantic and the near-Pacific provinces, are richer in maritime plant species than the cooler sectors. The greatest species number is found in the Kanin-Pechora subprovince of the European–West Siberian Province (52) and in the Southern Chukotka subprovince of the Chukotka Province (57). Gradients of the number of maritime species (Map 2.6) are also conditioned by the varying age of the coastline. Nearly the entire lowland contemporary coastal zone between Novaya Zemlya and Wrangel Island was under ice during the last ice age. The differentiation of the Arctic flora in general and the maritime flora in particular took place mostly in the Beringian and the Barents sectors, and finally resulted in their greater species' richness.

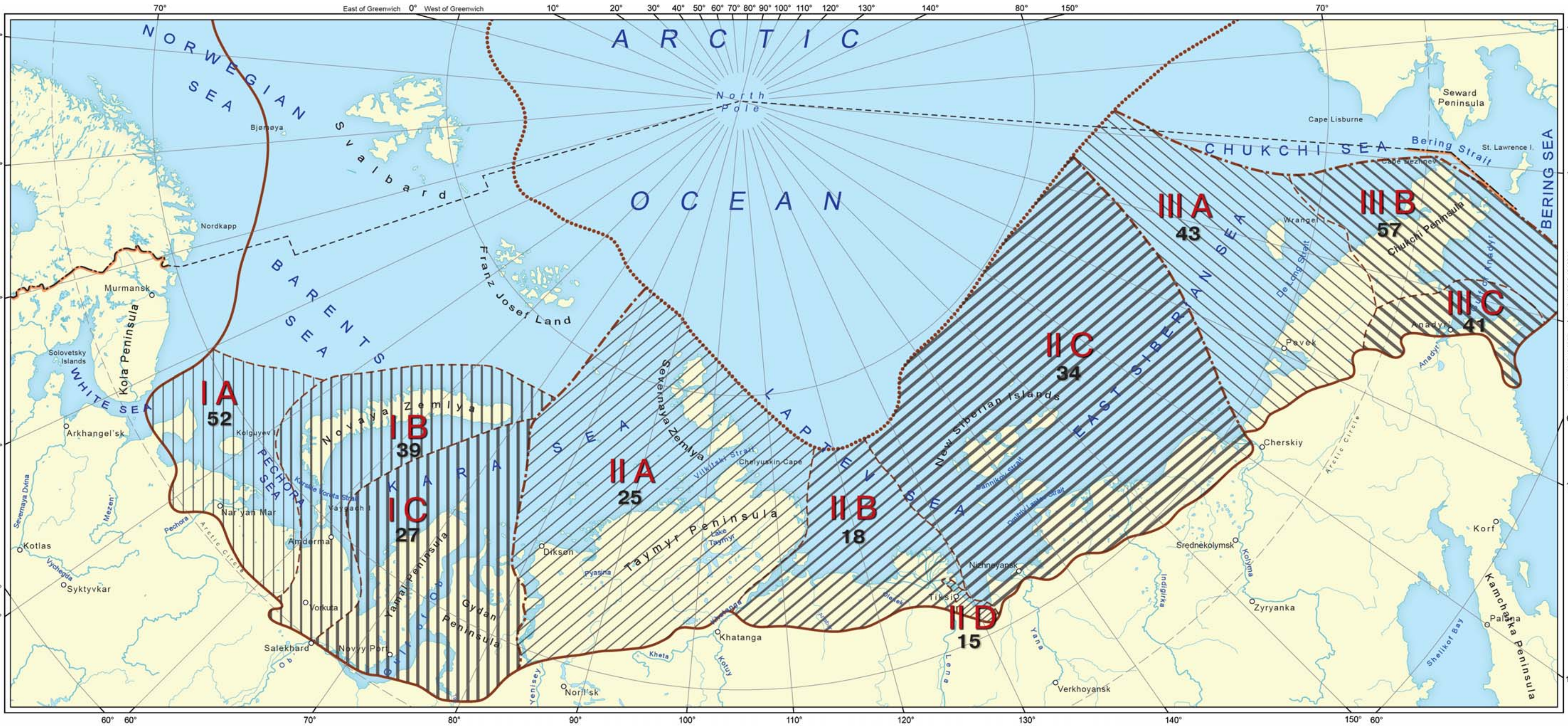
Pojarkova's wort (*Salicornia pojarkovae*) [17]

In the strict sense, the White Sea and the Kola coast of the Barents Sea ado not belong to the Arctic Floral Area. According to a widely accepted geobotanical regionalization scheme [Lavrenko, Isachenko, 1976], the Kola coast of the Barents Sea belongs to the Circumpolar Tundra Area (East-European subprovince of the European-West Siberian Tundra Province), while the White Sea coast is part of the Eurasian Taiga Area (Kola-Pechora and Valday-Onega subprovinces of the North European Taiga Provinces). The marsh flora of the White Sea coast includes about 70 species of vascular plants. The main species forming plant communities are turf-producing sedges (*Carex* spp.) and alkali grasses (*Puccinellia* spp.). A specific feature in the formation of maritime plant communities on the White Sea coast is the pioneer role played by the succession of vegetation present on the salt marshes and which belong to the Atlantic European species sea aster (*Tripolium vulgare*), sea plantain (*Plantago maritima*), seaside arrowgrass (*Triglochin maritimum*). European species such as *Atriplex lapponica*, subpolar plantain (*Plantago subpolaris*), alkali grass (*Puccinellia capillaries*), and Pojarkova's wort (*Salicornia pojarkovae*) dominate on the muddy tidal flats of the Pomorskiy, Onezhskiy, Zimniy, and Abramovskiy coasts of the White Sea and on the southern shores of the Kanin Peninsula. Arctic Atlantic species Puccinellia coarctata dominate on primary marshes in the Gorlo of the White Sea.

Mudflats of the Severnaya Dvina delta area are particularly rich in species. This can be explained by the significant freshening of the water (salinity less than 14 ppt), thus most of the species are associated with mid- and low-saline soils. Some of them (*Carex recta, C. paleacea, C. salina, Spergularia marina, Bolbochoenus maritimus, Blysmus rufus*) are found on the north-eastern frontier of the distributional range.

On the high rocky shores of the Kola Coast of the Barents Sea, muddy tidal flats occur only in the mouths of small rivers. Here Arctic circumpolar species dominate: in particular Hoppner's sedge, creeping alkali grass, marsh cinquefoil, and salt marsh starwort.

Maritime meadow on the coast of the Barents Sea [18]



Provinces and subprovinces

I — European-West Siberian

- I A — Kanin-Pechora
- I B — Ural-Novaya Zemlya
- I C — Yamal-Gydan

II — East Siberian

- II A — Taymyr
- II B — Anabar-Olenek
- II C — Yana-Kolyma
- II D — Kharaulakh

III — Chukotka

- III A — Continental Chukotka
- III B — Bering Sea-Chukotka
- III C — Southern Chukotka

Boundaries

- Abyssal depths of the Arctic Basin
- Arctic Floral Area
- Provinces
- Subprovinces

34 — Number of maritime marsh species (both obligatory and facultative) in different subprovinces of the Arctic Floral Area

- State border of the Russian Federation
- Boundary of the polar domains of the Russian Federation

Scale 1 : 16,000,000

Compiled by *L.A. Sergienko* and *M.A. Shroeders*

Section 3

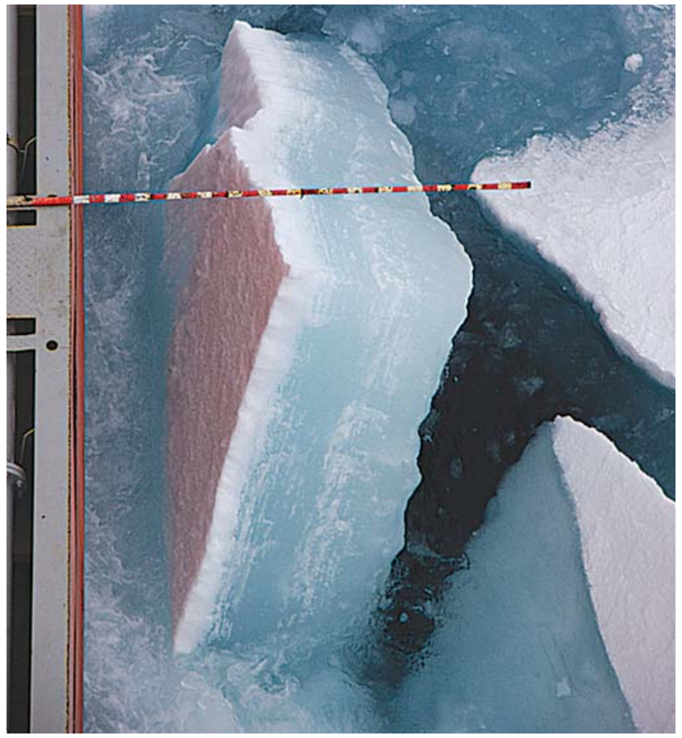
HABITATS AND BIODIVERSITY OF PRINCIPAL BOUNDARY ZONES

3.1. SEA ICE HABITATS AND ASSOCIATED ECOSYSTEM *M.V. Gavrilo* and *V.A. Spiridonov*

In the winter (November to April or even May) most of the Arctic seas (White, Kara, Laptev, East Siberian, Chukchi) and the Arctic Basin are covered by dense ice (Maps 3.1). Immovable fast ice forms on coastal shallows; seaward of the fast ice edge; ice floes are in constant motion due to currents and winds. The prevailing direction of sea ice drift – determined by the Trans-Arctic Current from the Bering Strait to the North Atlantic, was first observed by Fridjof Nansen and inspired him to reach the North Pole on a vessel frozen into the drifting ice.

In the other Arctic and Subarctic seas ice cover is less developed. The southern and the western Barents Sea are influenced by warm currents from the Atlantic, with the result being about one third of the sea area remains ice-free. The summer season in the Russian Arctic seas lasts from about July to September. During this period the ice cover melts and diminishes in both extent and thickness. While in summer most of the Barents Sea, the White Sea and the Bering Sea are ice free, other seas of the Russian Arctic retain some ice cover. The Arctic Basin remains generally ice-covered all year round; this is how multi-year ice is created. Sea ice coverage in the seas of the Siberian shelf varies greatly, the multi-year variation of ice concentration in the Kara, the Laptev and the East Siberian Sea exceeds 80%.

Usual thickness of sea ice at present (40 cm) [19]



Following the current climate trends the sea ice cover of the Arctic seas has been gradually decreasing in the 20th and early 21st centuries. Along with this trend, quasi-cyclic variation (periods of about 60, 10 and 20 years) are observed [Frolov et al., 2007; 2009]. In the Barents and the Kara seas the long-term cycles of approximately 60 years period dominate. In the Laptev, East Siberian and the Chukchi Seas ice coverage shows a greater variation, and 60-year cycles are less frequently experienced there. In recent decades when the Arctic entered the warm period the decrease of sea ice coverage became particularly pronounced (Fig. 3.1.1). Between 1998 and 2008, the area of sea ice in September (which is the month of the annual sea ice minimum extent) in the entire Arctic decreased by 36%, while in the Siberian seas along the Northern Sea Route a decrease of 87% was observed [Alekseev et al., 2009]. As a result, the summer ice edge tends to move further north from the coast. That said, some coastal areas do retain ice massifs in the summer. Thus, in spite of the considerable ice retreat in 2007, the Vilkitsky Strait remained covered by drifting ice of the Taymyr ice massif in the summer.

While the summer sea ice coverage rapidly decreases, in winter the decrease is much less pronounced (Map 3.1). However, the composition of sea ice is changing: there is less multi-year ice, while the share of thin one-year ice is increasing (Maps 3.1 A,C; Fig. 3.1.2). According to measurements made on board R.V. «Akademik Fedorov» and nuclear ice breakers between 1977 and 2005, mean thickness of the ice in August decreased by 40 cm (23%), while the same decrease was observed between 1987 and 2006 in the month of May. The cause of the decrease was a diminishing share of perennial ice [Frolov et al., 2009]. According to the forecast of AARI, which takes into account climatic cycles and actual trends, in the 21st century we can expect this oscillating (rather than linear) pattern of sea ice cover in the Arctic seas [Frolov et al., 2009] to continue. However, other forecasts indicate that a trend of decreasing sea ice will in general dominate in the 21st century [Evaluation.., 2008; Katzov et al., 2008]

Juvenile polar cod under sea ice [20]

In the polar seas, the following sea ice biotopes can be observed [Kupetsky, 1961]: oceanic pack ice massifs; drifting sea ice and ice massifs of marginal seas; fast ice; flaw polynyas and leads, a system of leads above the continental slope. The ice edge zone can be added to this classification. In some areas of the Russian Arctic seas, large ice massifs form and may persist throughout the year. The Taymyr, the Ayon and the Wrangel massifs are the most important obstacles to ship traffic along the Northern Sea Route [Problems of Northern Sea Route, 2006]. Generally, the water column in the areas of permanently or long-term ice coverage is not productive, thus the key factor of biological productivity in the ice seas is the biota living in the ice itself.

Specific sea ice microflora consists of bacteria, flagellates and sea ice diatoms producing organic matter (see 2.3); micro- and meiofauna includes mostly representatives of ciliates, foraminipherans, harpacticoids [Melnikov, 1989]; and nematodes (which dominate in biomass) [Tschesunov, 2006]. Most of the animals feed on bacteria, ice algae, other protists and fungi; while some nematode species are predators at the top of the food chain in the highly specific sea ice ecosystem. This food chain is further complicated by sea ice-associated (sympagic) amphipods and other crustaceans living at the ice/water interface and which obtain their food from ice biota and their predators. The polar cod (*Boreogadus saida*) is the most important link to seabirds and marine mammals [Klumov, 1937].

Under stable climate conditions, multi-year sea ice represents a persistent ecological system with a stable species composition [Melnikov, 1989]. By contrast, seasonal ice is a dependent, temporally unstable ecosystem which lifecycle is determined by a number of environmental factors, temperature being the most significant [Melnikov, 2008]. The decrease in multi-year sea ice coverage may influence the diversity and distribution patterns of specific sea ice biota, which still have to be documented in much greater detail than are currently known. The adaptation potential of sea ice biota to climate changes remains unknown. However, observations of sea ice-specific forms of marine nematodes indicate that in the seasonally ice-covered White Sea these species survive the ice-free seasons thanks to some as yet unknown mechanism [Tschesunov, 2006]. Thus, the White Sea, with its marine scientific bases acts as an important research area where the various adaptations of the sea ice biota to changing climate can be studied and understood. Other priority areas from a research and especially a conservation standpoint, are the ice massifs such as Taymyr massif, where the multi-year sea ice ecosystem will in all likelihood survive in the future, even though the current general trend towards declining multi-year sea ice is continuing.

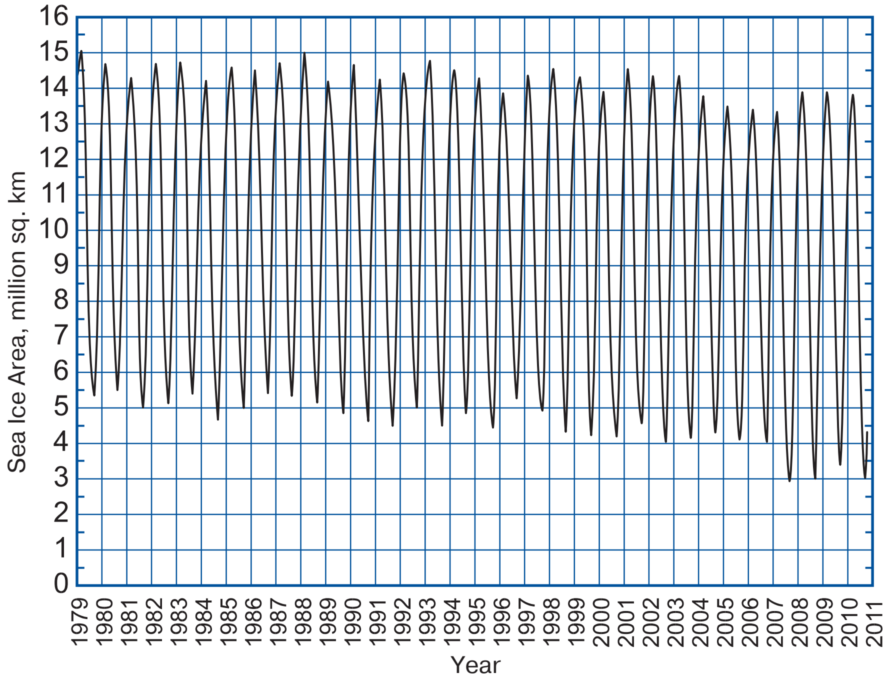
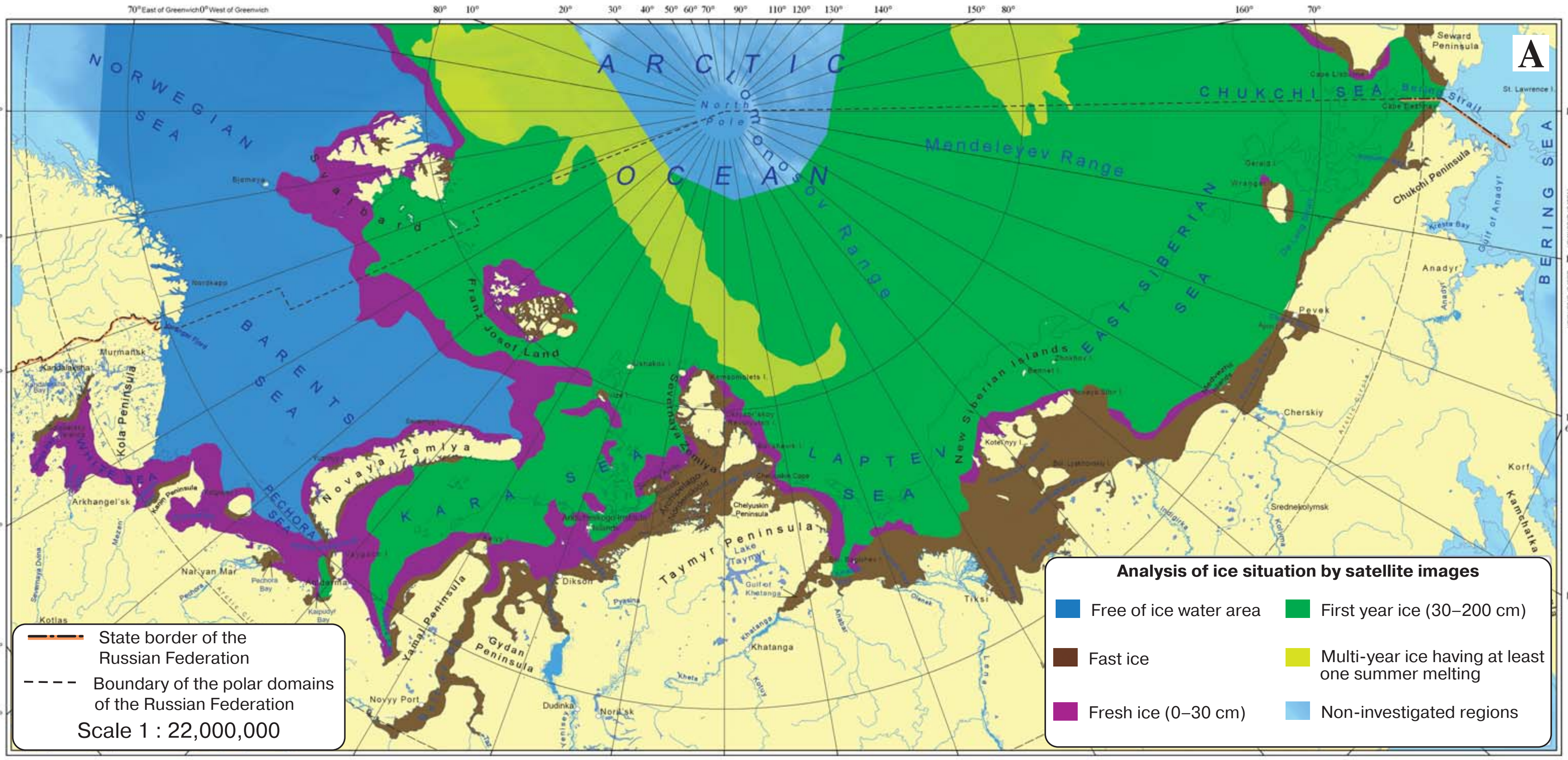
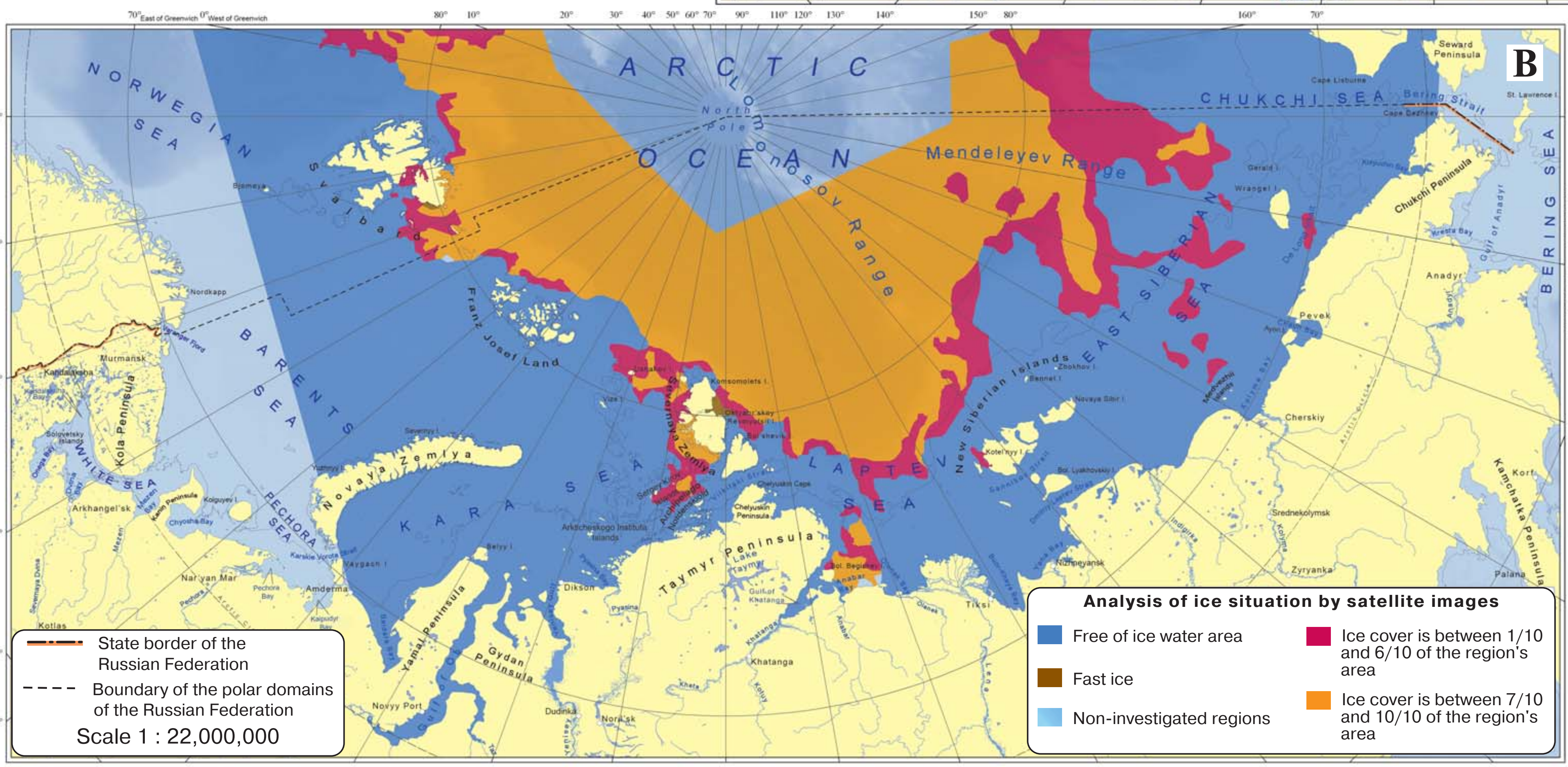


Fig. 3.1.1. Northern Hemisphere Sea Ice Area (data provided by the National Snow and Ice Data Centre — NSIDC: NASA SMMR and SSMI). Source: http://arctic.atmos.uiuc.edu/cryosphere/





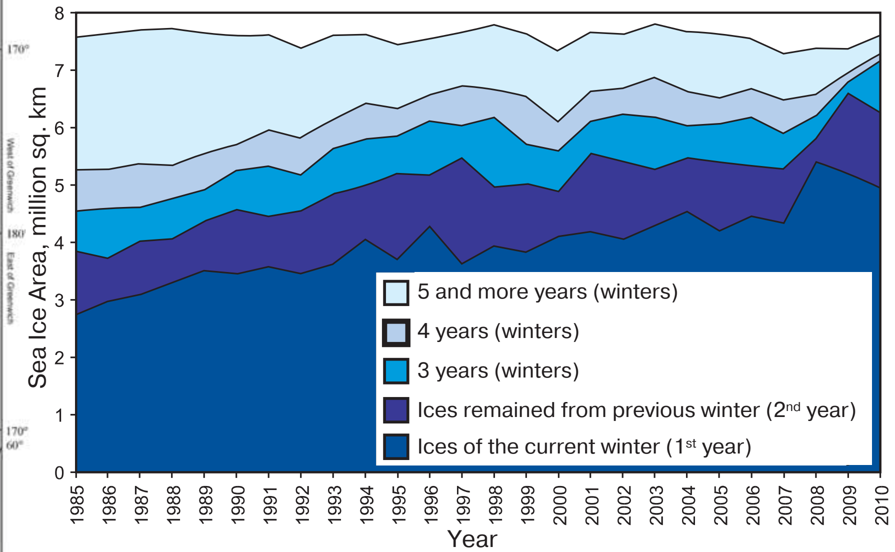


Fig. 3.1.2. Ice Age Distribution in the Northern Hemisphere in March (Week 11) between 1985 and 2010.

Source: http://climateprogress.org/2010/09/14/exclusive-scientists-track-sharp-drop-in-oldest-thickestarctic-sea-ice

Source: Arctic and Antarctic Research Institute (AARI) (see. http://www.aari.ru for archive and current information).

Polynyas are the characteristic feature of the Arctic seascape. These extensive areas of open water, with new unstable ice up to 30 cm thick are regularly formed in the winter season between shore fast ice and close pack ice. Some authors [i.e. Zakharov, 1966, 1996] also include in their definition of polynyas areas covered by young sea ice up to a thickness of 50–70 cm. In the current study the maximum ice thickness in polynyas is fixed at less than 30 cm. Some polynyas extend to hundreds of kilometres with a width often ranging from a dozen to many hundred kilometres. In some areas they are open for a short time and do not spread significantly. In other areas the probability of their occurrence is very high. Their lifetime is typically several months, while their surface area can be as large as about 105 km². The stability of polynyas is traditionally assessed using monthly average frequency of occurrence: those with a frequency of 75% and above are called stationary polynyas, those with a frequency of 50–74% are stable polynyas, and those which frequency is less than 50% are episodic ones.

Flaw polynyas are a remarkable natural phenomenon. Opening up the water surface among the polar sea ice under severe frost is a unique process in itself. The polynya is formed as a result of specific atmospheric processes, in particular regular winds pushing drifting ice offshore. Other factors besides the wind, either upwelling of the warm Atlantic waters or convective heat transfer in the polynyas, likely are not of principal importance in the process of flaw polynyas development.

From the moment of its formation until its complete closure, a polynya has a very strong impact on the surrounding atmosphere and the ocean. This impact may be observed over various time scales, from several days to years. It is safe to say that the polynya is both a cause and a consequence of complex interactions between the atmosphere and the ocean in particular coastal areas.

The passage of winds over the sea surface leading to the development of polynyas also results in intensive heat transfer from the ocean to the atmosphere. As a result, a large volume of new ice is produced and transported to the lee side of the polynya. At the same time, polynyas also facilitate processes including increase of the salinity of surface water and the development of convection. Polynyas play a key role in the formation and melting of sea ice: in the cold season they build up a zone of active ice production. V.F. Zakharov called polynyas «ice factories», highlighting the fact that up to 70% of the total volume of sea ice developing in the Arctic seas may be produced in polynyas. In the spring and the summer, polynyas accumulate heat and become centres of seasonal sea ice decay [Zakharov, 1966, 1996].

Recurring (and quasi-recurring) polynyas are of particular value for ecosystem processes and for maintaining biological diversity in the Arctic [Kupetsky, 1958, 1959; Brown, Nettleship, 1981]. Because of their biological importance polynyas are also considered life oases in the ice-covered seas. The unusually early and long (for the Arctic) vegetation season in polynyas contributes to increased biological productivity, positively impacts seasonal development of most abundant zooplankton species, and supports sustainable top predator populations (fish, seabirds and marine mammals) [Deming et al., 2002; Ringuette et al., 2002]. Benthic communities in the areas of flaw polynyas are also characterized by increased biomass and species diversity [Antipova, Semenov, 1989; Sirenko et al., 1995; Gukov, 1999; Petryashov et al., 2004] because of the enrichment of the near bottom layers and sediments with organic matter. It is not surprising that the largest seabird colonies in the high Arctic are associated with polynyas (see 3.3; 3.4–3.6), and that walruses, beluga whales and bowhead whales often spend winter in or near them. Seabirds migrate to their breeding grounds along polynyas at a time when the surrounding sea is covered with dense ice.

Small polynya in the Barents Sea [21]

Monuments left by ancient whalers of Chukotka who used polynyas resources [22]

Polynyas play a particularly important role in the recruitment of polar cod (Boreogadus saida), which is a key food item for most of the top predators in the high Arctic ecosystems. If polynyas open up early, polar cod could start spawning as early as January. Open water provides the first-feeding larvae with the minimum light necessary to detect and capture plankton prey and thereby obtain better nutrition. Thus they grow to larger pre-winter sizes and provide protection against predators. On the whole, years with well-developed polynyas tend to be characterized by the highest levels of polar cod recruitment [Bouchard, Fortier, 2008].

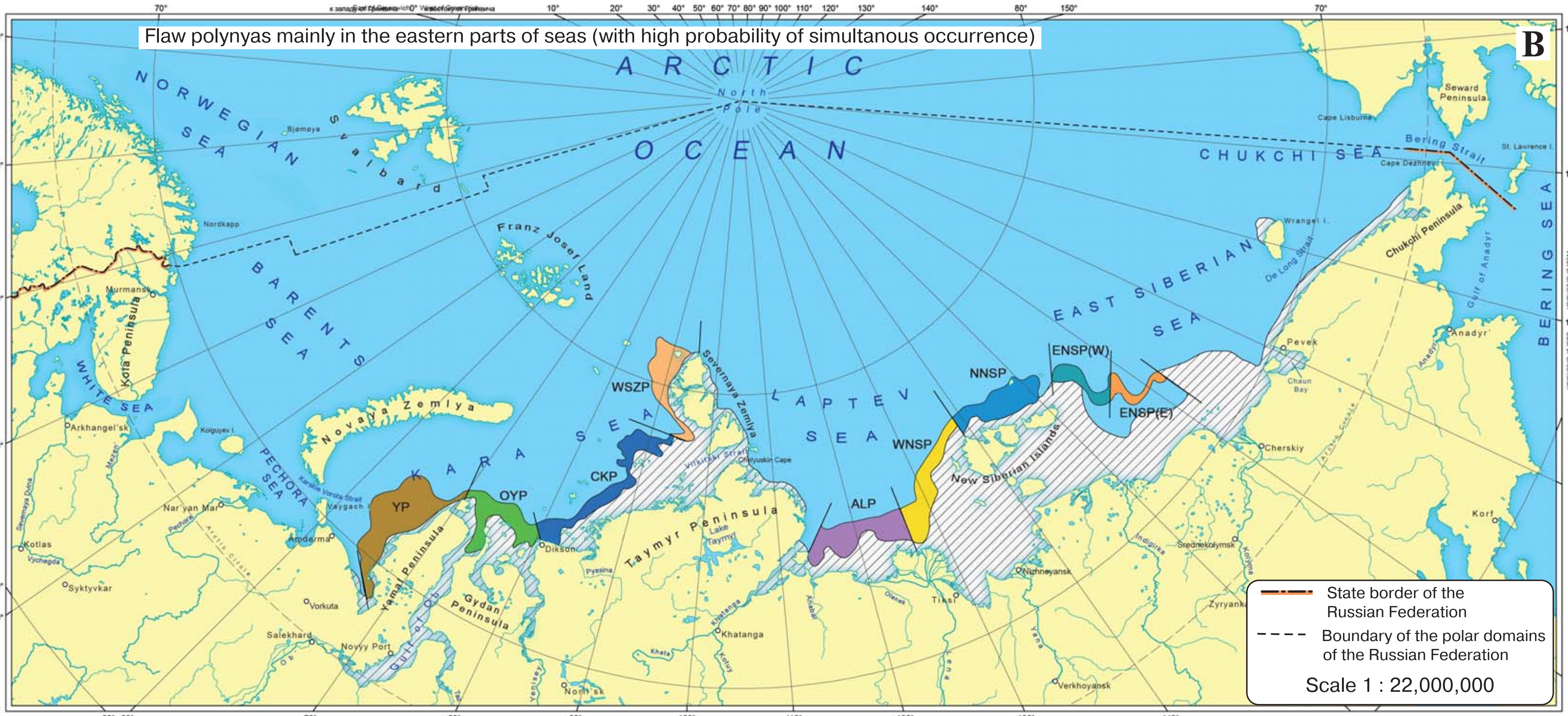
For millennia, indigenous Arctic peoples, and more recently the first polar explorers, have observed and made use of the two principal characteristics of recurring polynyas: the presence of open water in winter and the abundance of seabirds and marine mammals. The location of ancient and contemporary settlements of indigenous people and the routes used for early exploratory expeditions closely match the distribution of polynyas. The full complement of characteristics of recurring polynyas makes them an Arctic archetype. This reinforces their role in the early evolution of the Arctic geo- and ecosystems.

Polynyas of the Siberian shelf

Between the 1930s and the 1970s data on polynyas came mostly from aerial ice reconnaissance. The shortcomings of these data included incomplete coverage of polynya areas and overly long intervals between observations. Relatively reliable information only became available with the onset of the satellite era when images could be obtained every few days throughout the entire cold period. The principal dataset used for polynyas characterization is based on the satellite data of 1978–2008. According to their location flaw polynyas showed at Map 3.2 bear names which are conventionally [Zakharov, 1996] abbreviated.

Polynyas

- **SFJLP** — Southern Franz Josef Land
- **NNZP** — Northern Novozemelskaya
- **SNZP** — Southern Novozemelskaya
- **AP** — Amderminskaya
- **ESZP** — Eastern Severozemelskaya
- **NETP** — Northeastern Taymyrskaya
- **ETP** — Eastern Taymyrskaya
- **AYP** — Ayonskaya
- **NWP** — Northern Wrangelevskaya
- **WCP** — Western Chukotskaya
- **ECP** — Eastern Chukotskaya
- Fast ice
- Polynyas boundaries



These maps show maximum development of polynyas. In nature all polynyas never reach maximum development simultaneously.

Polynyas

- **YP** — Yamalskaya
- **OYP** — Ob'-Yeniseiskaya
- **CKP** — Central Karskaya
- **WSZP** — Western Severozemelskaya
- **ALP** — Anabar-Lenskaya
- **WNSP** — Western Novosibirskaya
- **NNSP** — Northern Novosibirskaya
- **ENSP(W)** — Eastern Novosibirskaya (west)
- **ENSP(E)** — Eastern Novosibirskaya (east)
- Fast ice
- Polynyas boundaries

Compiled by *A.V. Popov*

Sea birds are an important link between marine and coastal ecosystems, especially in the Arctic. Distribution of their colonies is influenced by favourable combinations of biotope characteristics, the degree of protection from predators and available food resources. The latter is the most important factor. Although the characteristics of coastal biotopes are not a determining factor of the distribution of seabird colonies, they may play a limiting role. Most Arctic colonial seabirds nest on coastal rocky outcrops; this offers them protection from predators, such as polar foxes (*Alopex lagopus*). Along the Russian Arctic coastline (from Cape Kanin Nos to the western Chukotka) most of the rocky biotopes that offer appropriate nesting habitats for obligate colonial species are located on the islands, while the plain continental coasts tend to be used by facultative colonial and non-colonial sea birds and waders.

A section of seabird bazaar (rookery), the Barents Sea [23]

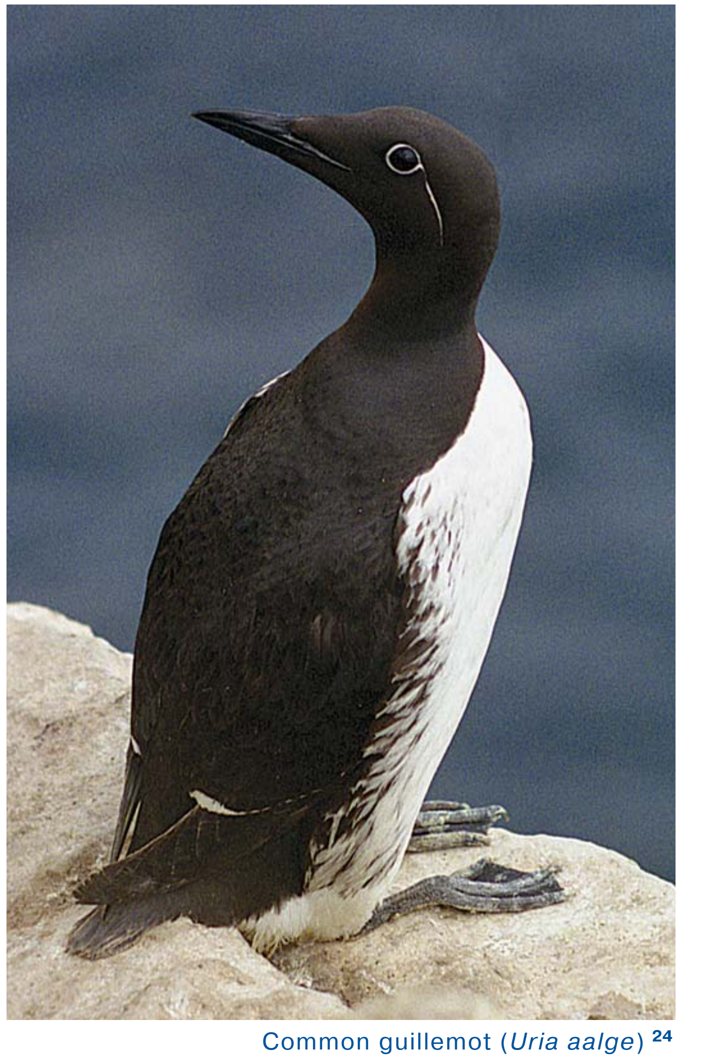
It is currently generally accepted that seabird colonies (Map 3.3) are associated with marine areas of high biological productivity while their specific distribution is determined by regional oceanographic patterns. The location of foraging areas is also influenced by hydrological factors and seabed topography. Hotspots of high biological productivity correspond to various frontal zones and are supported by intensified vertical water circulation, which transfers nutrient supplies from deep waters to the surface layers. The Polar Front zone is most significant in the Arctic seas; it is formed at the central Barents Sea where the Atlantic and the Arctic waters meet. Due to its high biological productivity and concentrating effect on zooplankton and fishes, it also provides favourable feeding conditions for sea birds during the nonbreeding period. The position of the Polar Front fluctuates seasonally and inter-annually, with the greatest variation taking place in the eastern Barents Sea near Novaya Zemlya. In the west, the topography of the seabed adjacent to Spitsbergen (Svalbard) and Medvezhii (Bear) Island contributes towards stabilizing the Polar Front. The frontal zone, created at the area of contact between the Arctic and the Pacific waters, is less pronounced. Another zone associated with intensified vertical circulation is located along the continental shelf break. Frontal zones which form at the boundaries where river discharge spreads out into the sea (common from the eastern Barents Sea to the East-Siberian seas) are less important for seabirds. Seabirds associated with pelagic ecosystems generally avoid the areas of river discharge per

Sea ice plays a special role in the life of the Arctic marine biota, and, in particular of seabirds. Among the sea ice biotopes identified by Kupetsky [1961], (see 3.1) ice massifs and fast ice prevent seabirds from accessing food, which is typically obtained from open water habitats. The marginal ice zone, which includes polynyas, other areas of low ice concentration, leads, and the zone of the drifting ice edge per se generally provide favourable conditions for primary producers (ice algae and phytoplankton), zooplankton, sympagic animals such as amphipods and planktivorous fish, foremost polar cod (*Boreogadus saida*). All the above areas are also known for their high concentration of seabirds [Mehlum, 1997; Decker et al., 1998; Krasnov et al., 2007]. The degree of association of seabirds with sea ice biotopes depends on situations in cryopelagic communities; most probably the abundance of particular species is higher in the marginal zone of the multi-year ice. The ivory gull (*Pagophila eburnea*), the species most closely associated with sea ice, is listed in the Red Data Book of the Russian Federation and the IUCN Red List. Its distribution range does not extend beyond ice-filled waters throughout the entire annual cycle.

In general, all large colonies of seabirds as well as spring migration routes and staging areas in the northern Barents Sea and the seas of the Siberian shelf are located close to flaw polynya systems [Kupetsky, 1959] (see 3.5 to 3.7. for details).

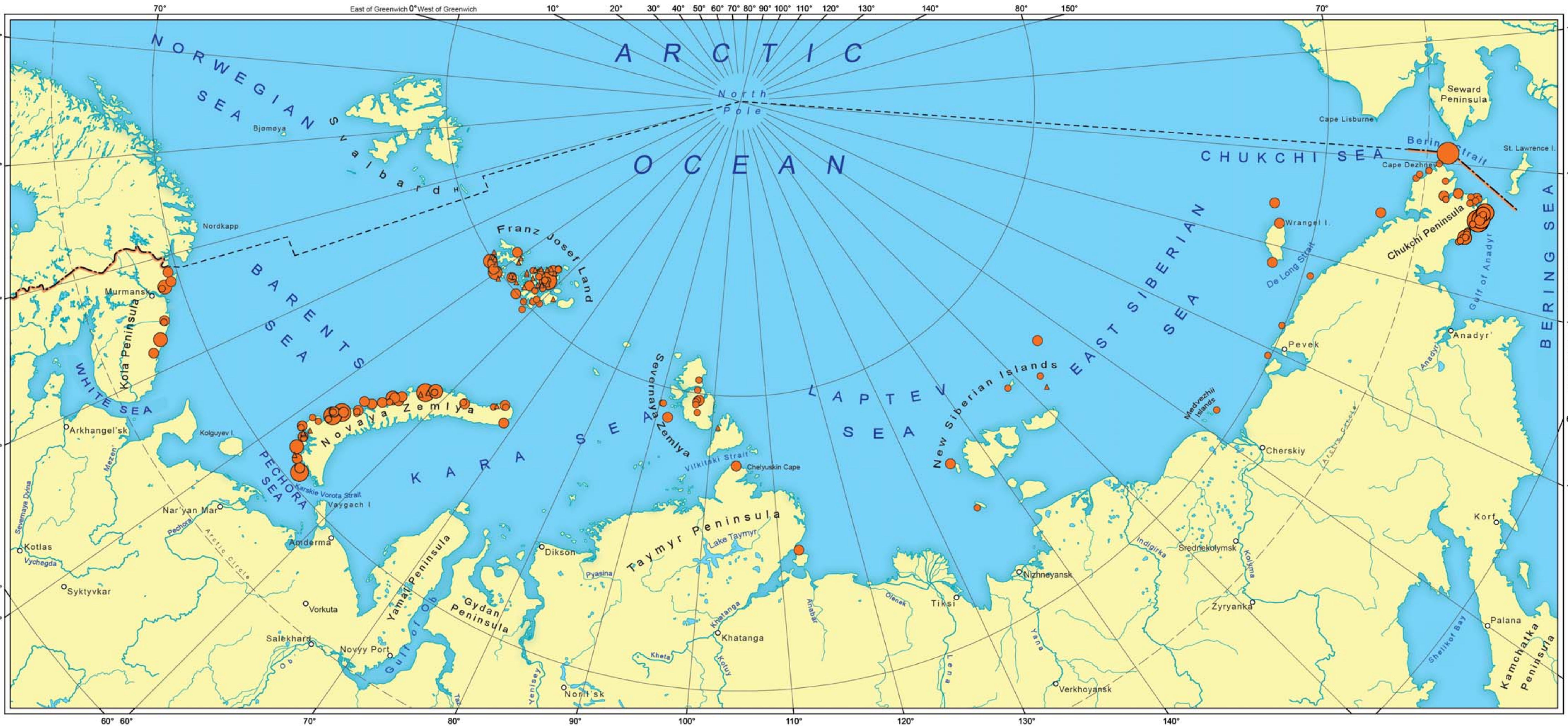
During the breeding period, the most important sites for sea birds nesting on the coast are marine areas within foraging areas of breeding colonies. To provide chicks with necessary feed even the «most pelagic» bird species need to find sufficient resources at a distance of less than 100 km from nesting grounds. During the non-breeding period the distribution of many species also corresponds to zones of increased biological production but is not limited at this time by the proximity of land.

In general, seabirds are found throughout the Arctic Ocean, but the largest colonies are restricted to the Barents and the Bering seas sectors, while the Siberian region (where pelagic ecosystems are generally less productive) has qualitatively and quantitatively impoverished seabird populations (Map 3.3). Looking at species composition, the seabird colonies of the Russian Arctic can be divided into three principal types [Uspensky, 1959]: Arctic, Atlantic-Boreal, and Pacific-Boreal. Arctic-type colonies are dominated by Bruennich's guillemot (*Uria lomvia*) and kittiwake (*Rissa tridactyla*) and distinguished by the presence of glaucous gull (*Larus hyperboreus*). This type of colonies is common in the northern and eastern Barents Sea islands (Franz Josef Land, Novaya Zemlya) and in most seas of the Siberian shelf. In the more severe conditions such as those found in the Kara Sea and the north-western Laptev Sea, there are no Bruehnich guillemots and a high-Arctic species, the little auk (*Alle alle*), typically dominates. The colonies of the southern Barents Sea



Common guillemot (*Uria aalge*) [24]

are rich in Atlantic-Boreal species: great cormorant (*Phalacrocorax carbo*), European shag (*P. aristotelis*), puffin (*Fratercula arctica*) and razorbill (*Alca torda*). Here, the dominant species is the common guillemot (*Uria aalge*), which outnumbers the Bruenich guillemot. The sea bird communities of the western Chukotka and Wrangel Island are of transient type, here some seabird species that are more commonly found in the north Pacific nest: the pelagic cormorant (*Phalacrocorax pelagicus*), horned puffin (*Fratercula corniculata*) and tufted puffin (*Lunda cirrhata*). However they are not numerous, and the colonies are still dominated by the Bruehnich guillemots and the kittiwakes. The Pacific- Boreal type colonies (with considerable contribution of the North Pacific species) are common on the Arctic coast of the Eastern Chukotka and the Bering Sea coast. There the major role of Bruehnich guillemots and kittiwakes remains unchanged, but the share of Pacific species increases (Map 3.7) while in the Bering Sea the dominance shifts to auklets (*Aethia* spp.).



Numbers in colonies (pairs)

- More than 200,000
- 100 000 – 200 000
- 50 000 – 100 000
- 10 000 – 50 000
- 1000– 10 000
- Unknown number

State border of the Russian Federation

Boundary of the polar domains of the Russian Federation

Scale 1 : 16,000,000

Compiled by *M.V. Gavrilo*
Sources: *Gavrilo* [1998], *Konyukov et al.* [1998], *Bakken* [2000]

About one-third of the Barents Sea does not freeze in winter because of the warming impact of the North Atlantic Current. Seasonal ice cover in the northern and the eastern Barents Sea usually builds up from September onwards. Multi-year variability of the sea-ice area follows the variability of hydrometeorological features; maximum sea-ice extent can vary over several hundreds of kilometres from year to year. In the 20th century, the ice-covered area of the sea in April (the month with maximum ice cover development) ranged between 25 and 92% [Zubakin et al., 2007].

The north-eastern Barents Sea has the most severe ice conditions; these are described in subsection 3.5 along with details of the sea-ice conditions in the Kara Sea. In this chapter we will confine our review to the sea-ice biotopes of the southern and the eastern Barents Sea, the three homogenous sea ice regions: the Kola, the Pechora and the Novaya Zemlya regions [Mironov, 1996]. Sea ice coverage in these regions, especially in the Pechora region, plays a significant role in maintaining the Arctic appearance of the Barents Sea ecosystems. Land-fast sea ice in the Barents Sea is generally weakly developed, similarly, there are few flaw polynyas; narrow leads and young-ice zones are characteristic of the south-eastern Barents Sea (Pechora Sea) and the west coast of Novaya Zemlya. The marginal ice zone is the most important from the biological standpoint (Map 3.4 A). This zone often coincides with oceanographical fronts where physical and biological mechanisms support high primary production [Romankevich, Vetrov, 2001; Stiansen et al., 2009] and the downward flux of phyto-detritus [Denisenko, Titov, 2003]. In these areas increased biomass of zooplankton, including euphausiids (krill), is often observed resulting in high concentrations of immediate predators, primarily polar cod (Boreogadus saida) [Borkin, 1995], as well as in organisms of higher trophic levels, i.e. piscivorous fishes, sea birds and marine mammals. Benthic life in the marginal ice zone is also rich. The area of high benthic biomass coincides with the area with a 20% sea-ice concentration along the «Spitsbergen (Svalbard) — Medvezhii (Bear) Island — Novaya Zemlya — south-eastern Barents Sea» line [Denisenko, Titov, 2003; Denisenko, 2008].

Bruennich's guillemots (*Uria lomvia*), black guillemots (Cepphus grille), and little auk (*Alle alle*) can be found in winter in the marginal ice zone in the central Barents Sea. However, detailed information on their abundance and distribution is very scarce [Krasnov et al., 2007]. Some populations of little auk can be found in the marginal ice zone in the eastern Barents Sea [Krasnov et al., 2002] but the bulk of Bruehnich guillemots and kittiwakes (Rissa tridactyla) only migrate there in the latter half of the winter. Sea birds are known to forage in the region during the pre-breeding season and then move slowly to the colonies on the west coast of Novaya Zemlya (3.3). The spring migration of ducks follows the network of polynyas and leads of the Pechora Sea. It starts already in April [Krasnov et al., 2007].

In summer in the Pechora Sea, sea birds can be found in high concentrations in the marginal ice zone (if it is present); once the ice has completely melted they migrate towards the area bounded by the oceanographical fronts at the Novaya Zemlya Trench and the Karskie Vorota Strait [Gavrilo et al., 1998]. After hatching, most young Bruennich's guillemots leave their hatching grounds and migrate to the sea bird bazaars of Novaya Zemlya [Krasnov et al., 2002].

Wintering of eiders off the Kola Peninsula [25]

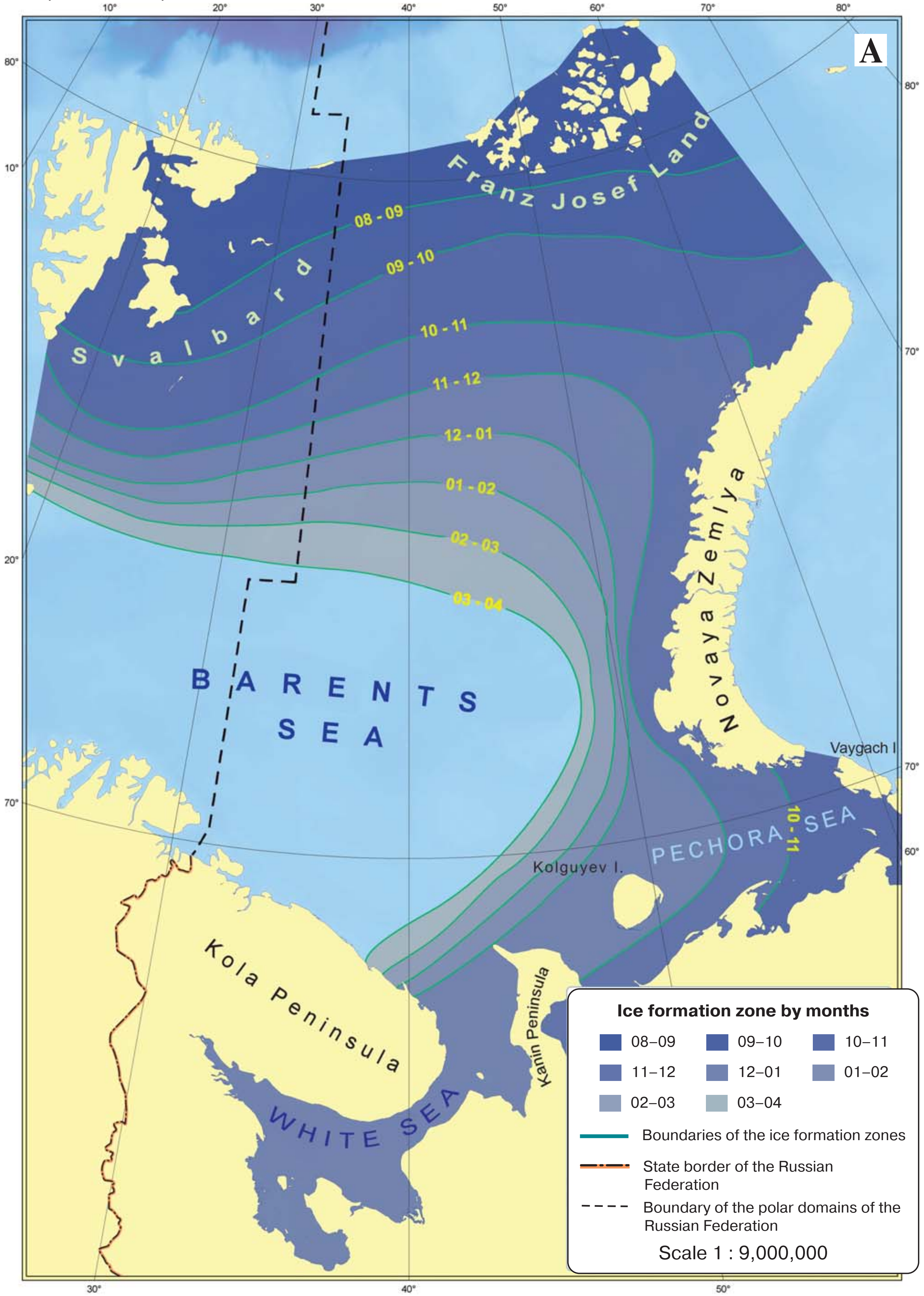
Many thousands of sea duck flocks occur at the Pechora Sea shallows during their moulting and staging in late summer and autumn. This phenomenon could be a result of the extraordinary richness of the available benthos food in the coastal zone, in particular the blue mussel (*Mytilus edulis*) beds [Kucheruk et al., 2003; Sukhotin et al., 2008]. With the onset of the sea-ice season most sea birds migrate to the Kola Peninsula coast and the Norwegian shores of the Barents Sea [Krasnov et al., 2002; Krasnov, 2004]. Ice floes drifting over the shallows of the Pechora Sea and the Kanin-Kolguev area provide a winter biotope for the Pechora population of Atlantic walrus (*Odobenus rosmarus rosmarus*) and pagophylous seals: ringed (*Phoca hispida*) and bearded seals (*Erignathus barbatus*). Walruses feed on the abundant benthic animals, especially bivalves which build up significant biomass [Kucheruk et al., 2003; Denisenko et al., 2003; Gavrilo et al., 2000].

Ice cover of the White Sea is entirely seasonal and the sea-ice regime is very dynamic and variable. Landfast ice builds up in the bays and inlets, however the land-fast ice zone is rarely wide, usually less than 1 km. Given the length and complexity of the coastline the land-fast ice is very uneven. The first stable ice forms in the Mezen' river mouth as early as in October; with the latest freezing period observed in the highly dynamic areas off the Terskiy Coast. The entire sea is usually ice-free again by late May. The open White Sea is a zone of drifting ice which makes up about 90% of the total sea-ice cover. The thickness of the drifting ice usually ranges between 35 and 40 cm; in severe winters it can reach as much as 1.5 m [Zalogin, Kosarev, 1999]. An important feature of the sea-ice regime of the White Sea is the regular export of the ice floes to the Barents Sea. The riverine discharge of Severnaya Dvina and the pattern of mesoscale water circulation combine to create so-called spiral eddies; this is a prerequisite for the formation of large and stable ice floes in the Basin and the Gorlo of the White Sea. These ice habitats attract harp seals which arrive in February and March from the Barents Sea and the adjacent North-East Atlantic to breed and moult [Melentyev, Chernook, 2009].

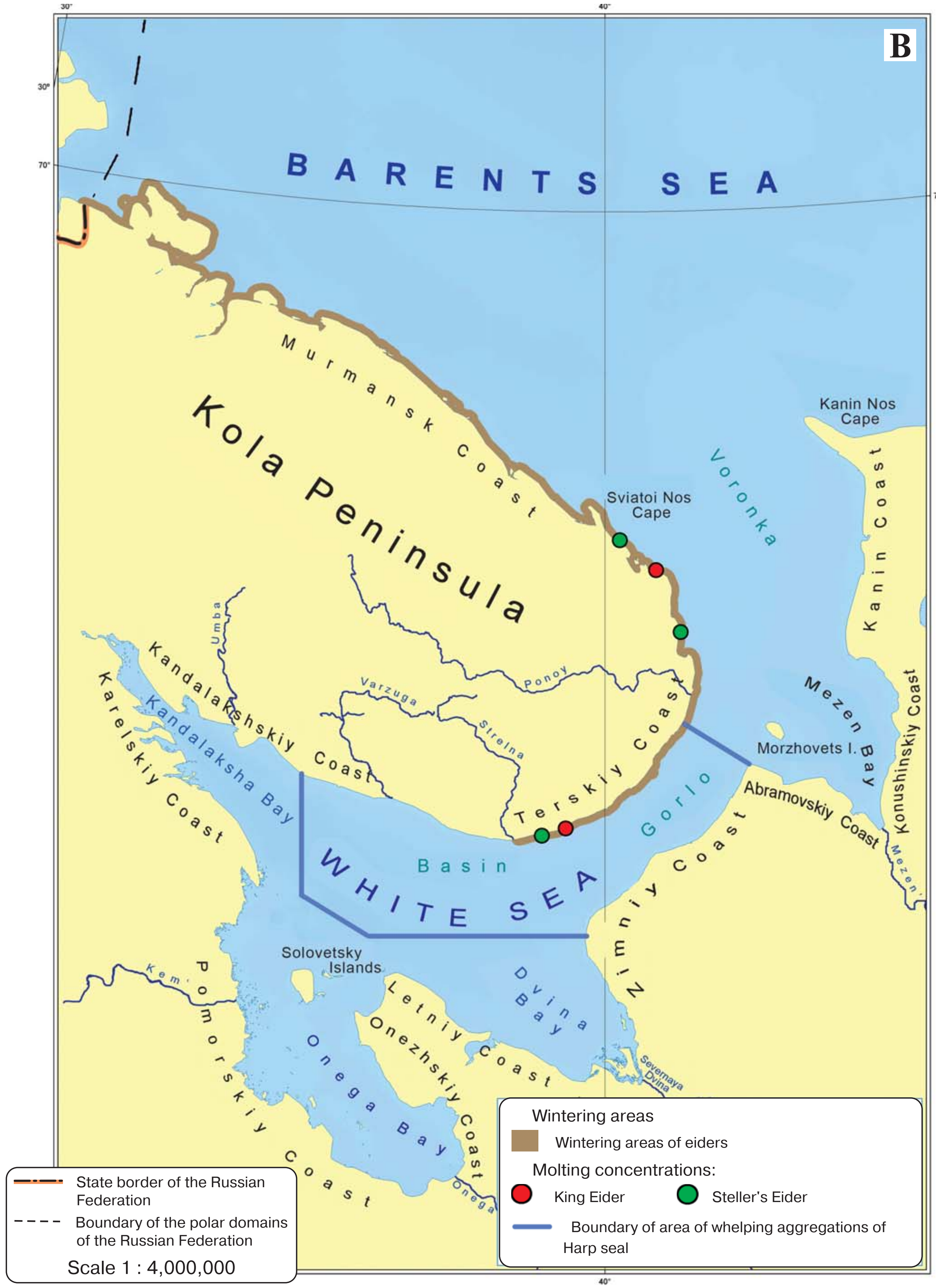
Water circulation and winds create a dynamic system of polynyas. The most stable polynyas are formed off the Terskiy Coast and in the Onega and Dvina Bays (Map 3.4 B). Smaller polynyas are located in the Kandalaksha and the Mezen' bays. Coastal and flaw polynyas form nodes of the White Sea ecosystem. Polynyas along the Terskiy Coast serve as wintering grounds for sea ducks which feed mainly on the blue mussels which develop in dense beds at depths ranging from 2 to 15 m under the influence of strong tidal currents [Gurjanova, 1948; Milyutin, Sokolov, 2006]. In the mostly ice-free shallows stretching from the mouth of Strelna River to Sviatoi Nos Cape, three species of eider spend the winter [Krasnov et al., 2004]. The common eider, which is most characteristic of this area, ranges more or less continuously along the Kola Peninsula coast, while the king eider (*Somateria spectabilis*) and Steller's eider congregate in several spots where their colonies can grow to more than a thousand individuals (Map 3.4 B). The polynyas off the Terskiy coast are the most important wintering ground for the king eider in the entire European North of Russia. This area on the coast of Kola Peninsula is the only one in the Russian Arctic where Steller's eider (a globally endangered species listed in the IUCN Red List) occurs year-round [Krasnov et al., 2004, 2006]. Along with eiders, glaucous gulls and black guillemots also winter; in February they are joined by other seagull species: herring gull (*Larus argentatus*), great black-backed gull (*L. marinus*) and kittiwakes. The distribution pattern of wintering birds in the polynyas of the Terskiy Coast depends on sea-ice conditions and may considerably change from year to year. In periods of heavy ice most of the sea birds migrate to the north-western part of Voronka (the outermost part of the White Sea) and to the Murmansk Coast (Map 3.4 B).

Large aggregations of wintering common eiders are observed annually in the productive coastal shallows of the Onega Bay, which house high benthic biomass [Naumov, 2001], and in the inner part of the Kandalksha Bay. The presence of polynyas in these areas allows year-round maintenance of the endemic White Sea population of common eider [Bianki, 1991]. The distribution and abundance of eiders in particular polynyas vary from year to year depending on the sea conditions [Shkliarevich, 1979]. However, even in the most severe winters most of the local population of eiders do not leave the White Sea. The wintering of sea ducks in the White Sea and off the Kola Peninsula Coast is a unique natural phenomena which is a result of different aspects of ecosystem functioning. This phenomenon requires regular study and special programmes for monitoring and protection.

3.4. A — Sea ice edge in the Barents Sea, multi-year mean position of ice formation zones from September to April



3.4. B — Wintering and molting areas of eiders and the area of whelping aggregations of harp seal off Kolla Peninsula coast and in the White Sea



Sources: **3.4. A** — *Johannessen* et al. [2007]. **3.4. B** — wintering areas of eiders — data by *Yu.V. Krasnov* and *M.V. Gavrilo*; whelping areas — *Mitibaeva* et al. [1991]

In this subsection the uniform ice regions of the north-eastern Barents Sea (the Franz Josef and the Kara regions), known for its severe sea ice regime [Mironov, 1996] are considered along with the Kara Sea. At the northern periphery of these regions and the entire Kara Sea, sea ice usually persists during the entire summer. At the boundary with the Arctic Basin, sea ice formation tends to start as early as late August or early September [Mironov et al., 2008]: the straits of Franz Josef Land freeze first with new ice developing among the ice floes remaining from the previous year in the northern Kara Sea. Because of the skerres off West Taymyr and numerous widely separated islands, extensive land-fast ice is developing in the north-eastern Kara Sea. In the south-western Kara Sea land-fast ice is well developed in large bays and inlets of the continental coast. Fast ice covers all the straits of Franz Josef Land, but along the Novaya Zemlya shore the fast ice belt is relatively narrow [Map 3.5].

Well-developed land-fast ice provides favourable habitats for successful reproduction of ringed seals (Phoca hispida), whose breeding grounds are located along the Kara Sea continental coast. In general, the population density of ringed seals in the south-eastern Kara Sea falls is at its highest in the Western Arctic area [Belikov et al., 1998].

Eleven flaw polynyas have been identified in the region (Map 3.5) [Zakharov, 1996]. The ice-free water was observed from the northern tip of Novaya Zemlya by participants of Willem Barents' expedition who spent the winter of 1596–1597 in the Ice Harbour (Ledynaya Gavan') [Kupetsky, 1959]. In addition to the polynyas in the Franz Josef Land area, in some parts of the straits and sounds of this archipelago ice is normally thinner than in the adjacent areas and leads sometimes last through the winter [Abramov, Zubakin, 1994].

Eastern coast of Novaya Zemlya, Kara Sea [26]

The monthly average frequency of polynya occurrence varies considerably between particular areas, seasons and years. In general, the multi-year mean frequency of polynya occurrence between November and May ranges between 7 and 100%. At the present time, only the Ob'-Yeniseiskaya and the Central Karskaya polynyas are recurrent (with a frequency of 75% and higher). For a few months of the year the Northern Novozemelskaya polynya and the Western Severozemlskaya polynya are classed as stable polynyas, even if for most of the year they recur with a high frequency. The Southern Novozemelskaya, the Amderminskaya and the Yamalskaya polynyas are episodic in November. In December they become stable polynyas and for the rest of the year they are considered recurrent polynyas. The Southern Franz Josef polynya belongs to the stable polynyas group throughout the year except in November when it must be included in the episodic polynyas group.

The formation of flaw polynyas in the Kara Sea is the result of a combination of the influence of the Barents Sea Depression of the Icelandic Low and the North Atlantic cyclones which influence the eastern Barents and Kara Seas. Their size varies between years and shows the multi-year trend for an increase (Fig. 3.5.1). Compared to today, the percentage of stationary polynyas between 1936 and 1970 was considerably lower with most polynyas coming under the episodic and stable categories [Gudkovich et al., 1972; Zakharov, 1996]. For example, the south-eastern polynya of Franz Josef Land, all the polynyas off Novaya Zemlya, and the Western Severozemelskaya polynya were for the most part episodic and were only considered stable for short periods of the year (there was only one stationary polynya). This change in the frequency of polynya formation and the increase of linear size is a result of the large-scale transformation of atmospheric circulation taking place throughout the entire Northern Hemisphere. The polynyas surrounding Franz Josef Land and the system of leads in the sounds of this archipelago sustain local populations of ice-dependent marine mammals year round. They are the wintering grounds for Atlantic walruses (*Odobenus rosmarus rosmarus*), bowhead whales (*Balaena mysticetus*), ringed seals (*Phoca hispida*), bearded seals (*Erignathus barbatus*) and the seals' predator, the polar bear (*Ursus maritimus*) [Belikov et al., 2002]. Sea birds (little auks, Alle alle and black guillemots, *Cepphus grylle*) are present in the polynyas and leads of the Franz Josef Land archipelago as early as February and early March; they are joined later by ivory (*Pagophila eburnea*) and glaucous (*Larus hyperboreus*) gulls and Bruennich's guillemots (*Uria lomvia*). Fulmars (*Fulmarus glacialis*) and kittiwakes (*Rissa tridactyla*) are later migrants to their nesting colonies at the archipelago.

Bowhead whales in the Franz Josef Land polynya [27]

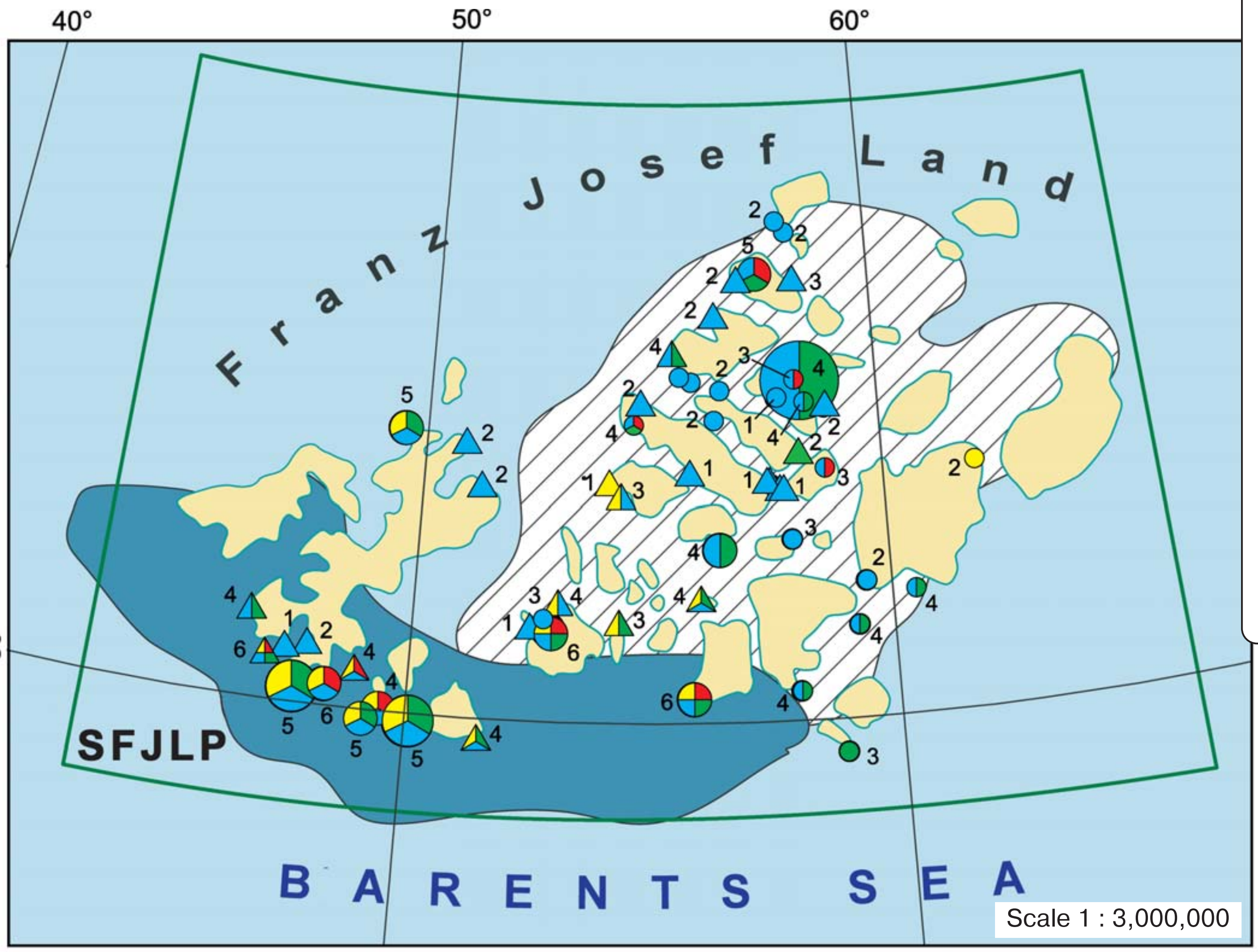
The heavy ice conditions and mainly low and plain coasts of the Kara Sea limit nesting possibilities for colonial birds such as Bruehnich's guillemots. The only large colony of this species is located on the north-eastern coast of Novaya Zemlya in the area influenced by the Atlantic water mass and close to the Northern Novozemelskaya polynya (Map 3.5). Post-breeding aggregations are formed also in the southwestern part of Kara Sea, which is influenced by the Barents Sea waters in late summer and autumn. There kittiwakes, Bruennich's guillemots from the Novaya Zemlya colonies, and also fulmars and glaucous gulls are foraging [Krasnov et al., 2007]. Sea ice biotopes of the Kara Sea ice are much more important for maintaining sea birds habitats and marine mammal populations than the open waters. Thus highest densities of foraging sea birds are observed in the marginal ice zone and among the drift ice in the north-eastern Kara Sea [Decker et al., 1998; Gavrilo, 2009, 2010]. Numerous and abundant colonies of the ivory gull (*Pagophila eburnea*) strike a unique sea bird population profile of the Kara Sea. This species is Red-listed in Russia and IUCN. The ivory gull is the most ice-dependent Arctic sea bird and its largest worldwide colonies are located on islands in the north-eastern Kara Sea.

Beginning in mid-summer, the mass migration of marine ducks proceeds in several pulses across the Kara Sea waters adjacent to the mainland. In July only males migrate to their moulting grounds, while in September and October groups of different age and sex take flight. Without stopping in the western part, the king eider (*Somateria spectabilis*) flies at a low height to the west in flocks, which include up to a thousand individuals. In October and November aggregations of long-tailed ducks (*Clangula hyemalis*) have been observed in the south-western Kara Sea.

Severe winter conditions restrict wintering possibilities for seabirds in the Kara Sea: small numbers of Bruehnich's and black guillemots, little auks, and glaucous gulls have been observed in winter in small polynyas of the Matochkin Shar Strait, in the Cape Zhelaniya area, and to the east of the Karskie Vorota Strait. Solitary glaucous gulls occur in winter also in the area of the Ob'-Yenisei shallow [Krasnov et al., 2007].

In spring, the polynyas of the south-western Kara Sea become the migration route and the staging area for sea ducks. The first to arrive are the king eider, common scoter (*Melanitta nigra*) and long-tailed ducks flying from their East Atlantic wintering grounds to the nesting areas on the Yamal and Taymyr coasts [Krasnov et al., 2007; unpublished data of AARI]. Flocks of common scoter enter the south-western Kara Sea via the straits of Kara Gate (Karskie Vorota), Yugorskiy Shar and Matochkin Shar beginning in mid-April [Krasnov et al., 2007].

The Kara Sea polynyas are also known for their large populations of marine mammals. In winter and spring a number of ringed seals, bearded seals, polar bears and beluga whales (*Delphinapterus leucas*) can be observed in the polynyas of the western Kara Sea [Belikov et al., 1998; Belikov, Boltunov, 2002]. Walruses commonly occur in polynyas to the west of Yamal as early as in March and April [Vorontsov et al., 2007].



Map shows the possible development of polynyas in March (based on high areas for each of the polynyas over the period between 2000 and 2007)

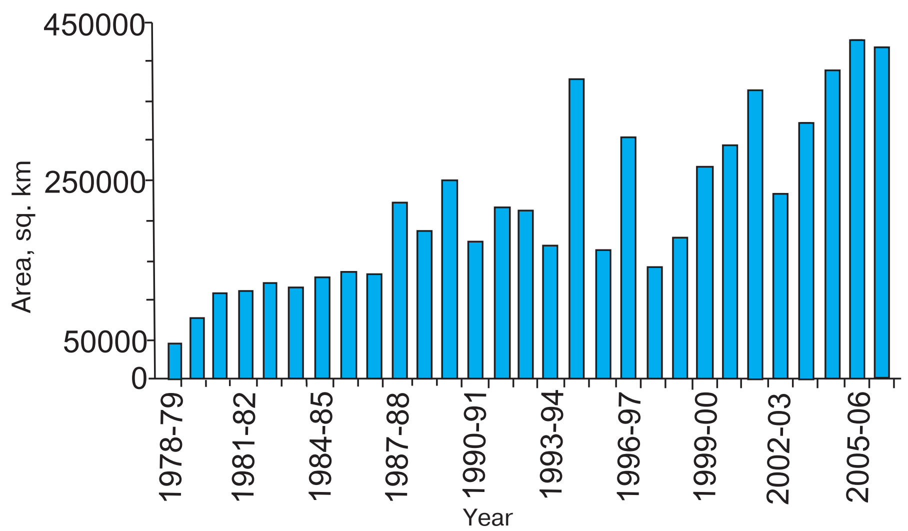
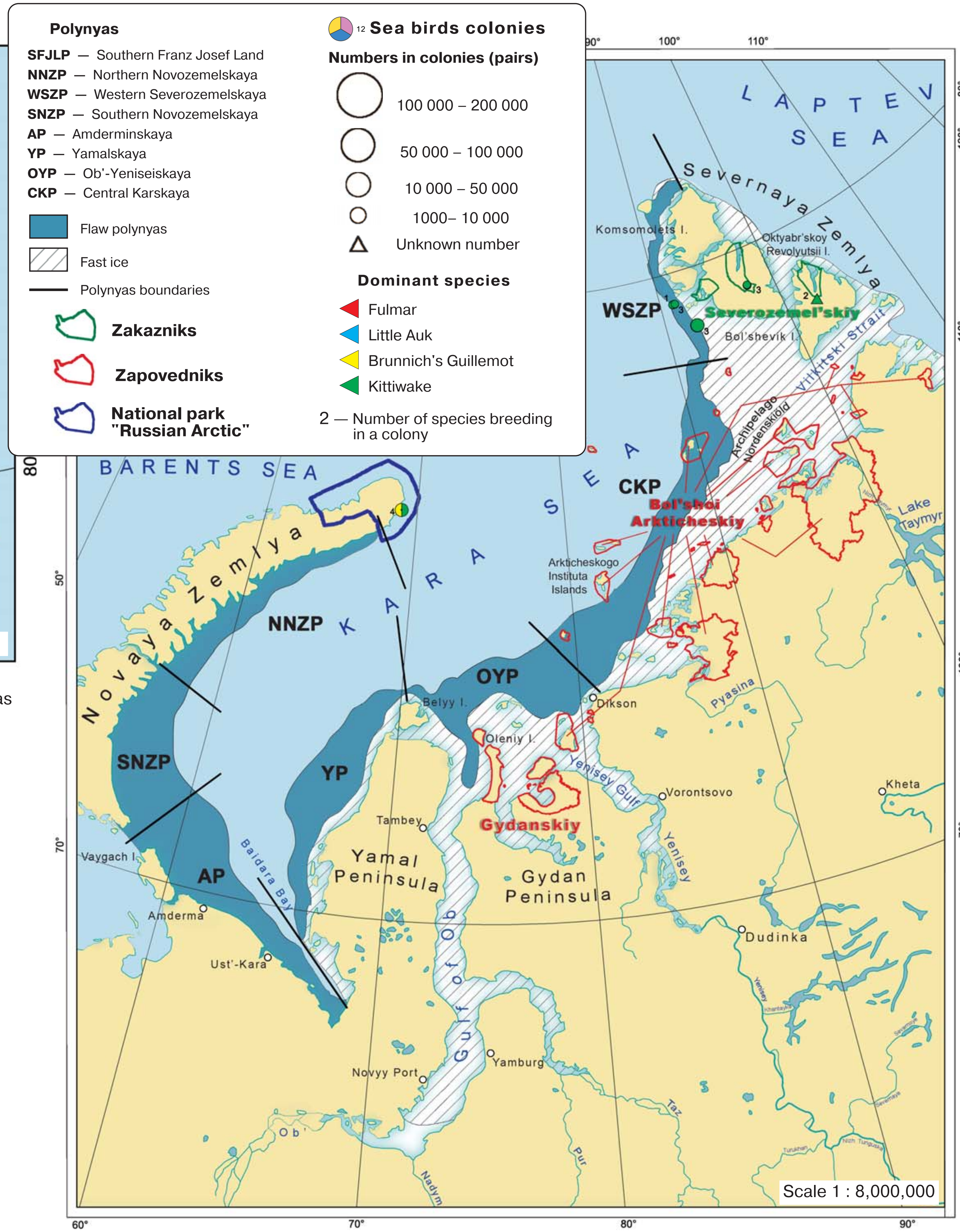


Fig. 3.5.1. Changes in the winter-spring total area of the Ob-Yenisei Polynya between 1978 and 2007 (based on satellite data).



Compiled by *A.V. Popov* and *M.V. Gavrilo*.

Sources: *Popov A.V.* and *Gavrilo M.V.,* Boundaries of the zapovedniks and zakazniks after: [Cartographic base.., 2002–2010]

The Laptev Sea is ice-covered for nearly nine months of the year, from October to June. The northwestern portion of the sea has a more severe ice regime, with the Taymyr ice massif persisting during the summer season. The most extensive land-fast ice forms in the south-eastern portion of the sea, between the Lena Delta and the western New Siberian (Novosibirsky) Islands, where the local Yanskiy ice massif can be observed in the summer season [Observations.., 2009]. In cold seasons fast ice can survive the summer in the straits and fjords along the eastern shores of the Severnaya Zemlya Archipelago. The Laptev Sea polynyas system has been known about for more than two centuries. Its eastern part, the Great Siberian Polynya, was discovered by Yakov Sannikov, a Siberian fur trader in 1810, while the contours of this open water area were first mapped by Matvey Gedenstrom in 1811. Later this polynya was studied by Peter Anjou, Ferdinand von Wrangel, and Alexander Kolchak. According to Kupetsky [1959], the particular features of this polynya gave rise to two mutually excluding legends: the story of the Sannikov Land and the story of the existence of the Open Polar Sea. According to these legends some explorers believed the dark vapour above the polynya to be a remote land while others thought that the ice-free sea extended to the North Pole because they could not see drifting sea ice in the huge area of open water.

At present six flaw polynyas have been identified in the Laptev Sea (Map 3.6) [Zakharov, 1966, 1996]. The monthly mean frequency of occurrence of the Laptev polynyas is high over the entire cold period (57 to 100%). As a result, all these polynyas are classed as either recurring or stable depending on the month. In November the frequency of occurrence is generally lower than in other months and all polynyas are considered stable. The most frequently occurring polynyas (not less than 65-70%) are those which are developing in the south and east of the Laptev Sea (Great Siberian Polynya). The Anabar-Lenskaya and the Western Novosibirskaya polynyas are least stable in early winter, while in February their frequency of occurrence reaches its maximum (96–100%) as does the frequency of occurrence of the Western New Siberian polynya which peaks in April. The frequency of occurrence of the Northern Novosibirskaya polynya is minimal in January; this polynya becomes the most frequent (96%) in April. The Eastern Severozemelskaya polynya appears generally less frequently than the others.

A Comparison of the characteristics of the Laptev Sea polynyas during the period 1936–1970 [Gudkovich et al., 1972; Zakharov, 1996] with the modern day (Fig. 3.6.1) indicates that the frequency of occurrence and the numbers of recurring polynyas in the last two decades have increased. In particular, the episodic (30–40%) Eastern Severozemelskaya (in May) and the Eastern Taymyrskaya polynyas (in April and May) have now become stable.

Polynya in the Laptev Sea [28]

Ivory gull in the breeding colony. Domashniy Island, Severnaya Zemlya [29]

Flaw polynyas of the Laptev Sea and their spatial-temporal inter-annual variability are a product of the interaction of processes associated with three atmospheric centres: the Icelandic Low, and the Arctic and the Siberian High. Deepening of the Icelandic Low intensifies the Atlantic cyclones which get their energy from the Kara Sea polynyas, cross the Taymyr Peninsula and form a wind system which facilitates the development of polynyas in the western Laptev Sea. Strengthening of the Arctic Hight leads to the development of polynyas in the eastern Laptev Sea.

The Laptev Sea polynyas have long been considered biodiversity hotspots. However, in contrast to data on plankton organisms [i.e. Abramova, 1996; Kosobokova et al., 1998; Timofeev, 2002; Abramova, Tuschling, 2005] and on benthos [Sirenko et al., 1995; Gukov, 1999; Petryashov et al., 2004], data on the quantitative distribution of fish, seabirds and marine mammals are scarce.

The largest seabird colonies of Severnaya Zemlya inhabited by little auks (*Alle alle*) are located along the eastern coast of the archipelago and correspond to the Eastern Severnaya Zemlya polynya. Different seagull species forage in this polynya during the post-breeding period, including the ivory gulls (*Pagophila eburnea*) from the colonies of the entire East Atlantic (up to East Greenland) [Gilg et al., 2010]. A chain of colonies dominated by Bruennich's guillemots (*Uria lomvia*) and kittiwakes (*Rissa tridactyla*) stretches from the Preobrazhenya Island in the Khatanga Bay via the islands of Stolbovoy and Belkovskiy to the De-Long Islands (New Siberian Islands). These colonies are associated with a more persistent system of polynyas in the south and the east of the Laptev Sea (Map 3.6). All polynyas are used by seabirds as flyways during spring migrations. Black guillemots (*Cepphus grylle*), little auks and gulls can be observed in the Eastern Severozemelskaya polynya as early as late March and early April, a time when their breeding cliffs are still under snow and ice. This spectacular phenomenon was first noticed by the first explorers of the Severnaya Zemlya archipelago Nikolai Urvantsev [1935] and Georgiy Ushakov [1951] in 1931. The Anabar-Lenskaya and the polynyas off New Siberian Islands serve as spring stopover routes for king eiders (Somateria spectabilis) and long-tailed ducks (*Clangula hyemalis*) before they reach their nesting grounds on the tundra [Solovieva, 1999]. Bruennich's guillemots, kittiwakes and pomarine skuas (*Stercorarius pomarinus*) can also be seen migrating westwards above the polyanyas.

The presence of open water over the shallows in winter supports the existence of a regional sedentary population of Laptev walruses, often considered as a subspecies *Odobenus rosmarus laptevi* [Chapsky, 1941; Belikov et al., 1998; Sokolov et al., 2001]; these are included in the Russian and IUCN Red Lists. This population winters in the polynyas from East Taymyr to the north of the New Siberian Islands. The latest molecular-genetic studies have failed to prove its isolation from the Pacific subspecies (*O. rosmarus divergens*) [Lindquist et al., 2008]. However, the Laptev walrus is indeed a peculiar population differing from the neighbouring Pacific populations by the absence of long seasonal migrations and the location of wintering grounds [Gorbunov, Belikov, 1990].

Relatively scarce spring sightings of beluga whales (*Delphinapterus leucas*) have also been observed in the Laptev Sea polynyas; in summer, the area of polynyas up to the Lena Delta is the range for the mass occurrence of belugas [Belikov et al., 1998, 2002; Belikov, Boltunov, 2002]. The system of Laptev Sea polynyas also supports dense populations of ringed seal (*Phoca hispida*) during the winter and spring seasons [Belikov et al., 1998]. As a result, the area also attracts the main seal predator: the polar bear (*Ursus maritimus*). A high abundance of polar bears has been observed in the Laptev Sea on the ice fringe of the Eastern Taymyrskaya and the Northern Novosibirskaya polynyas [Belikov et al., 1998].

Compiled by *A.V. Popov* and *M.V. Gavrilo*

Sources: *Popov A.V.* and *Gavrilo M.V.*, Boundaries of the zapovedniks and zakazniks after [Kartographic base.., 2002–2010]

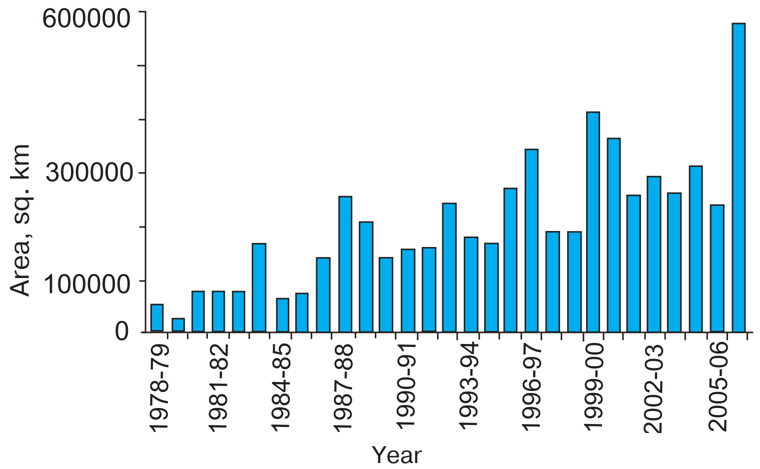
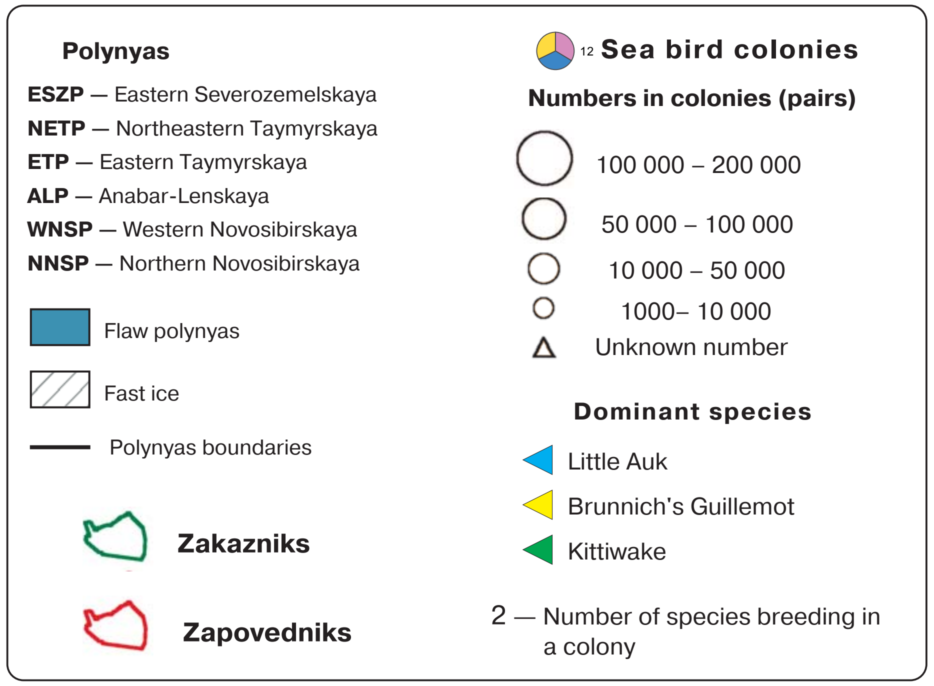


Fig. 3.6.1. Changes in the winter-spring total area of the Anabar-Lenskaya Polynya between 1978 and 2007 (based on satellite data).



Map shows the possible development of polynyas in March (based on maximum development of the polynyas over the period between 2000 and 2007)

The East-Siberian Sea is covered by ice for 8–10 months of the year (from October to May/June), while the Chukchi Sea, which is the southernmost of the Arctic seas in the strict sense, has a shorter ice season: it freezes in November. The Bering Sea lies nearly entirely in the Subarctic zone. The ice cover spreads gradually over the Bering Sea waters from November onwards; its maximal extent in severe winters going as far as 55°N. In general, compared to other Arctic seas (and similarly to the Barents Sea), the sea ice regime of the Bering Sea is subject to the greatest levels of seasonal and inter-annual variability. The sea ice coverage in the mildest years may be as little as half that during cold years [Observations.., 2009]. The most important biotopes for maintaining seabird and marine mammal populations are those associated with polynyas and the ice edge. Three flaw polynyas can be observed in the East Siberian Sea with a further four in the Russian part of the Chukchi Sea. Of these, the Eastern Chukotskaya polynya is often referred to as a «lead» on account of its narrow width (Map 3.7) [Zakharov, 1996]. The Anadyrskaya polynya is located off the south coast of Chukotka; the part of it adjacent to the settlement of Sireniki is also known as the Sirenikovskaya polynya (Fig. 3.7.1).

The formation of flaw polynyas in the East Siberian Sea is a result of the interaction between the Arctic and the Siberian Anticyclones. Strengthening of the Arctic Anticyclone creates a wind pattern which facilitates the development of polynyas in the western part of the East Siberian Sea and, simultaneously, their depression in the eastern part of the East Siberian Sea and the Chukchi Sea. Development of polynyas in the Chukchi Sea is supported by cyclones originating in the Aleutian Low. The different and changing year to year interactions of the processes originating in these centres of atmospheric activity explains the inter-annual variability of polynyas in the East Siberian and the Chukchi seas. During warm years the Arctic Anticyclone weakens and shifts to the Canadian sector of the Arctic; this results in the dominance of a system favouring polynya development in the Chukchi Sea. In the winter 2008 the Arctic Anticyclone was again strong and this led to a depression of the Chukchi Sea polynyas. No one of the polynyas can be fully classified as recurrent in the East Siberian Sea. The monthly mean frequency of polynya occurrence is significant throughout the entire cold season of the year but it is on average lower than in the neighbouring Laptev Sea and varies from 41 to 89%. Gray whales (*Eschrichtius robustus*) of the Californian-Chukchi population migrating from their wintering grounds show up near the eastern coast of Chukotka in the second half of May. Most of them move to the Chukchi Sea in June. In this season both gray and bowhead (*Balaena mysticetus*) whales use polynyas and leads for migration. In summer and autumn bowhead whales forage and travel up to Wrangel Island and along the Chaunskaya Guba — as far as the ice edge allows [Bogoslovskaya et al., 1982; Belikov et al., 2002]; in particularly favourable years (when the ice massif to the west of Ayon Island breaks up in summer) bowhead whales may reach the New Siberian Islands [Gavrilo, Tretyakov, 2008].

In winter, most of the Chukotka Peninsula coastal zone and the polynyas adjacent to Wrangel Island form the area of high concentration of ringed (*Phoca hispida*) and bearded (*Erignathus barbatus*) seals and their predators: the polar bears (*Ursus maritimus*) [Belikov et al., 1998]. Short-tailed shearwaters (*Puffinus tenuirostris*) migrating from Tasmania and Western Australia to the North Pacific (in the Northern Hemisphere summer) may also go as far as the boundary of drifting ice in the region [Gavrilo, 2009]. The system of polynyas and leads along the Chukotka coast serves as a spring migration path for seabirds including eiders, long-tailed ducks (*Clangula hyemalis*) and alcids. The Wrangel Island and East Chukotka seabird colonies are characterized not only by their abundance but also by the greater diversity of species than those located to their west on the coast of the Siberian seas. These colonies in the Chukchi Sea are associated with the trans-Wrangel Island polynyas and the coastal Eastern Chukotskaya lead, respectively. Small groups of wintering Pacific walruses (*Odobenus rosmarus divergens*) have been observed in the polynyas adjacent to Wrangel Island and off the north coast of Chukotka [Stishov, 2004].

Leads off Chukotka coast [30]

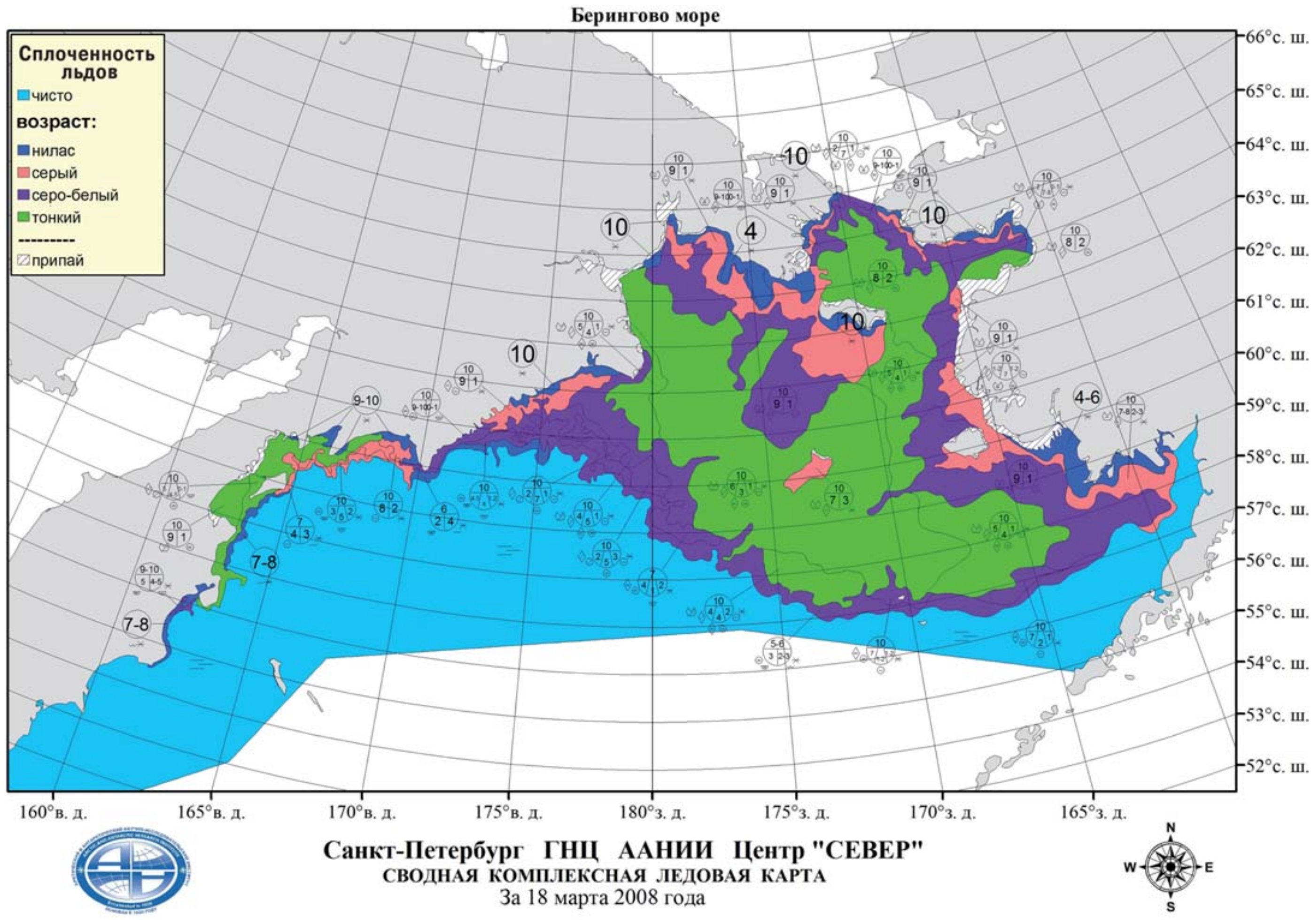
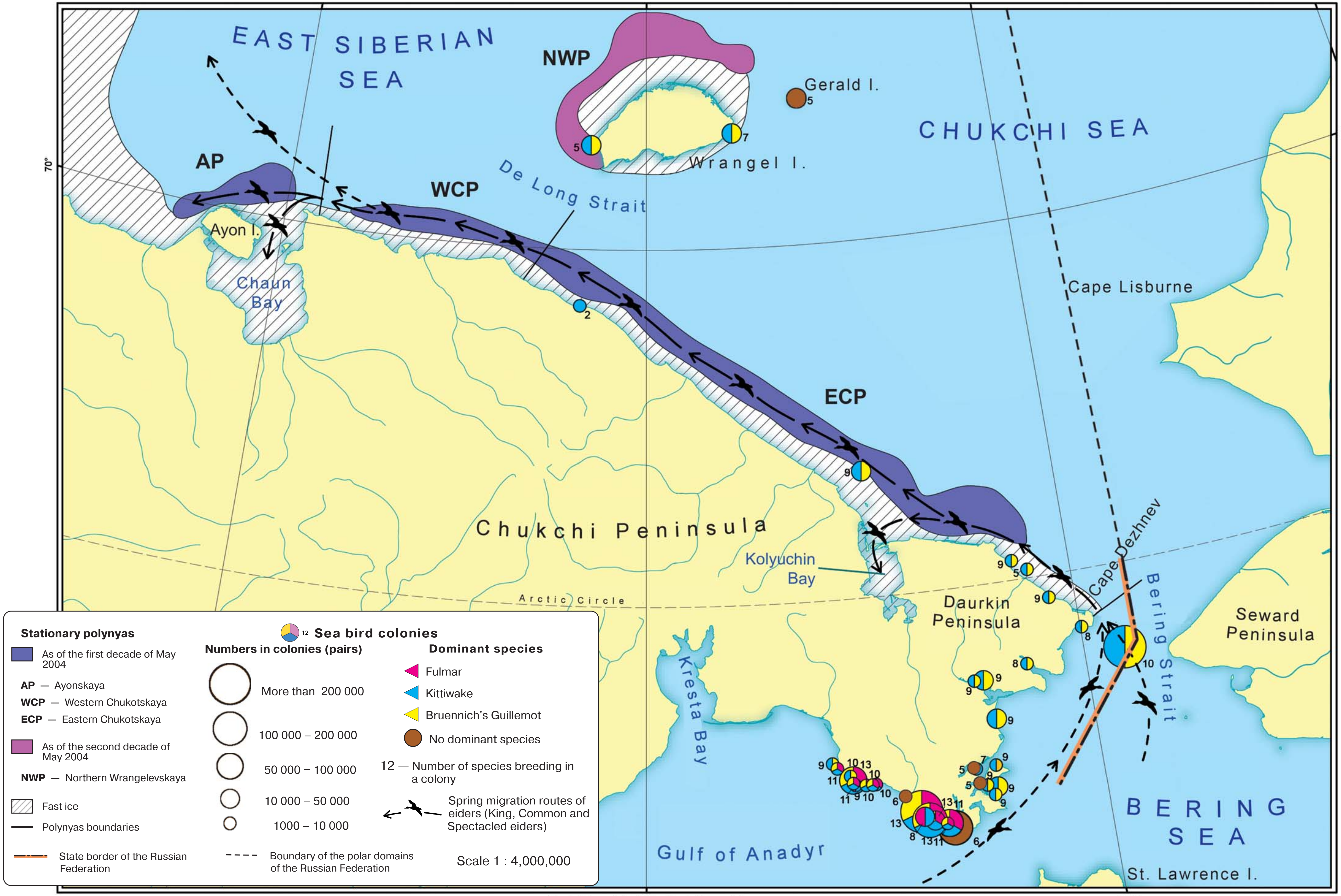


Fig. 3.7.1. Example of winter sea ice conditions in the Bering Strait and the northern Bering Sea showing development of flaw polynyas and the ice edge off southern Chukotka. Dark-blue areas — polynyas, covered by nilas; light blue area — open water. Source: AARI.

The Anadyr'-Sireniki polynya located off the southern coast of the Chukotka Peninsula is the largest one in the Chukchi-Bering Sea region (Fig.3.7.1). This is also the most well-known and biologically important polynya in the Russian part of the Bering Sea — a wintering ground for bowhead whales, beluga whales (*Delphinapterus leucas*), and Pacific walruses [Bogoslovskaya et al., 2008; Melentyev, Chernook, 2009]. Several species of seabird also spend winters there including long-tailed ducks, eiders and alcids [Konyukhov et al., 1998]. The Sireniki polynya has been critically important for the development and subsistence of the indigenous culture of the marine hunters of Chukotka for more than a thousand years [Arutyunov et al., 1982; Dinesman et al., 1996]. All these areas, along with the sea ice edge in the Bering Sea, are important wintering grounds for seabirds, in particular ivory (*Pagophila eburnea*) and Ross gulls (*Rhodostethia rosaea*), and alcids.



Compiled by *M.V. Gavrilo* and *A.V. Popov*

The area where the sea meets the land is called sea shore. In the tidal seas the coastline moves vertically up to twice a day [Leontiev et al., 1975]. Thus, it is not so much a line as a zone of greater or lesser width. The area that is under water at high tide and is exposed to the air at low tide is known as the intertidal zone, and often referred to as the littoral zone. The average point of the narrow belt of land adjacent to the recent coastline where the land has been shaped by the sea is called the coast by geomorphologists, while the zone of recent and past interaction of the sea and land is called a coastal zone, or poberezhie in Russian. This zone is bordered by elevated marine terraces on the land side and by ancient submerged coastlines on the water side.

In general, sea coasts can be divided into two classes: the accumulative and the basic ones. A beach is the simplest accumulative formation; it is formed by the surf. A coastal bar is an underwater or partially drying accumulative formation, which originates from the seaward transport and subsequent accumulation of sediment particles by tidal currents. Coastal bars stretch along the shores to distances of up to hundreds of kilometres thereby separating lagoons from the sea [Leontiev et al., 1975]. Among the basic shores, two further groups can be distinguished: those coasts little changed by the sea and abrasion coasts. A cliff is a steep margin of the coast formed by abrasion, while the area seaward of the cliff, flattened by waves and surf, is called a bench.

Muddy accumulative coasts with broad tidal flats are often occupied by maritime plants that are resistant to salt substrates. These parcels are called marshes, and they are common in the Russian Arctic [Leontiev, 1991]. The composition of the marsh plant communities depends on such abiotic and biotic factors as tides, water and soil salinity, marine water temperature, physical properties of the substrate (i.e. maritime soil), soil drainage and aeration, the level of underground waters, precipitation and evaporation, and surrounding zonal terrestrial vegetation [Sergienko, 2008].

Coastal marshes are divided into two groups: low or primary marshes and high or secondary marshes [Chapman, 1960]. The formation of primary marshes depends on stabilization of the coast line. Large accumulative structures such as bars and spits make a barrier and fine particles are deposited on the coastward side of them. Eventually these build up into muddy flats. These flats are constantly evolving into salt marshes populated by characteristic plant communities. Low marshes are far more influenced by tides and waves than are high marshes. Episodic and temporary flooding of high or secondary marshes influences maritime vegetation to a lesser extent. Thus arises an opportunity to accumulate organic matter. In contrast to primary marshes, secondary marshes contain all stages of dead and decaying plant matter; the concentration of humus in soil is greater, and the processes of primary peat formation become possible. Dense meadow vegetation facilitates accumulation of organic particles and prevents abrasion, thus stabilizing the coastline [Tseits et al., 2000].

The mudflats located in the lower non-vegetated part of intertidal zone, together with marshes, buffer against the impact of storms on one hand and act as major producers of organic matter on the other hand. In salt marshes production greatly exceeds consumption. Most organic matter produced is either transformed locally or transported ashore during storms thereby playing an important role in soil formation. A smaller proportion is transported to the intertidal zone during the ebb of the water [Burkovsky, 2006]. These salt marshes provide feeding grounds for migrating waders, brent and other species of geese. Some fifteen species of waterbirds nest almost exclusively in the narrow coastal zone, mostly in marshes. Thus, this narrow zone (it can reach widths of several kilometres) is one of the most important biotope systems in the Arctic.

Delta coast, Yakutia [31]

Map 3.8 shows the different types of sea coast in the Russian Arctic classified according to a morphogenetic system developed by Russian specialists [Kaplin et al., 1991; Pavlidis et al., 1998]. The accumulative coasts with tidal flats (sandy or muddy) are most important as salt marsh habitats. They are found along the coasts of the Barents Sea from Chyosha Bay (Chyoshskaya Guba) to Baidara Bay (Baidaratskaya Guba) and the coasts of Chukotka. In the coastal zones of the White, Barents, Kara and Laptev seas, salt marsh zones composed of different sediment types are developing along the lower zone of the abrasive tidal coasts. Here rocky, boulder, boulder-clay, sandy and sandy-muddy, nearly flat benches are formed which dry up at low tide and are overrun by salt marsh vegetation. This marsh vegetation is also found in abundance in the mouths of all rivers entering the Arctic Ocean where the alluvial-delta coasts are formed.

Abrasive coast, Kildin Island, Barents Sea [32]

CONVENTIONS TO MAP 3.8

A — Coasts formed by tectonic, subaerial erosion and glacial exaration-accumulative processes and little changed by sea waves

I — Coasts with narrow bays
- Fjord (**1**)
- Fiard (**2**)
- Skerry (**3**)
- Estuarine (**4**)

II — Primary flat
- Fault (**5**)

B — Coasts formed by the impact of non-wave processes

III — Potamogenic
- Delta (**6**)

IV — With tidal drying (muddy and sandy)
- Muddy (**7**)

V — Termo-abrasive
- Termo-abrasive (**8**)
- Ice (**9**)

VI — Denudation
- Denudation (**10**)
- Solifluction (**11**)
- Talus (**12**)

C — Coasts formed by waves

VII — Leveling
- Bay (**13**)
- Accumulative-bay (**14**)

VIII — Leveled
- Abrasive (**15**)
- Abrasive-accumulative (**16**)
- Accumulative (**16a**)
- Lagoon (**17**)
- With cliff and terrace (**18**)
- Accumulative with erosion, with sandy-boulder beach (**18a**)

IX — Secondary dissected
- Abrasive-accumulative-inlet (**19**)

Note:

A, B, C — Types of marine coasts;

I – IX — Subtypes of sea coasts partition ;

1 – 19 — Main reasons caused by initiate partition of coastline

State border of the Russian Federation

Boundary of the polar domains of the Russian Federation

Scale 1 : 22,000,000

Scale of removal 1 : 8,000,000

Compiled by *L.A. Segienko* and *M.A. Shroeders.*

Sources: *Kaplin et al.* [1991]; *Pavlidis et al.* [1998].

The salt marsh flora of Russia's European North is distinguished from that of the remainder of Russia by its spectacular richness (2.6). Depending on the frequency and duration of flooding, salt marsh vegetation may be subdivided into three groups or levels. The low level «maritime meadows» consist of those plant communities which are developing in the lowest-lying areas and are flooded at every high tide; the middle-level communities are those which grow on the more elevated parts of the coastal terrain and are only flooded during the highest tides or during strong storms; the high-level meadows are those which are never flooded but receive salt water in the form of splashes [Leskov, 1936; Sergienko, 2008].

Marshes are unevenly distributed along the sinuous coastline of the White Sea (Map 3.9 A). In the west (i.e. Kandalaksha Bay) rocky abrasive and abrasive accumulative coast dominate, while in the east extensive accumulative coastal forms are common. The width of sandy or clay-sandy tidal flats stretches as far as 2 km (mouths of the rivers Mezen, Chizha, Nes'). On the Onega Bay coast in the area of Cape Lopshen'gsky, dune beaches with widths of up to 0.5 km extend along 200–300 km of coastline.

One characteristic of the zone occupied by White Sea maritime marsh vegetation is the presence of three terraces sloping gently towards the sea. The first terrace forms the boundary of the marsh zone. The plants growing here are sometimes submerged in salt or brackish water for up to 4 hours a day and as a result do not form densely growing assemblages. This marsh zone is in fact an open muddy substrate with algal films and separate plants of the pioneer species slender spike-rush (*Eleocharis uniglumis*) or the endemic White Sea species Pojarkova's wort (*Salicornia pojarkovae*) — particularly in the mouths of southern rivers, and the sedge *Bolbochoenus maritimus* in northern areas. The most densely growing maritime plant assemblages are found in the middle section of the slopes and are dominated by species which are adapted to saltwater flooding and salination of the soil, first of all Hoppner's sedge (*Carex subspathacea*). The transition from the middle-level marshes to high-level marshes is marked by a local accumulation of turf. The upper level of marsh zone is an ecotone or transitional area where species of local flora resistant to minute salination of the soil can be observed. Maritime marsh vegetation occupies estuaries of all rivers entering the White Sea and has its own characteristics.

The inlets of the Murmansk coast situated in the Barents Sea tend to be characterized by rocky shores. As a result there is little maritime vegetation, and that which does grow is found mainly on the protected inner shores of the inlets and coves. In the south-eastern Barents Sea (Map 3.9 B) most diverse maritime marsh communities (resembling the White Sea ones) populate the coast of Chyosha Bay (Chyoshskaya Guba). The low-level marshes on the Pechora Sea coast which suffer frequent and long-term flooding and abrasive effects of sea ice are usually located along the muddy coasts of the marine inlets and salt lakes. Their vegetation cover is essentially homogenous: it consists mostly of a bright-green, dense but low (2–4 cm) «carpet» of sprouts of creeping alkali grass (*Puccinellia phryganodes*) often accompanied by solitary Hoppner's sedges and salt marsh starwort (*Stellaria humifusa*). The species are characteristic for the northern part of the Malozemelskaya Tundra between the Kolokolkova Inlet (Guba) and the Pechora Bay (Pechorskaya Guba) of a vast plain composed of wind transported sands. Vast maritime meadows with similar plants are also found on the muddy eastern coast of the Kolokolkova Inlet and extend up to 4 km from the seashore. The vegetation in the frequently flooded areas of the middle-level marshes is characterized by simple meadow associations, made up mainly of pure Hoppner's sedge and Dupontia psilosantha. All the derivative communities of the middle-level marshes contain Hoppner's sedge, circumpolar reedgrass (*Calamagrostis deschampsioides*), saltmarsh starwort and marsh cinquefoil (*Potentilla egedii*). Hoppner's sedge also dominates the vegetation on the high-level marshes along with red fescue (*Festuca rubra*) and bog star (*Parnassia palustris*). Another characteristic of the high-level marshes is a thick moss cover which is absent from most marsh communities at the middle-level. Characteristic features of the Kara Sea coast are geological heterogeneity, all-round presence of the coastal permafrost and a long lifetime of the land-fast ice, which restricts the wave impact on the shore for more than half a year. A narrow band of maritime vegetation stretches along the elevated abrasive coasts of Yamal Peninsula, borders the islands of Belyi and Shokalsky, and the northern coast of the Gydan Peninsula. Wherever the Kara Sea salt water reach huge estuarine areas, patches of marsh vegetation occur on the shores of the Gulf of Ob (Obskaya Guba) and the Yenisei Bay (Map 3.9 C).


Salt marshes near Varandey [33]

On the south-western coast of the Kara Sea maritime marsh communities are dominated by creeping alkali grass, lesser saltmarsh sedge (Carex glareosa), Hoppner's sedge, salt marsh starwort, and circumpolar reedgrass. In the Kharasavey area on Yamal Peninsula arrowgrass (*Triglochin maritima*) has been found, that species is characteristic for the Atlantic maritime flora. A band of maritime vegetation with characteristic for the shores of Baidara Bay (Baidartskaya Guba) distribution extends along the entire shoreline of Marre-Sale Peninsula broadening in mouths of small rivers.

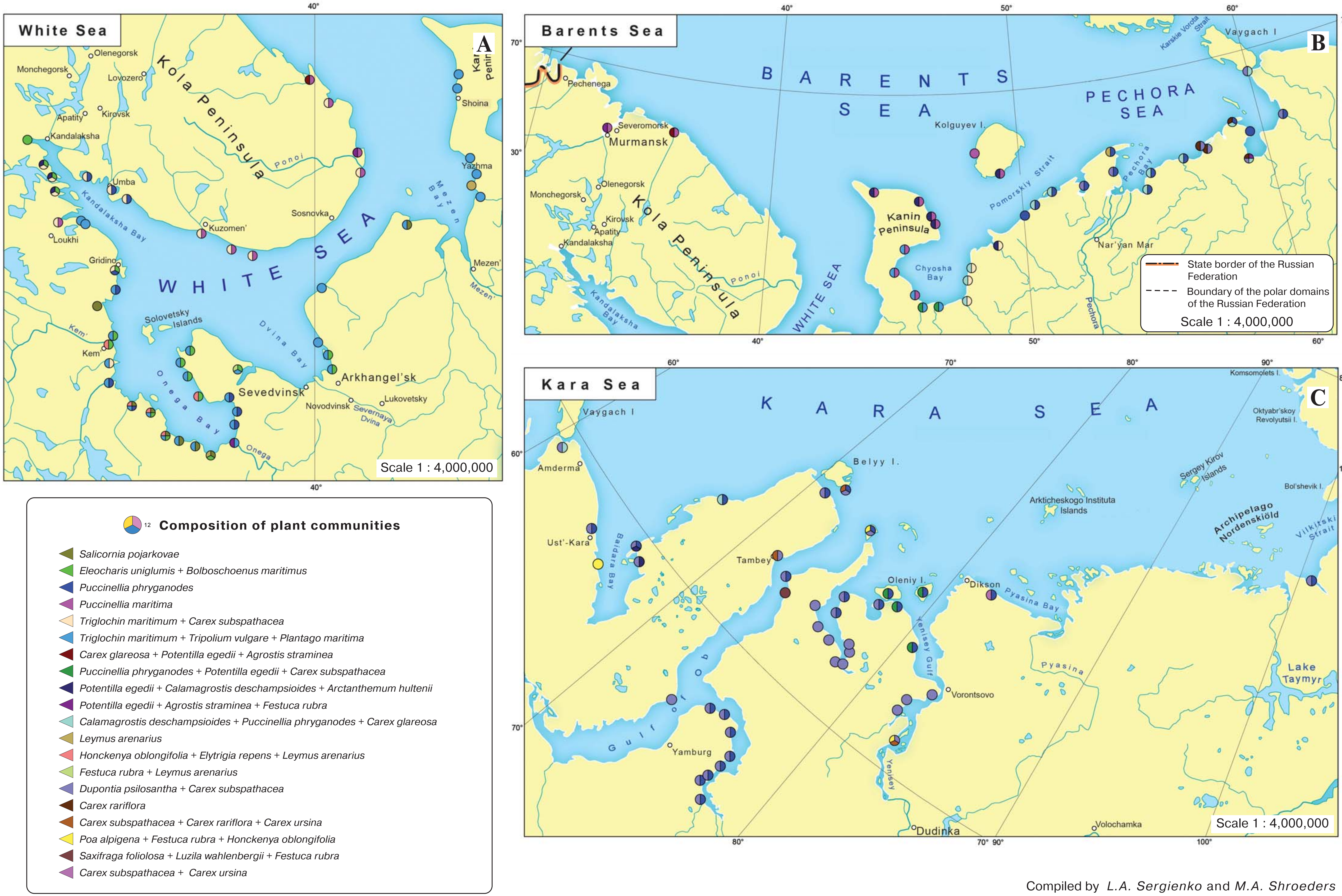
The inner part of Obskaya Guba is filled by nearly fresh or brackish waters (not more than 5–8 ppt); the shores are occupied by a typical tundra vegetation with some contribution of such salt marsh species as *Dupontia psilolantha* and pendantgrass (*Arctophila fulva*).

In Taymyr Peninsula glacial forms of the coastal morphology (both denuded or not transformed by the sea and accumulative ones) are spread nearly all-round. Sandy and muddy beaches on the water front are flooded every day; at low tide small pools cover up to 30% of their area. Marsh vegetation is poor; creeping alkali grass is the only dominant species in these communities. The beach continues to a low plain which is flooded from time to time. Soils in this zone contain not as much water and are relatively stable. This is a biotope of halophytic sedges communities. A higher zone is flooded only sporadically, at high pileup. There wet low parcels are intermittent with sandy elevations.

Marsh biotopes of the White, the eastern Barents, and the Kara seas play a tremendous role in the life cycles of waterbirds, especially waders and geese, providing them with food and shelter during breeding, molting and migration seasons [Gavrilo et al., 1998].

Marsh biotopes are protected in the Nenetskiy state zapovednik, in the neighboring federal zakaznik of the same name (see 4.1), and also in some regional SPNA (4.2, 4.4). However, the present coverage of marshes by SPNAs does not fit the priority of protection appropriate to such an important component of coastal biological diversity.

Map 3.9. Plant communities of maritime marshes on the coasts of the White (A), Barents (B), and the Kara (C) seas



Compiled by *L.A. Sergienko* and *M.A. Shroeders*

The tidal magnitude in the Laptev Sea is not high (not more than 0.8 m) but storm surge may be very significant and lead to sea level changes within the range of two and even five meters. Small parcels of marsh vegetation are located in the Khatanga Bay, in the Terpyai Tumus coast and the Yana Delta area. The delta of Lena River, the largest delta system on the Arctic Ocean Coast extends to 28.5 thousand km^2. Its eastern part comprises of numerous islands and creeks. At the high water season many islands are flooded, and this is followed by significant accumulation of muddy sediments and changes in the coastline. Even in these harsh conditions maritime grass communities persist on the shores. The coverage of maritime species is nonetheless low, and does not exceed 20%. There such widespread species as circumpolar reedgrass (*Calamagrostis deschampsioides*), arrowgrass (*Triglochin maritima*), *Dupontia psilosantha*, salt marsh starwort (*Stellaria humifusa*), marsh cinquefoil (*Potentilla egedei*), sea thrift (*Armeria maritima*), Arctic Daisy (*Arctanthemum arcticum* ssp. *polare*) are common.

The western part of the East-Siberian Sea coastal zone is characterized mainly by thermoabrasive shores. Large rivers (Indigirka, Kolyma, Alazea, Bolshaya Kuropoatochaya, Chukochaya – a branch of the Kolyma delta) carry a large volume of suspended matter to the sea; this explains the poor development of marsh vegetation in the open estuaries on the one hand, while also explaining the significant development of marsh vegetation on the shores of the river mouth system as these are protected from wave erosion. The largest marsh areas are those surrounding the Chukochya River. The mouth of the Bolshaya Kuropotochya River is a low plain composed of easily transported muddy sediment, and characterized by high rates of the coastline retreat (about 1.06 m per year) [Grigoriev, Kunitsky, 2000]. The result is that the salt marsh communities stay persistently at early stages of development. The maritime vegetation is made up of communities of Arctic circumpolar species: creeping alkali grass (*Puccinellia phryganodes*), Hoppner's sedge (*Carex subspathacea*), marsh cinquefoil, maritime buttercap (*Ranunculus tricrenatus*), *Dupontia psilosantha*, and pandantgrass (*Arctophila fulva*).

To the east of the Kolyma Delta the coast consists of parcels with abrasive cliffs, interspersed with low accumulative shores with beaches and flats, which dry up depending on the wind and surf. There is no vegetation on the abrasive shores because mudslides from the cliffs cover the beaches. In places where the shore is low and flat the marsh is sparsely covered by creeping alkali grass, including Hoppner's sedge and saltmarsh starwort (*Stellaria humifusa*). However, this vegetation is often scoured by sea ice or destroyed by mud sliding or flowing from steep shores.

The coast of the largest bay of the East-Siberian Sea, Chaun Bay (Chaunskaya Guba) is a hilly plain. The shore extends along a belt of 10-15 km and is exposed to greater or lesser levels of salination (depending on the strength of the storms). During the north and north-west stormy winds, salt water extends 10–20 km upstream in the Chaun River estuary brining with it salt marsh plant species. Thanks to several years of research carried out by research station of the Institute of Biological Problems of the North of the Russian Academy of Sciences, much is known about the composition and dynamics of the salt marsh vegetation in the areas (Map 3.10).

In contrast to most other polar seas, the coast of the Chukchi Sea is bordered by spits and tombolos, which separate variously sized lagoons from the sea. Here, smoothened abrasive coasts dominate, while purely accumulative coasts are less common. Remarkable capes and bays, which cut deep into the land, are rare with the exception of Kolyuchin Bay (Kolyuchinskaya Guba). The coastal relief is characterized either by hilly plains or mountain range spurs. The coasts of the Anadyr Bay of the Bering Sea are more complex and include two large bays, Kresta Bay and Anadyrskiy Liman.

The diversity of the morphogenetic coast types that characterize the Chukotka shoreline determine the structure and duration of the vegetation that develops upon its landscapes. In most cases, different coastal formations are separated by diffuse, indistinct borders (Map 3.10). The development of vegetation on the muddy salt marsh depends on the salt content, soil acidity, flooding regime, sediment properties and accumulation rates, and rock underlying the alluvial soil. The earliest vegetation consists of turf and stolon-forming species and creeping alkali grass. These are replaced in the upstream estuarine areas of numerous small rivers by Dupontia, which grows under similar conditions of flooding but in lowersalinity soils. In the north of the Chukotka Peninsula Arctic halophytes are abundant: bear sedge (*Carex ursina*), Arctic coastal saxifrage (*Saxifraga arctolitoralis*).

The species composition of the vegetation of the coastal sands and the successive patterns of vegetation on the sandy-pebble beaches, spits and

Spoon-billed Sandpiper [34]

bars are similar along the entire Chukotka Peninsula coastline. On sandy beaches of the southern Chukotka sea sandwort (*Honckenya oblongifolia*) forms separate vegetation patches, in the north – on the De Long Strait coast, in the area of town Billings and on Cape Yakan the dominance shifts to oysterleaf (*Mertensia maritima*). More densely populated patches of sea sandwort, herbs and sedges occur on acclivous slopes of coastal spits and bars all-round in Chukotka Peninsula. On most elevated parts of sandy pebble spits of southern Chukotka similar (beach pea, *Lathyrus japonicus* ssp. *pubescens* and seabeach groundsel, *Senecio pseudoarnica*) multispecies closed plant communities are developed.

Several rare and endangered aquatic birds in Chukotka show a clear association with marsh plant communities. For example, the emperor goose (Chen canagica), a species listed in the Red Data Book of the Russian Federation as a rare species with a declining population, breeds in the coastal zone of the Chukotka Peninsula between the Anguema River mouth in the east, to Dezhnev Cape and then along the Bering Sea coast up to Navarin Cape. Nests are most common on the Vankarem Plain and along the coast of Kolyuchin Bay (Kolyuchinskaya Guba); non-breeding moulting specimens also gather in this area. The distribution of emperor geese on these flooded maritime plains during the breeding period corresponds to the distribution of the creeping alkali grass and Hoppner's sedge communities. These biotopes are very important as feeding grounds for geese in the summer (Map 3.10). The nesting and breeding habitats of the endangered spoon-billed sandpiper (Eurynorhynchus pygmeus), a species endemic to Chukotka and Kamchatka and listed in the Red Data Book of the Russian Federation and the IUCN Red List, are located in the coastal biotopes with the presence of lichens or birch-sedge tundras, and in muddy salt marches with maritime vegetation which provide breeding grounds for birds (Map 3.10).

While some of the maritime marshes of the Laptev Sea are protected by the Ust'-Lenskiy Zapovednik and several regional protected areas (4.1–4.2) marsh biotopes, those in the East Siberian and Chukchi Seas, and the Chukotka section of the Bering Sea are poorly protected. On Wrangel Island, within the zapovednik of the same name, salt marshes are found only on the north coast where a large sandy bar or a spit extends along the shore. In the south, where the accumulative coast has numerous inlets, marsh vegetation develops in low places. There are two enclaves of the regional reserve along the shoreline of the Chaunskaya Guba.

Compiled by *L.A. Sergienko, M.V. Gavrilo* and *M.A. Shroeders.*

Extensive river mouth systems (RMS) are a characteristic feature of the coastal zone of the Russian Arctic seas, with the exception of the Barents Sea, the western part of White Sea and the Chukchi Sea. RMS are specific geographical entities (see Addendum), which cover the entire area of the river/sea boundary zone and are characterized by a specific geomorphology, landscape and hydrological regime. They are a product of the processes of interaction between riverine and marine systems (i.e. dynamics and mixing of marine and river waters, sedimentation, re-suspension and re-sedimentation of riverine and partly marine suspended matter) [Mikhailov, 1997]. The RMSs of the largest rivers in the Russian Arctic differ considerably in their morphology. In turn this determines specific characteristics of the river mouth ecosystems including levels of salinity and inter-annual variation of the hydrological regime. For the most part RMSs are classical ecotones, i.e transitional zones where marine, brackish water and freshwater species can be found alongside plants and animals typical of salt marsh communities (these are well developed in deltas and estuaries of the Arctic rivers; see 3.8–3.10). Ecotone communities are dependent on the export of organic matter and recruitment of populations from outside the habitat: populations of marine and many brackish water species are recruited from the seaside, while freshwater species depend on the populations in the watershed. The composition of the flora and fauna follows the salinity gradient and is continually changing to form ecoclines [Burkovsky, 2006]. An interesting phenomenon was described for near-river sea-sides and adjacent shelf areas of the Pechora and the Ob'–Yenisei areas. There phytoplankton bloom begins in early spring (while still under the ice). This is explained by the avalanchine discharge of dead and live organic matter which has been earlier accumulated in the watersheds and estuaries [Makarevich, 2007].

Atlantic salmon on the spawning migration [35]

In river mouth ecosystems unicellular diatome algae that develop on the tidal flats (i.e. microphytobenthos) play an important role. Along with suspended matter transported by the river and the tides, they provide food to so-called mesobenthos represented mainly by chironomid larvae (Chironomidae) and olygochaets; these invertebrates are an ideal food for fish, particularly juveniles. Given the broad spectrum and gradients of the environmental conditions which provide optimal feeding grounds for different species and age groups of fishes found in RMSs, they constitute a unique biotope system for whole communities of fish including freshwater, marine and anadromous species (those which mainly inhabit marine or brackish water but which migrate upstream to spawn) (2.5).

Fish faunas of the river mouths differ considerably from the ones of neighbouring marine areas [Kudersky, 1987]. It is possible to distinguish between anadromous fish species in the strict sense (those that migrate over great distances at sea) and semi-anadromous (those species that do not usually leave the seaside of the RMS). The first group includes Atlantic salmon (*Salmo salar*), which breeds in the rivers of the Barents Sea and the White Sea watersheds, the marine form of Arctic char (*Salvelinus alpinus*) and the Pacific salmon species: chum (*Oncorhynchus keta*) and pink (*O. gorbuscha*) salmon commonly occurring in the Bering and the Chukchi Sea and whose range is currently expanding further west as a result of climate change. Currently these species are regularly caught by fishermen in the mouth of Kolyma River. Pink salmon was introduced in the late 1950s into the White and the Barents Seas [Berger, 2001] and now this species is entering the rivers in the western Kara Sea. Semi-anadromous fish mostly include whitefish (Coregonidae) and smelts but also Siberian sturgeon (*Acipenser baerii*).

Distribution of total allowable catches (TAC) of semi-anadromous fish, mostly coregonids as presented in Map 3.11 may be considered as a proxy for an assessment of the importance of RMS as biotopes for valued commercial species. In the Severnaya Dvina RMS anadromous fish stocks are relatively low. The Atlantic salmon stock in this river is very depleted. In the Pechora watershed, previously home to the greatest numbers of salmon, the size of the stock has now declined: commercial quotas for Atlantic salmon in the Pechora River have not been set for several decades with the result that only so-called «scientific» fishery estimates are carried out which provide little insight into the current status of the fish stock. The population of inconnu (*Stenodus leucichthys nelma*) has also declined. The core of the anadromous fish assemblage consists currently of sardine cisco (*Coregonus sardinella*), whitefish (*C. lavaretus sensu lato*), muksun (*C. muksun*) and Arctic cisco (*C. autumnalis*).

Gulf of Ob (Obskaya Guba) and the associated Taz River mouth (Tazovskaya Guba) are nursery grounds for juveniles of sturgeons, coregonids (muksun, peled — *Coregonus peled*, humpback whitefish — *C. lavaretus pidshian*, broad whitefish, sardine cisco, Arctic cisco), and smelt (*Osmerus mordax dentex*). These bays also serve as wintering grounds for both the juveniles and adults of these species. The key to life in this huge estuary is river discharge. Its value determines spatio-temporal characteristics of the hydrological regime, and in turn the environmental conditions for all stages of fish lifecycles: reproduction, foraging/growth periods, and wintering. More favourable conditions for fish stocks in the Ob'–Irtysh watershed are associated with medium and high water discharge. Important factors are the spring flood levels and the duration of flooding of the spawning and foraging areas in river valleys. Along with temperature conditions they determine the effectiveness of spawning and egg survival, and the development of food resources. Interactions of the river flow and tides play a tremendous role in determining distribution patterns and dynamics in Ob'–Taz river mouth area. The Ob'–Taz RMS supports the largest stocks of sardine cisco, humpback whitefish, muksun and smelt. The role of the characteristic polar species, Arctic cisco in this assemblage is relatively unimportant as this fish prefers RMSs with higher salinity and does not breed in the Ob' watershed. The area of greatest concentrations of this species is located near Oleniy Island in the Kara Sea, where fisheries exploit the Yenisei stock of Arctic cisco, as well as Gydan Bay.

The importance of the semi-anadromous fish stocks of Yenisei and the Yenisei Bay cannot be compared to that of the Ob'–Taz RMS. Muksun, humpback whitefish, sardine cisco and Arctic cisco are the key species here. The Yenisei has experienced lower rates of discharge (about 17% in average years) because of dam construction; this is expected to drop further following completion of the Boguchanskaya Hydroelectric Power Plant in Angara. The less water Yenisei brings to the Kara Sea the more changes are expected in the RMS as well as in the marine ecosystems and respective fish stocks.

Sardine cisco and muksun play a major role in the assemblages of semi-anadromous fishes of large rivers entering the Laptev and the East-Siberian seas. In the RMS of Lena and Indigirka stocks of Arctic cisco and inconnu, although depleted, remain significant. While the first species mostly foraged in marine and brackish waters, Lena's inconnu uses a wide range of habitats for feeding and growth: from the shelf areas in the delta to the rivers themselves. Sturgeons are also present in the watersheds of the Laptev and the East Siberian Seas, but, in contrast to the RMS of the Kara Sea where they are semi-anadromous, sturgeons in the Lena, Yana, Indigirka and Kolyma usually do not leave the rivers [Ruban, 1999]. While the Lena sturgeon populations are in better condition, the semi-anadromous stocks in other watersheds have become greatly depleted. From the early 1990s the sturgeon populations in the Ob' and Yenisei declined greatly due to increased poaching in post-Soviet Russia [Ruban, 1999; data of the directorate «Zapsibrybvod»]. The Yenisei sturgeon fishery is now closed while the Ob' sturgeon has been listed in the Red Data Book of the Russian Federation. Practically all populations of anadromous and semi-anadromous fishes are threatened by illegal catch (most of specialists of the state institutions gathering fishery statistics agree that real catches may be 2–3 times higher than reported), dam construction, and watershed pollution. There is an urgent need to develop plans for stock restoration and fishery management, where functional zoning of the RMS should play a major role.

Addendum

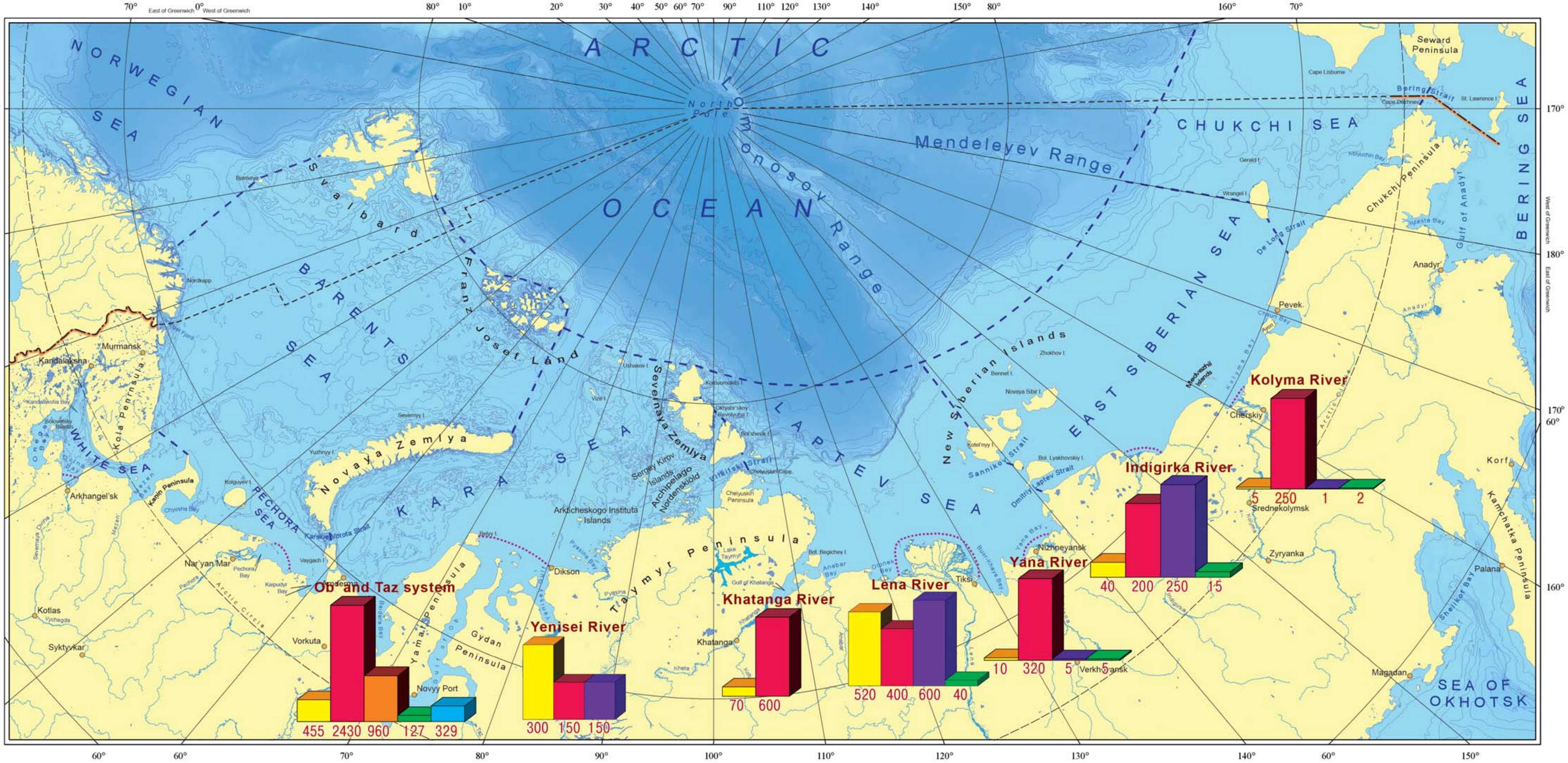
RMS includes the following features:

— River mouth — a fragment of the river where winds and tides cause pronounced variations in the water level (outside of the area of the salinated waters' expansion);

— Estuary — a semi-closed system of water bodies within the RMS where general mixing of riverine and marine water masses takes place; it is connected to the sea permanently or periodically [Schubel, Pritchard, 1971; Mikhailov et al., 2009];

— Delta — a cone-shaped surface formed by sediment deposits at the mouth of the river which has a complex and dynamic hydrographic network branching from a common node and is characterized by a specific landscape [Mikhailov, 1997];

— Near river seaside — a part of the sea which is strongly influenced by the impact of the river; a distinction can be made between the semi-closed near river seasides (inside the marine bay) and open ones.



Fish species

- Muksun
- Sardine cisco
- Whitefish – Siberian Whitefish (Pydschjan)
- Arctic cisco
- Inconnu
- Smelt

300 — Total Allowable Catch (tons)

Sea boundaries of the river mouths areas

Boundary of the Arctic seas

State border of the Russian Federation

Boundary of the polar domains of the Russian Federation

Scale 1 : 16,000,000

Compiled by *F.I. Lashmanov* and *A.V. Makarov.*
Source: Federal Agency of Fishery

Section 4

SPECIALLY PROTECTED NATURAL AREAS AND OTHER RECOGNIZED AREAS OF CONSERVATION VALUE

4.1. FEDERAL MARINE AND COASTAL SPECIALLY PROTECTED NATURAL AREAS *V.A. Spiridonov, Yu.V. Krasnov, N.G. Nikolaeva* and *M.V. Gavrilo*

Protected natural areas fulfill several important tasks. These include creating areas where nature is allowed to provide for itself; where species, populations and their communities are allowed to thrive free of negative influences; and where they can use their own natural mechanisms to adjust to changing conditions, with minimal intervention from humans. Zapovedniks are also intended to alert us to changes taking place in nature. In Russia zapovedniks have traditionally served as research stations. Under Russian legislation the internal marine waters, territorial sea, Exclusive Economic Zone (EEZ) and Continental Shelf all come under federal jurisdiction. Thus, legally, marine protected areas have federal status. They are regulated by the Federal Law «On specially protected natural areas» (# 33 FZ of 14 March 1995).

The patchwork of federal protected natural areas in the Arctic coastal zone has been shaped by a long history (Map 4.1; Table 4-1). Perspective planning and analysis of the challenges inherent to preserving marine biological diversity have played no significant role in its formation. Rather, protected areas were created on parcels important for biodiversity conservation only where it was feasible. Four Arctic zapovedniks include marine areas (Kandalakshskiy, Nenetskiy, Great Arctic, Taymyrskiy, Wrangel Island («Ostrov Wrangelya»)), while two zapovedniks include only buffer maritime zones (Gydanskiy and Ust'-Lenskiy). Koryakskiy zapovednik, another federal strict nature reserve with two marine areas, is located in the south-western Bering Sea. Recently a new national park, the «Russian Arctic» was designated in the north of the Novaya Zemlya area. It includes a marine zone extending up to the border of the territorial sea (12 nautical miles). In addition to these there are four federal zakazniks (reserves) with marine or coastal areas: Franz Josef Land, Nenetskiy, Nizhne-Obskiy and Severozemelskiy, and the Mogilnoe Lake Federal Natural Monument (Table 4—1). Federal protected areas include a variety of marine and coastal areas but their importance in the context of the general aims of marine environment and biodiversity protection differs significantly.

The total area of all offshore zones located within the federal protected areas in the Arctic Ocean (excluding the Bering Sea) amounts to 95,583 km^2, which constitutes ca. 2% of the area of Russia's Arctic Seas (internal marine waters, territorial sea and the EEZ).

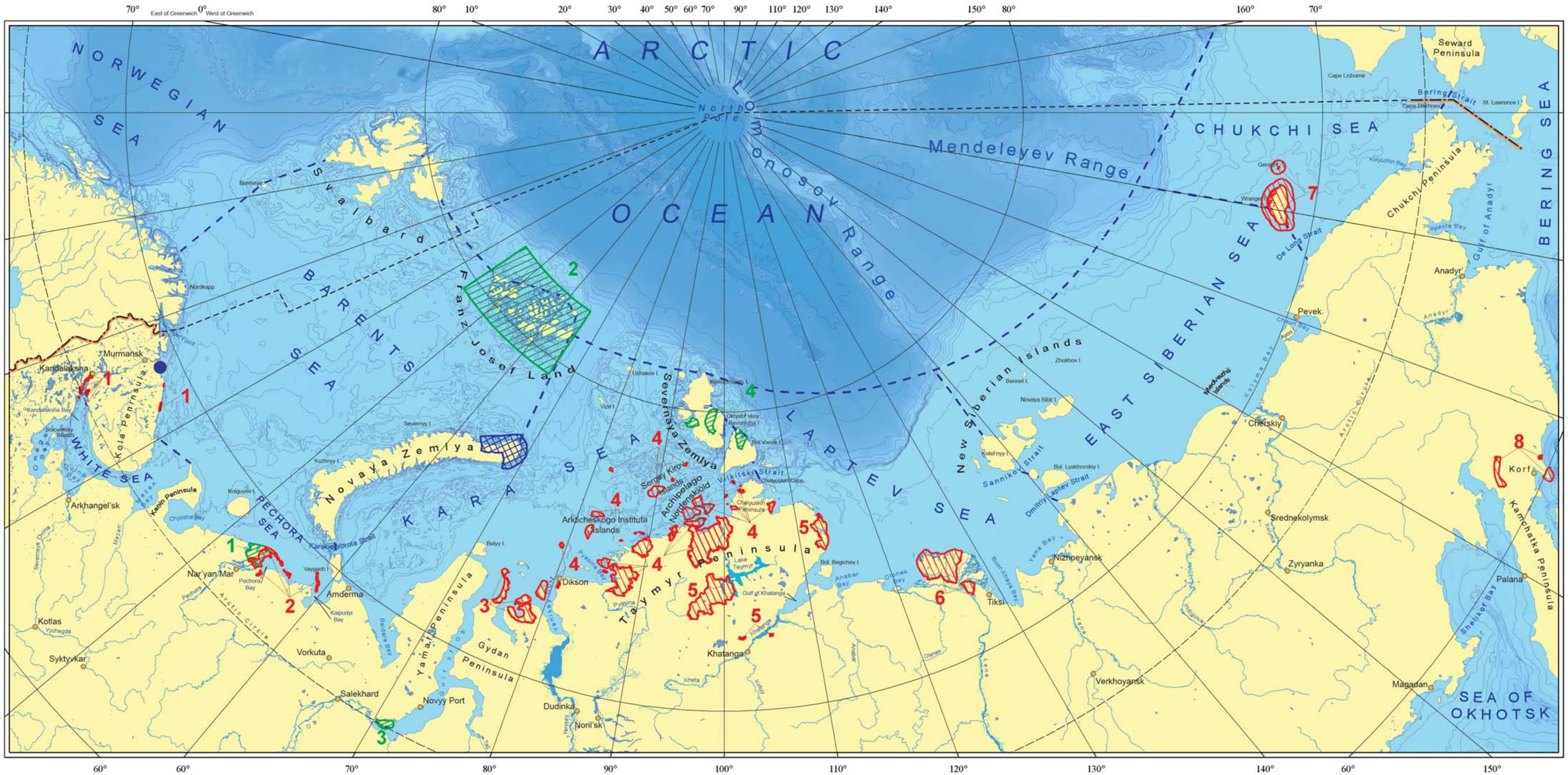
Zapovedniks are federal institutions with their own budgets and staff but limited capacity for maritime activities. A 2008 Management Effectiveness Assessment of the Arctic zapovedniks with emphasis on marine and coastal areas (using the Management Effectiveness Scorecard — METT; maximum score 100) resulted in relatively low scores. The indices calculated for specific reserves ranged between 29 and 50. For the sake of comparison it is worth noting that zapovedniks located in other parts of Russia which focus on protection of marine and brackish water ecosystems, the Far Eastern Marine Biosphere Zapovednik and the Astrakhanskiy Biosphere Zapovednik, achieved the highest scores of 63 and 62 respectively. This indicates that there is much room for improvement in the effectiveness of existing marine and coastal protected areas in the changing Arctic.

Coastal tundra on Dolgiy Island, zapovednik Nenentskiy [36]

Table 4-1. Federal marine and coastal specially protected natural areas in the Russian Arctic. Size data are mainly from Zabelina et al. (2006).
International status:
RW — Wetland of International Importance (Ramsar site); BR — UNESCO Biosphere Reserve; WH — World Heritage site.

	Name	International status	Sea	Area on land (ha)	Area at sea (ha)	Total area (ha)	Marine buffer zone (ha)	Year of establishing
	Zapovedniks, or strictly protected reserves (category I IUCN)							
1.	Great Arctic		Kara, Laptev	3 188 288	980 934	4 169 222	0	1993
2.	Gydanskiy		Kara	878 174	0	878 174	60 000	1996
3.	Kandalakshskiy	RW	Barents, White	20 947	49 583	70 530	0	1932
4.	Koryakskiy	RW	Bering	244 156	83 000	327 156	0	1995
5.	Nenetskiy		Barents	131 500	181 900	313 400	242 800	1997
6.	Taymyrskiy	BR	Laptev	1 744 910	37 018	1 781 928	0	1979 (1994)*
7.	Ust'-Lenskiy		Laptev	1 433 000	0	1 433 000	1 050 000**	1985
8.	Wrangel Island	WH	Chukchi	795 650	1 430 000	2 225 650	3 240 000	1976
	National parks (category II IUCN)							
9.	"Russian Arctic"		Barents, Kara	632 090	793 910	1 426 000	0	2009
	Zakazniks, or natural reserves (category IV-V IUCN)							
10.	Franz Josef Land		Barents	1 600 000	2 600 000	4 200 000	0	1994
11.	Nenetskiy	RW	Barents	188 500	120 000	308 500	0	1985
12.	Nizhne-Obskiy	RW	Kara	128 000	0	128 000	0	1985
13.	Severozemelskiy		Kara, Laptev	367 771	53 930	421 701	0	1996
	Nature monuments (category III IUCN)							
14.	Mogilnoe Lake		Barents	0	17	17	0	1985

* year of inclusion of the regional SPNA "Bikada" into the zapovednik.
** buffer zone includes the New Siberian Islands and the regional resource reserve "Lena-Delta" (4.2)



Zapovedniks

1 — Kandalakshskiy
2 — Nenetskiy
3 — Gydanskiy
4 — Great Arctic
5 — Taymyrskiy
6 — Ust'-Lenskiy
7 — Wrangel Island ("Ostrov Wrangelya")
8 — Koryakskiy

National Parks

"Russian Arctic"

Zakazniks

1 — Nenetskiy
2 — Franz Josef Land
3 — Nizhne-Obskiy
4 — Severozemelskiy

Natural Monuments

Mogilnoe Lake

State border of the Russian Federation

Boundary of the polar domains of the Russian Federation

Scale 1 : 16,000,000

Compiled by *A.V. Makarov*

Source: Boudaries of zapovedniks and zakazniks after [Cartographic base.., 2002–2010]

Types of SPNAs and approaches to the planning of protected areas differ considerably in the various administrative regions of Russian Federation. In the Murmansk Oblast' nature monuments are most common, in the Republic of Karelia zakazniks make up the bulk of protected areas, while in the Republic Sakha – Yakutia the preferred category is a resource reserve (Map 4.2; Table 4-2).

The range of natural areas, biotopes and objects under protection is indeed broad. It includes geological nature monuments, natural therapeutic mud grounds, unique forms of coastal geomorphology, landscapes or coastal vegetation. A considerable number of protected areas have been established to protect wetlands that contain nodes of migration routes and breeding areas of water birds, i.e. most of the zakazniks in Karelia, the Arkhangelsk Oblast' and several resource reserves in Yakutia [Zabelina et al., 2006]. Some of them support protection of internationally important wetlands designated as Ramsar sites: the Polyarnyi Krug and Kuzova Islands zakazniks in the White Sea, the Brekhovskie Islands in the Kara Sea and Karaginskiy Island in the Bering Sea. These protected areas are supplemented with offshore zones, but the legislative basis for such inclusion is vague.

The regional coastal protected areas network can potentially be further expanded with the focus on marine ecosystem conservation. In doing this particular attention should be given to salt marshes, colonies and areas of water birds in non-breeding concentrations (molting and wintering areas, migration stopovers), haul-outs of marine mammals (primarily walruses), and denning areas of polar bears. All these phenomena are spatially explicit and relatively long-lived. Salt marshes are very poorly covered by special protection, for example, the Nenentskiy and Chaunskaya Guba zakazniks.

Tufted puffin (*Lunda cirrhata*) [38]

Recently marine conservation priorities have been taken into account when establishing two coastal nature monuments in the Murmansk Oblast': in the Ivanovskaya Guba, with biotopes of sea grass (*Zostera marina*) at the boundary of its distribution range in the Atlantic, and in the Dvorovaya Guba, where sea bird colonies are located. Another example can be found in Chukotka, where a nature monument was established on Cape Vankarem to protect the walrus haul-out area, which is growing and becoming increasingly important in these times of changing climate.

In most cases regional protected areas have neither funding nor enforcement staff, and this seriously impedes monitoring and management. In some regions the situation is less critical due to recently established directorates of specially protected nature reas which manage all regional nature monuments, zakazniks and nature parks. Some coastal protected areas are overseen by scientific institutions and NGOs. For example the N.A.Pertsov White Sea Biological Station of the Moscow University supports the Polyarnyi Krug zakaznik. This is one way to achieve effective monitoring and protection of the coastal regional protected areas.

Walrus (Odobenus rosmarus divergens) haul-out [37]

Table 4-2. Coastal regional SPNAs of the Russian Arctic shown on Map 4.2.

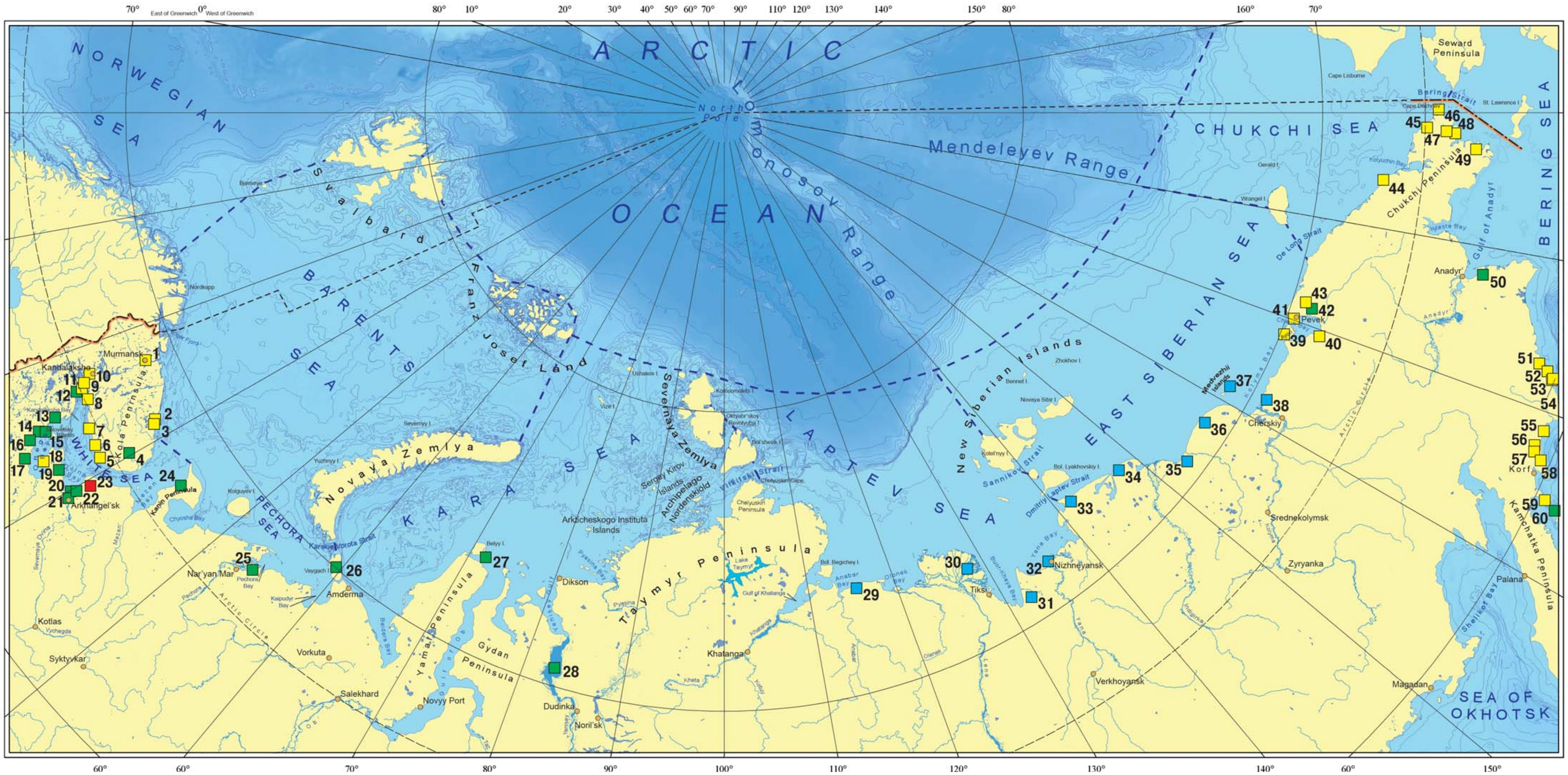
Order follows West-East direction.

Types of SPNAs (in brackets IUCN category): **NR** — natural reserve, or zakaznik (IV–V); **NM** — nature monument (III); **NP** — nature park (IV); **RR** — resource reserve (V).

Regions: **MO** — Murmansk Oblast'; **RK** — Republic of Karelia; **AO** — Arkhangelsk Oblast'; **NAO** — Nenets Autonomous District; **YaNAO** — Yamal-Nenets Autonomous District; **KK** — Krasnoyarskiy Krai; **S-Ya** — Republic Sakha-Yakutia; **KAM** — Kamchatskiy Krai; **ChAO** — Chukotka Autonomous District.

Data from Zabelina et al. [2006] with additions of information obtained from the regional administration and the Kola Branch of Biodiversity Conservation Centre. Nature Park Berengia, occupying most of Chukotka Peninsula is not shown on Map 4.2.

# on Map	Name	Type	Region
1.	Geological monument near Semenovskoe Lake	NM	MO
2.	Sea bird bazaars of Dvorovaya Inlet	NM	MO
3.	Guba Ivanovskaya	NM	MO
4.	Ponoiskiy	NR	MO
5.	Waterfall on Chapoma River	NM	RK
6.	Waterfall on Chavan'ga River	NM	MO
7.	Ametists of Cape Korabl'	NM	MO
8.	Flyorites of Elokorgovskiy Navolok	NM	MO
9.	Endoziyes of Verchnyi Navolok Cape	NM	MO
10.	Medical mud of Palkina inlet of the White Sea	NM	MO
11.	Granitoids of Mikkov Island	NM	MO
12.	"Polarnyi Krug"	NR	RK
13.	Von'gomskiy	NR	RK
14.	Shoiostrovskiy	NR	RK
15.	Kuzova Islands	NR	RK
16.	Sorokskiy	NR	RK
17.	Bog near Nyukhcha Village	NR	RK
18.	Planted forest near Lyamtsa village	NM	AO
19.	Unskiy	NR	AO
20.	Dvinskiy	NR	AO
21.	Mudyugskiy	NR	AO
22.	Belomorskiy	NR	AO
23.	Promorskiy	NP	AO
24.	Shoinskiy	NR	NAO
25.	Nizhnepechorskiy	NR	NAO
26.	Vaygach	NR	NAO
27.	Yamalskiy	NR	YaNAO
28.	Brekhovskie Islands	NR	KK
29.	Terpei-Tumus	RR	S-Ya
30.	Lena Delta (incl. New Siberian Islands)	RR	S-Ya
31.	Omoloi	RR	S-Ya
32.	Yana Delta	RR	S-Ya
33.	Buustakh	RR	S-Ya
34.	Kytalyk	RR	S-Ya
35.	Chaigurgino	RR	S-Ya
36.	Kurdigino Krestovaya	RR	S-Ya
37.	Medvezhyi Islands	RR	S-Ya
38.	Kolyma-Koren (Kolyma-Delta)	RR	S-Ya
39.	Ayonskiy	NM	ChAO
40.	Pineiveemskiy	NM	ChAO
41.	Routanskiy	NM	ChAO
42.	Chaunskaya Guba	NR	ChAO
43.	Utinyi	NM	ChAO
44.	Cape Vankarem	NM	ChAO
45.	Chegitunskiy	NM	ChAO
46.	Vostochnyi	NM	ChAO
47.	Termalnyi	NM	ChAO
48.	Mechigmenskiy	NM	ChAO
49.	Klyuchevoi	NM	ChAO
50.	Avtotkuul	NR	ChAO
51.	Bukhta Anastasii	NM	KAM
52.	Bogoslova Island	NM	KAM
53.	Cape Witgenstein	NM	KAM
54.	Island Kekur Witgensteina	NM	KAM
55.	Cape Groznyi	NM	KAM
56.	Potat-Gytkhyn Lake	NM	KAM
57.	Ilkir-Gytkhyn Lake	NM	KAM
58.	Yuzhno-Glubokaya Inlet	NM	KAM
59.	Verkhoturov Island	NM	KAM
60.	Karaginskiy Island	NR	KAM



Regional coastal specially protected natural areas:

- Zakazniks
- Nature Monuments
- Nature Park
- Resource Reserves

- State border of the Russian Federation
- Boundary of the polar domains of the Russian Federation

Scale 1 : 16,000,000

Compiled by *A.V. Makarov* and *V.A. Spiridonov.*

Sources: *Zabelina* et al. [2006] with additions of the data provided by administrations of Karelia Republic, Chukotka Autonomus District, Arkhangel'sk and Murmansk regions, and the Kola Branch of Biodiversity Conservation Centre. Names of SPNA are given in Table 4-2.

Important Bird Areas (IBAs) are areas that are particularly important for maintaining the biological diversity of the birds on our planet. Their identification was initiated by the international association for the protection of birds and the environment, BirdLife International; in the Russian Federation this work has been implemented by the Russian Bird Conservation Union since 1994 [Important Bird Areas.., 2000, 2006]. Only those areas which fit strict quantitative criteria approved by BirdLife International may be recognized as IBAs. For globally endangered bird species, those areas which are home to the greatest populations of such species are able to acquire IBA status. For waterbirds forming aggregations, the criteria for IBA designation has been set at a limit of 1% of the global or European species population. Narrow corridors, which act as migration paths for more than 1% of a migrating species' population also qualify for IBA status. Another criterion for IBA status is the biomic criterion which focuses on protection of sensitive ecosystems where birds provide an indication of the value of ecosystems. In the Arctic one such biome, i.e. the tundra, has been designated. In this particular biome, an area is designated an IBA if it includes the habitats of at least five stenotopic (specialized) species.

Thanks to the efforts of dozens of ornithologists, more than 700 IBAs have been designated in the last 15 years in Russia; 84 of them are located in the Arctic (of these, 79 are marine and coastal — Table 4–3). Sea coast and coastal tundras provide nesting habitats for many bird species which, after breeding season, disperse over all continents including America, Australia and even Antarctica. Several migration paths extend along the coastal zone; as these routes cross entire geographical regions «bottlenecks» are sometimes created at the points where populations and species meet. Marine shallows provide safe habitats for large numbers of waterbirds which moult before migrating from the north and are unable to undertake long journeys at this stage of their lifecycle. Some seabird species spend their entire lives in the Arctic, never leaving polar latitudes. They gather for wintering at the sea ice edge and in large polynyas which do not freeze even during most severe winters. Finally, seabird colonies should be mentioned as a symbol of Arctic wildlife. Seabird colonies occupy suitable rocky shores, mostly on large and small Arctic islands.

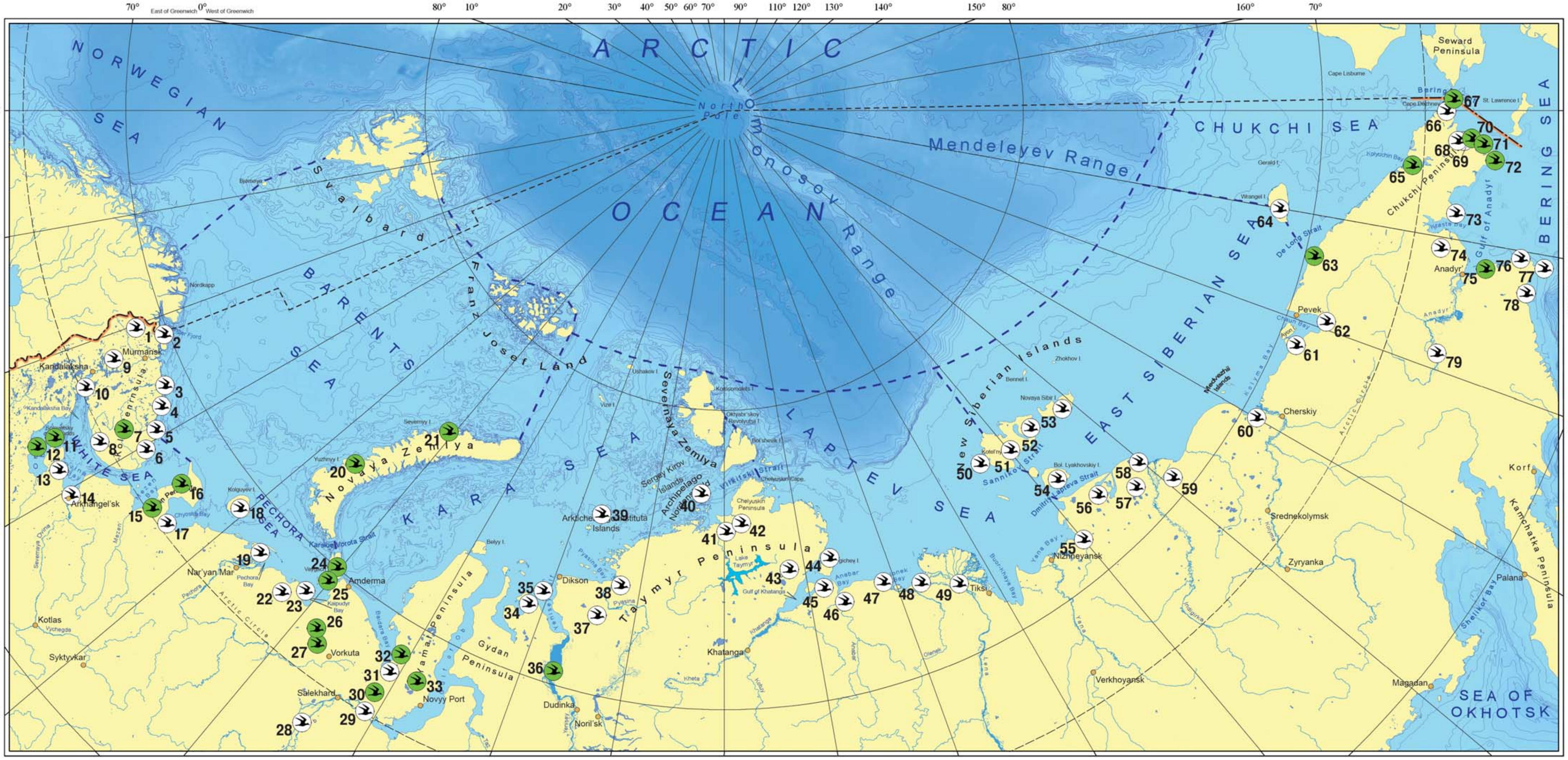
Arctic Important Bird Areas are usually extensive territories and parts of marine basins. Two-thirds of the IBAs extend to more than thousand square kilometres each, occupying a total of some 270,000 km^2. They include separate islands and entire archipelagos, small inlets and large marine bays, peninsulas, capes, coastal spits, significant fragments of coastal shallows, extensive deltas of large Siberian rivers and the lower streams of medium-sized rivers, and salt and brackish water lagoons (Table 4–3; Map 4.3). As a rule, terrestrial zones of the Arctic IBAs are covered by lowland, hilly or mountain tundras, with the northernmost ones located within the area of the Arctic deserts. Polar Russia has a plenty of lakes and peatlands; the river network is very dense; most of the country's polar land is in the permafrost zone, where only the upper thin layer of soil thaws out in summer.

The majority of Important Bird Areas are located in inaccessible places where anthropogenic influences are limited to the indirect effects of transboundary pollution and industrial fishing which influence trophic conditions. In some areas, poaching is a real threat; in some places local people collect eggs thereby negatively impacting upon seabird populations. In the shelf areas hydrocarbon exploration, extraction and transportation are becoming a growing threat. Similarly, water pollution from industrial sources and agriculture is a reality in the lower streams of rivers and estuaries. Some IBAs have now become popular tourist destinations, and the increase in the number of visitors may further disturb the birds. Places with higher concentrations of birds of prey are the focus of criminal interest on the part of individuals involved in the illegal trade of falcons and hawks.

Many Important Bird Areas do not have protected natural area status, and only half of the Arctic IBAs are protected by zapovedniks, zakazniks, national and natural parks and natural monuments. Among currently unprotected areas are some very valuable sites which require the urgent establishment of a special protection regime (Map 4.3). What these areas require urgently is the development of action plans which include strategies for the protection of key bird species along with targets for economic development and which factor in the needs of local populations.

Table 4–3. List of Important Bird Areas in the maritime Russian Arctic

# on Map	Code	Name	# on Map	Code	Name
1.	EU-RU011	Surrounding of Kiesh'yaur Lake	41.	AS-RU012	Lower (Nizhnyaa) Taymyra River
2.	EU-RU	Ainov Islands	42.	AS-RU014	Lower Leningradskaya River
3.	EU-RU010	Gavrilovski Archipelago	43.		Gusikha River Basin with lower Bol'shaya River
4.	EU-RU004	Seven Islands	44.	AS-RU058	Preobrazheniya Island
5.	EU-RU005	Coast Belt of Eastern Murmansk	45.	AS-RU016	Khara-Tumus Peninsula and Norvik Bay
6.	EU-RU437	Terski Coast	46.	AS-RU059	Anabar
7.	EU-RU007	Ponoiskaya Depression	47.	AS-RU060	Terpyaya-Tumus
8.	EU-RU006	Watershed of the rivers Strelna and Varzuga	48.	AS-RU061	Olenek (Olenyok) Bay
9.	EU-RU008	Lapland Biosphere Reserve	49.	AS-RU062	Lana Delta
10.	EU-RU009	Kandalaksha Bay	50.	AS-RU065	Bel'kovskiy Island
11.	EU-RU020	Solovetski Archipelago and Zjizjginski Island	51.	AS-RU066	Kotelnyi Island
12.	EU-RU018	Onega Bay of the White Sea	52.	AS-RU070	Faddevskiy Island
13.	EU-RU270	Unskaya Bay (Unskaya Guba)	53.	AS-RU071	Novaya Sibir' Island
14.	EU-RU022	Delta of River Severnaya Dvina	54.	AS-RU068	Bol'shoi Lyakhovskiy Island
15.	EU-RU034	Kanin Peninsula	55.	AS-RU062	Yana Delta and Suruktyakh River
16.	EU-RU021	Torna-Shoina watershed	56.	AS-RU072	Sanga-Yuryakh
17.	EU-RU033	Southern coast of Cheshskaya Bay (Chyosha Bay, Chyoshskaya Guba)	57.	AS-RU072	Kytalyk
18.	EU-RU436	Kolguev Island	58.	AS-RU074	Indigirka Delta
19.	EU-RU036	Russki Zavorot Peninsula and eastern part of Malozemelskaya tundra	59.	AS-RU076	Kremesit-Sundrun watershed
20.	EU-RU025	Bezymyannaya and Gribovaya Bays and adjoining waters	60.	AS-RU075	Kolyma Delta
21.	EU-RU026	Arkhangelskaya Bay	61.	AS-RU078	West Chaun Plain
22.	EU-RU032	River Chernaya	62.	AS-RU079	Chaun Delta
23.	EU-RU031	Varandeiskaya Lapta Peninsula	63.	AS-RU081	Billings Cape
24.	EU-RU030	Vaygach Island	64.	AS-RU082	Wrangle Island
25-26.	EU-RU035	Khaipudyrskaya Bay, islands of B. Zelenets, Dolgi, Matveev	65.	AS-RU087	Vankarem Lowland and Kolyuchin Bay
27.	EU-RU029	Vashutkiny, Padimeyskie and Kharbeiskie lakes	66.	AS-RU091	Ichoun and Uelen Lagoons
28.	WS-RU000	Dvuob'e	67.	AS-RU092	Ratmanova Island
29.	WS-RU000	Lower Ob'	68.		Mechigmen Bay (Guba)
30.		Basins of Schuchya and Khaytayakha rivers	69.		Mechigmen Bay and Getlyagen Lagoon
31.	WS-RU000	Valley of Yorkutayakha River	70.	AS-RU090	Khalyustkin Cape
32.	WS-RU000	Lower Yuribey	71.	AS-RU089	Senyavina Strait
33.	WS-RU000	Upper and Middle Yuribey	72.	AS-RU088	Sireniki Coast
34.	AS-RU001	Oleniy Island and Yuratskaya Bay (Guba)	73.	AS-RU086	Meechkyn Spit and adjacent plain
35.	AS-RU002	Sibiryakova Island	74.	AS-RU083	Kanchalan River Basin
36.	AS-RU004	Brekhovskie Islands	75.	AS-RU084	Lower Anadyr Lowland
37.	AS-RU005	Pur River Basin	76.		Beringovski
38.	AS-RU006	Pyasina Delta	77.		Navarin Cape
39.	AS-RU003	Izvestiy TSIK Islands	78.	AS-RU085	Meynypylginsi and Kapylgin lakes
40.	AS-RU011	Nordenshal'da Archipelago (Nordenskjold Archipelago)	79.	AS-RU080	Lebediny Refuge (Markovo Depression)



Important Bird Areas

Important Bird Areas. Federal specially protected areas proposed for establishment on the base of Important Bird Areas

State border of the Russian Federation

Boundary of the polar domains of the Russian Federation

Scale 1 : 16,000,000

Marine and sea-dependent bird species protected by the Important Bird Areas in the Russian Arctic:
Pelagic Cormorant (*Phalacrocorax pelagcus*), Shag (*P. aristotelis*), Barnacle Goose (*Branta leucopsis*), Brent Goose (*Branta bernicla*), Pintail (*Anas acuta*), Scaup (*Aythya marila*), Goldeneye (*Bucephala clangula*), Long-tailed Duck (*Clangula hyemalis*), King Eider (*Somateria spectabilis*), Common Eider (*S. mollissima*), Steller's Eider (*Polysticta stelleri*), Spectacled Eider (*S. fischeri*), Velvet Scoter (*Melanitta nigra*), Red-breasted Merganser (*Mergus serrator*), White-tailed Eagle (*Haliaeetus albicilla*), Peregrine Falcon (*Falco peregrinus*), Gyr Falcon (*Falco rusticolus*), Ringed Plover (*Charadrius hiaticula*), Wood Sandpiper (*Tringa glareola*), Terek Sandpiper (*Xenus cinereus*), Ruff (*Philomachus pugnax*), Spoon-billed Sandpiper (*Eurynorhynchus pygmeus*), Temminck's Stint (*Calidris temminckii*), Little Stint (*C. minuta*), Curlew Sandpiper (*C. ferruginea*), Purple Sandpiper (*C. maritima*), Dunlin (*C. alpina*), Red-necked Phalarope (*Phalaropus lobatus*), Arctic Skua (*Stercorarius parasiticus*), Long-tailed Skua (*Stercorarius longicaudus*), Great Black-backed Gull (*Larus marinus*), Lesser Black-backed Gull (*L. fuscus*), Claucous Gull (*Larus hyperboreus*), Ivory Gull (*Pagophila eburnea*), Kittiwake (*Rissa tridactyla*), Ross's Gull (*Rhodostethia rosea*), Arctic Tern (*Sterna paradisaea*), Little Auk (*Alle alle*), Rasorbill (*Alca torda*), Brunnich's Guillemot (*Uria lomvia*), Common Guillemot (*U. aalge*), Black Guillemot (*Cepphus grylle*), Crested Auklet (*Aethia cristatella*), Least Auklet (*A. pusilla*), Parakeet Auklet (*A. psittacula*), Atlantic Puffin (*Fratercula arctica*).

Compiled by *E.D. Krasnova*
Source: Data of the Russian Bird Conservation Union provided by *T.V. Sviridova, S.A. Bukreev* and *E.D. Krasnova* with consultations of *Yu.V. Krasnov*

Conclusions

OUTLINES OF FUTURE MARINE SPATIAL PLANNING OF THE RUSSIAN ARCTIC

The place of Russia in the northern arena is also determined by its geographic dominance in the circumpolar space, which allows Russia to initiate global northern projects and makes it responsible for understanding the historical role of the North.

A.V.Golovnev,
"Anthropology of Movement", 2009

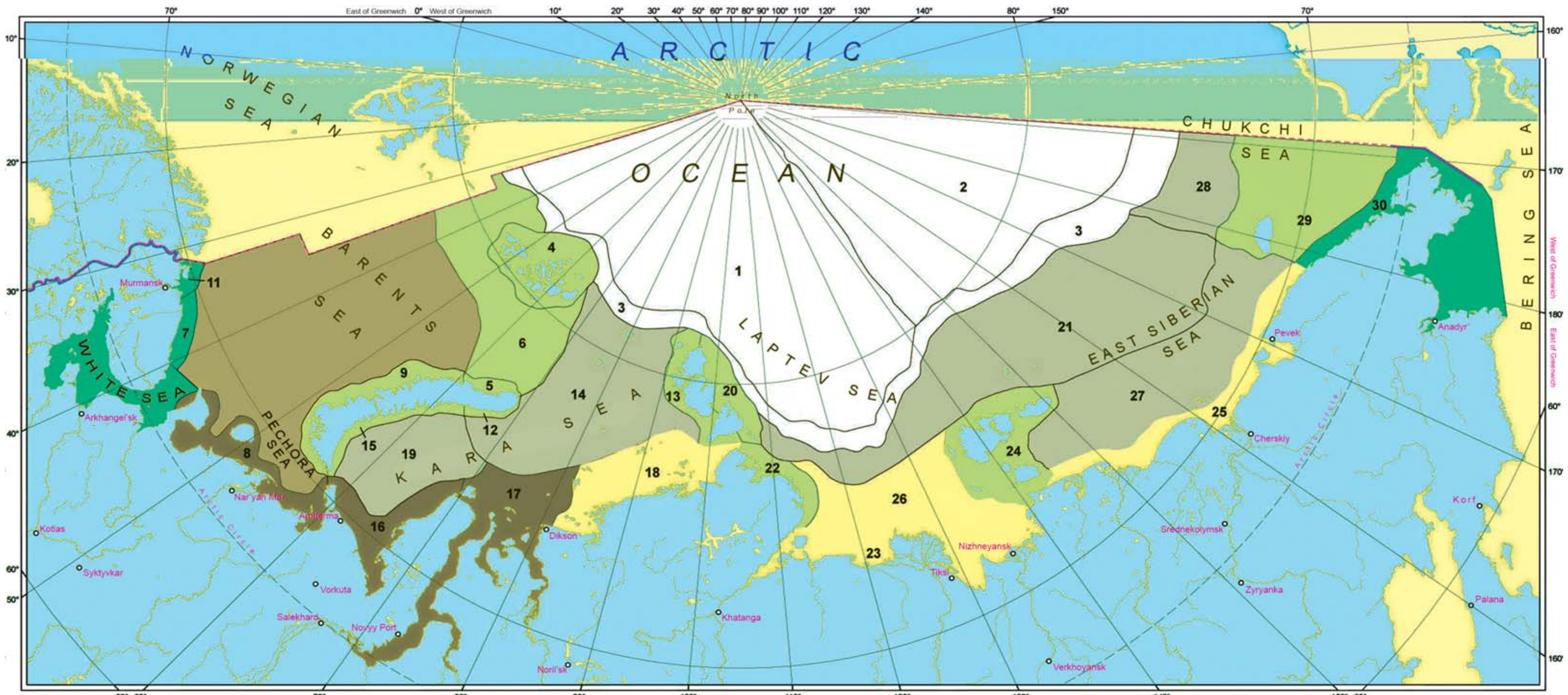
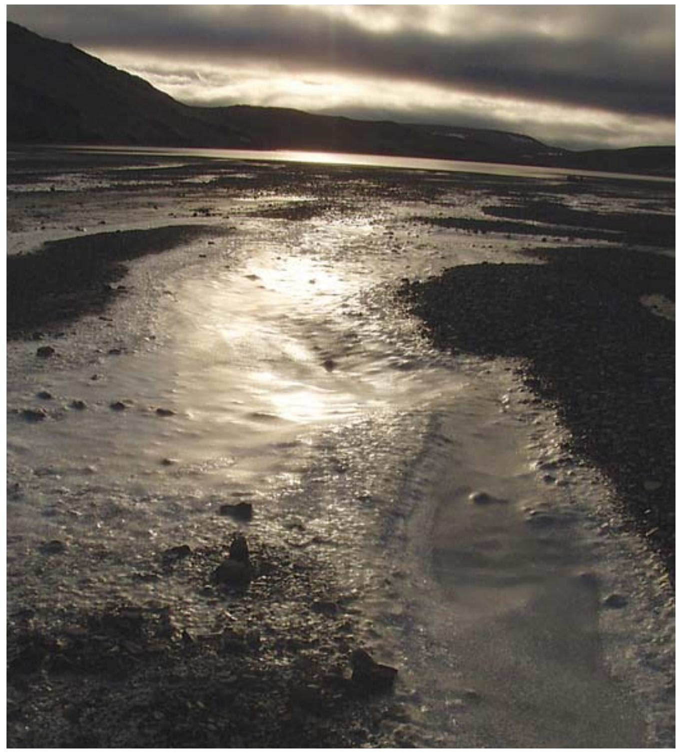


Fig. C-1. Proposed initial scheme of marine spatial planning for the Russian Arctic seas and adjacent parts of the Arctic Basin 1, 2, 3 — the Arctic Basin zone; 4, 5, 6, 12, 13, 20, 22, 24, 29 — zone of extensive natural protected areas; 10 — zone of commercial fishery managed on the ecosystem basis; 7, 11, 30 — White Sea, Chukotka waters — zone of multiple use; 8, 16, 17 — zone of intensive shipping along the Northern Sea Route; 18, 23, 25, 26 — zone of potentially intensive shipping; 14, 19, 21, 27, 28 — zone of scientific exploration and episodic use.
For explanations see text.

In this Atlas we considered the components of marine biotopic and biological diversity which the authors view as most essential in the era of changing climate and increasing anthropogenic pressures. This first, and no doubt, incomplete review does not settle the matter of how to best assess and conserve marine and coastal biodiversity in the Arctic seas and the coastal zone. We hope that this work will serve as an intermediary step for the preparation of more comprehensive updates, reviews, atlases and interactive information resources dedicated to Arctic biological diversity. We believe that scientific and public discussions and a consultation process for the Arctic marine spatial planning proposal should already be underway. Our material makes its possible to give a preliminary outline of the future marine spatial planning. That proposal calls for the conservation of biological diversity, the protection of marine living resources and the maintenance of marine ecosystem services to be priorities. For convenience we use the scheme of physiographical regionalization presented in this Atlas (2.1). We do not imagine that this scheme alone will be used in subsequent stages of the consultation process. Depending on environmental conditions, characteristics of biological diversity, contributions to large-scale ecosystem processes, the history of exploitation and the practice and potential of marine resources usage, marine zones and provinces can be grouped in several functional zones (Map 2.1 and Fig. C-1).

The deep-water zone of the Arctic Basin comprises the provinces West Polar Arctic (1), East Polar Arctic (2) and the province of continental slope (3). For the most part this zone does not belong to the continental shelf (this notion is used here in the juridical sense) of the Russian Federation. Regardless of the decision by the UN Commission on the Limits of Continental Shelf on Russia's application regarding sovereignty over the sea bed in the Lomonosov and Mendeleev ridges areas, this zone has to remain the priority area for scientific research and scientific and technical cooperation. The Arctic Basin is used (and no doubt will continue to be used) for strategic naval purposes, but an increase in economic activities on a significant scale in the following decades is difficult to imagine, even in a rapid warming scenario (apart from a limited development of extreme and cruise tourism on the «top of the planet»). As part of the country's application to extend its sovereignty over the sea bed of the Arctic underwater ridges and their bases, Russia has to outline special commitments for environmental protection in the Arctic Basin and pledge to carry out regular work aimed at monitoring the marine environment in the deep sea areas, and for identification of sea bed biotopes which are essential for the functioning of the marine Arctic ecosystems. A prerequisite for this is the unique experience and logistical capabilities to perform the basic and applied investigations of the Arctic Basin using the «Severnyi Polyus» drifting stations, as well as the ship- and aircraft-based platforms which our country has acquired.

Provinces 4, 5, 6, 13, 20, 22, 24, 29, and partly 12 (Fig. C-1) have to be considered as a zone of extensive protected natural areas with a priority usage for scientific research and monitoring as well as regulated polar tourism. Let us discuss in details the characteristics of this zone using the north-eastern Barents Sea — the provinces of the Franz Josef Land (4), of the Northern Novaya Zemlya (5), and the Northern Barents Sea province (6) as an example. The coastal waters of the Novaya Zemlya archipelago are also partly associated with this area. The north-eastern Barents Sea is the northernmost location for a large-scale interaction between the North Atlantic and the High Arctic biotas (see schemes of biogeographical regionalization in 2.2). Regular biological and oceanographic studies in the long-term research areas are highly relevant for understanding processes in the Arctic ecosystems under the influence of global climate change. These are areas of high biological diversity associated with flaw polynyas and the marginal ice zone (3.4 – 3.5); due to a combination of favorable conditions, the archipelago's coasts are home to numerous sea bird breeding colonies (3.3, 3.5), haul-outs of pinnipeds and denning grounds of polar bears. Two federal SPNAs are located there: the Franz Josef Land zakaznik, which occupies practically the entire area of province 4, and the Russian Arctic national park, which covers most of province 5 (1.2). Multi-aspect


Ukromnaya Inlet, Novaya Zemlya, Kara Sea [39]

environmental monitoring (on the basis of the Roshydromet network), atmospheric, oceanographic, sea ice, ecological and biodiversity studies (on the long-term research areas associated with SPNAs) and SPNA management should become the principal activities in the north-eastern Barents Sea. Victoria Island and the adjacent marine areas need to acquire protection status as well. Eco-tourism and educational tourism (mostly ship-based) are expected to become a developing economic activity. A unified tourism management plan for the Northern Barents Sea should be developed using the Russian Arctic national park and the Franz Josef Land Zakaznik as the basis (Map 4.1). This plan must apply the best world practices, in particular the practice of tourism regulation in the Antarctic Treaty area. Current climatic changes and the general tendency for the growth of the Barents Sea commercial fish stocks [Arneberg et al., 2009] may shift the zone of intensive industrial fishery to the shelf of the Northern Barents Sea province. The realization of such a scenario in a region of such high conservation value may cause far-reaching and unpredictable consequences. Thus a moratorium for commercial fishery can be considered an appropriate interim measure until reliable scientific data on the impacts of fishery on fishdependent ecosystem components are obtained.

Geologists believe that the Northern Barents Sea shelf has potential for hydrocarbon development. However, a robust evaluation of these hydrocarbon resources is lacking, while the expenses for reconnaissance and development are exceedingly high. When the very high environmental risks endemic to oil and gas projects in the highest latitudes are taken into account, the feasibility of such projects becomes very unclear.

The provinces of Kara – Severnaya Zemlya (13) and Laptev – Severnaya Zemlya (20) include unique insular habitats where the ivory gull (Pagophila eburnea) breeds and forages during its autumn migration. The ivory gull is an important symbol of the Russian Arctic. In the Kara and the Laptev Sea a healthy population of this highly-endangered Arctic species (3.5) exists, while in many other parts of its distribution ranges ivory gull populations are declining [Gavrilo et al., 2007, 2008; Gilchrist et al., 2008]. One can expect that the Severnaya Zemlya area will retain the high-latitude appearance of marine and coastal ecosystems — even if the scenario of rapid warming in the Arctic comes to pass [ACIA, 2005]. Thus the protection and monitoring of the biological diversity of this archipelago area are becoming extremely important for both basic science and global conservation. A small part of the Severnaya Zemlya Archipelago belongs to the Severozemelskiy zakaznik, which needs to be extended both on land and offshore. The East Taymyr Province is adjacent to it, and the fast ice and flaw polynyas biotopes of the region are extremely important for maintaining the biological diversity of the Laptev Sea (3.6). A parcel of the Taymyr Biosphere Zapovednik with a small marine buffer zone is located on the eastern coast of the Taymyr Penninsula. This marine zone must be expanded, at least up to the offshore border of polynyas, and regular research there must be undertaken.

The New Siberian Islands area (province 24) is no less valuable in terms of landscape and biological diversity (2.2; 3.6) than the insular areas discussed above. Additionally the New Siberian Islands are known for their paleontological and archaeological sites and monuments of the heroic era of Arctic explorations. We expect the Islands to soon become a focus area for polar tour operators. This is why a plan for a national park on the islands with an extensive marine zone would be very timely. The national park regime should be well planned to support and regulate tourism, development and scientific research on the New Siberian Islands.

The last area included in the zone of extensive natural protected areas is the Southern Chukchi Province with the coastal ecosystems of the Wrangel Island Zapovednik. There sea birds and marine mammals show high sensitivity and clear responses to changing climatic and sea ice conditions [Stishov, 2004]. As the observation of such responses becomes critically important in the changing Arctic, regular monitoring and research to understand these processes are sorely lacking in the zapovednik.

The Chukchi Sea shelf may contain (although it is not yet confirmed) hydrocarbon resources, which is why the oil and gas sector closely monitors the area. Recent reports have been published forecasting a significant increase in the fishery potential of the Chukchi Sea due to rising temperatures [Cheung et al., 2009]. However, without large scale oceanographic and biological research, all such conclusions regarding the potential resources of the Chukchi Sea shelf can not be considered as a basis for plans of future marine use and spatial planning. As a World Heritage site and a potential core area of a large scale biosphere reserve, the Wrangel Island state zapovednik will have a prominent place in this program. The Central Barents Sea Province (10) is one of the fishery regions of global importance. In the future it is viewed as a zone of commercial fishery managed on the ecosystem basis within the system of fishery refuge zones. The Shtokman gas-condensate field is also located in this area, and should be exploited in these first decades of the 21 st century with the most stringent measures to ensure environmental safety. The coastal waters and coasts of the Kola Peninsula and the entire White Sea, which have been used by humans for a century, should receive the status of multiple use zones. The Barents Sea coast of the Kola Peninsula and the adjacent coastal waters, e.g. the Norwegian-Murmansk (11) and the Kola (7) provinces (an area historically known as Murman), are one of the most heavily utilised areas of the Russian Arctic. Murmansk, the largest port and transport node of the High North, is located there, and military bases neighbor coastal fishery and developing aquaculture parcels. Vessel traffic is increasing, and shipping of hydrocarbons along the coast occurs on an unprecedented scale. It is expected that these coastal provinces may become be the scene of events deeply impacting the ecosystem. These will be related to climate change, Atlantic species moving to higher latitudes and increasing anthropogenic pressure. Due to the increase in shipping, the introduction of alien species is now likely. These invaders will join the Kamchatka crab (*Paralithodes camtschaticus*), which was intentionally introduced in the south-western Barents Sea in the 1960s and now has abundant and fully-established populations. From a biodiversity standpoint (2.2, 3.3, 3.4), the coastal zone of the Kola Peninsula is one of the most important areas in the Russian Arctic. Several specially protected natural areas are located on the Murman coast: parcels of the Kandalakshskiy

Coast of the Gulf of Ob (Obskaya Guba) [40]


Zapovednik, Lake Mogilnoe, the federal nature monument, some regional coastal protected areas (see maps 4.1, 4.2), and the establishment of more SPNAs has been proposed. The coastal zone in this area requires more detailed spatial plans, which can harmonize multiple uses of marine space and resources, balance environmental and economical priorities and provide information on the adaptability of the coastal socio-ecological systems to possible climate changes.

We refer here to the White Sea as belonging to the multiple use zone, which probably merits even more detailed spatial planning than the Barents coast of the Kola Peninsula. Here port zones are located, both developing (e.g. Arkhangelsk, Kandalaksha) and stagnating (e.g. Belomorsk); there are coastal fishery grounds, which have centuries-long history, and zones of developing marine and coastal tourism (Solovetskie Islands, Karelskiy Coast and some other parts of the coast). Tourism is actively developing but must be regulated with regard to its impact on the environment and cultural heritage.

The ecosystems of the White Sea are tightly connected to Arctic ecosystems, and the area may be viewed as a unique natural laboratory in which Arctic biota and environmental conditions are found south of the Polar Circle (2.2, 2.3, 3.1, 3.4). The White Sea is the cradle of Russia's marine economy and culture, but today communities of Pomor, the historical Russian settlers of the White Sea coast, have seen their local economies, rural coastal society and culture — all largely dependent on marine resources — nearly wiped out [Plyusnin, 2004]. Their revival will not be possible without a detailed plan integrating marine ecosystems and resources management, similar to those which our Norwegian neighbors are developing for their marine waters and coasts [Report of the Government to the Storting, 2006].

Another group of provinces is located along the Northern Sea Route, the vigorous development of which is very much hoped for in today's Russia [Problems of the Northern Sea Route, 2006]. The Kanin-Pechora Province in the south-western Barents Sea, and the Baidara and Ob'–Yenisei provinces in the Kara Sea (8, 16, 17) constitute the zone of intensive shipping along the western segment of the Northern Sea Route, and the reconnaissance and extraction of hydrocarbons (in the Pechora Sea and the Yamal area). Vessels are using and will continue to use flaw polynyas, which play a pivotal role in maintaining biological diversity and ecosystem functions (3.4–3.5). Though they are areas of high biodiversity and ecological importance, maritime marsh biotopes are inadequately protected as natural areas (3.9). The mouth systems of the largest rivers (Pechora, Ob', and Yenisei) support the principal stocks of anadromous and semianadromous fishes of the Russian Arctic (3.11). It is expected that special measures will be developed to protect biodiversity and traditional uses of natural resources in this zone. These measures will incorporate the network of marine and coastal SPNAs, fishery refuge zones, territories of traditional use, oil spill contingency plans, and regulations designed to minimize the negative impact of shipping on biota associated with flaw polynyas and land-fast ice.

Mengirs — monuments of ancient maritime culture, White Sea [41]

Fishermen's base, Chukotka [42]

Other provinces (18, 22, 23, 25, 26) are located in a zone of potentially intensive shipping along the eastern segment of the Northern Sea Route [Problems of the Northern Sea Route, 2006]. Special measures to prevent/minimize the negative impact of shipping on marine biota associated with flaw polynyas and fast ice should be developed and applied in these zones. In spite of a relatively high number of protected natural areas on the coasts and in coastal waters, including three federal (zapovedniks – Great Arctic, Taymyrskiy, and Ust'-Lenskiy), and several regional ones, particular valuable biotopes lack necessary protection. It is recommended, therefore, to design and implement new SPNAs, particularly in maritime marsh biotopes and river mouth areas.

Provinces 14, 19, 21, and 27 are in a zone which is currently used only intermittently for shipping along the North Sea Route. The resources and biological diversity of these provinces require further investigation, as do possible scenarios of environment and ecosystem modifications due to climate change.

Finally, the coastal waters of Chukotka should be considered a very special zone of multiple use, which only in some respects is similar to multiple use zones off the Kola Peninsula coast and in the White Sea. Many deposits of mineral resources have been discovered on the Chukotka coast [Problems of Northern Sea Route, 2006], and plans for the development of these deposits are equally abundant. Even in cases in which these plans are successfully actualized, priority should be given to the protection of the traditional use of natural resources, the study and monitoring of biological diversity, the securing of the environmental safety of shipping traffic along the Northern Sea Route, and the development of ecotourism, educational tourism, and ethno-tourism. These aims may be achieved by developing the Beringia national park along with the network of regional SPNAs and zones of marine mammal protection. We also emphasize the need to protect the most important flaw polynyas of Chukotka.

Short-sighted attitudes woefully undervalue the seas and coasts of the Russian Arctic — their biological diversity, importance in the ecosystem, traditional use of natural resources, and historical and cultural importance. But when deciding policies and making priorities, we would do well to heed the words of Kirill, Patriarch of Moscow and All Russia. In August 2010 the Patriarch visited the Svyato-Preobrazhenskiy Solovetsky Monastery on the White Sea, a site with a distinguished role in the spiritual, cultural, and political history of Russia; in the realm of natural history, the monastery developed an exemplary system of a self-sufficient marine economy and supported the foundation of the first marine biological station in the Russian North (1881). While there, the Patriarch said, «It is the North that in many respects represents the future of civilization; here are those treasures that are yet unused and that potential which is yet unspoiled by Man's sin». This is the potential of the human spirit and the promise of the Arctic — and we all are responsible for that.

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Hyperiidea, suborder — 2.3.
Komokida, kingdom Protozoa — 2.3.
Mollusca, phylum — 2.3.
Nemathelmithes, phylum — 2.3. (map)
Ostracoda, class — 2.3.
Porifera, phylum — 2.3.
Radiolaria, phylum — 2.3.
Rotifera, phylum — 2.3.
Saduria entomon, Crustacea, order Isopoda — 2.4.
Scyphozoa, class — 2.3.
Sipunculida, phylum — 2.4. (map)
Tardigrada, phylum — 2.3.


Isopoda *(Jaera sp.)* [43]


Bivalve and gastropod mollusks [44]

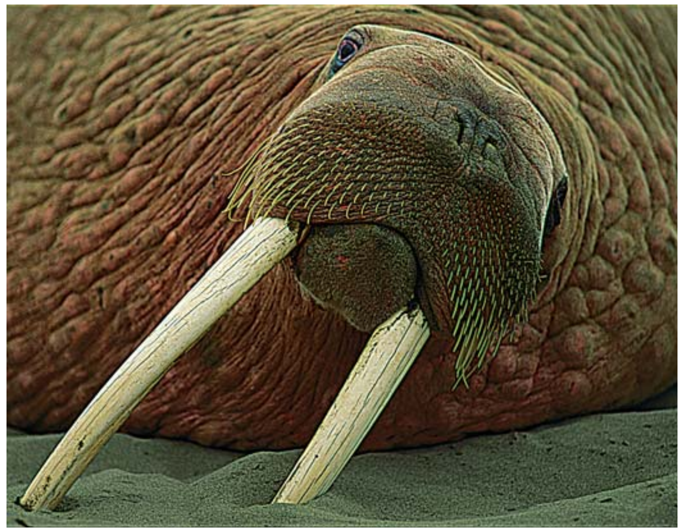

Sea-star *(Ctenodiscus crispatus)* [45]


Amphipod on the ice undersurface [46]


Atlantic Walrus *(Odobenus rosmarus rosmarus)* [47]


Ringed Seal *(Phoca hispida)* [48]


Bowhead whale *(Balaena mysticetus)* [49]


Pacific Walrus *(Odobenus rosmarus divergens)* [50]


Kittiwake *(Rissa tridactyla)* [51]


Kittiwake *(Rissa tridactyla)* [52]


Long-tailed Duck *(Clangula hyemalis)* [53]


Little auk *(Alle alle)* [54]


Herring Gull *(Larus argentatus)* [55]


Fulmar *(Fulmarus glacialis)* [56]


King Eider *(Somateria spectabilis)* [57]


Bean Goose *(Anser fabalis)* [58]


Oyster plant *(Mertensia maritima)* [59]


Lyme grass *(Leymus arenarius)* [60]


Seaside sandplant *(Honckenya peploides)* [61]


Seaside plantain *(Plantago maritima)* [62]


Marsh vegetation [63]


Sea aster *(Tripolium vulgare)* [64]


Eelgrass *(Zostera marina)* in the Barents Sea [65]


Coastal marsh [66]

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